Adaptive Mooring Management Plan

Sandy Island Oyster Bay Marine Protected Area

Carriacou, Grenada

Written by Monica Reed, Sustainable Grenadines Inc.

October 2016

Please cite this document as:

Reed, M. (2016) Adaptive Moorings Management Plan for Sandy Island Oyster Bed Marine Protected Area, Carriacou, Grenada. Prepared by Monica Reed, Sustainable Grenadines Inc. and The Nature Conservancy for Tobago Cays Marine Park with funding from USAID.

Technical team:

This plan was written by Monica Reed, masters degree candidate at Dalhousie University, Canada. Technical support and editing was provided by Sonia Jind, MPA coordinator, Sustainable Grenadines Inc., James Lord, executive director, Sustainable Grenadines Inc., Felicity Burrows, Marine Conservation Manager, Caribbean Program, The Nature Conservancy and Chris Bergh, South Florida Conservation Director, The Nature Conservancy.

Cover photo:

A 65-foot catamaran in Sandy Island Oyster Bed Marine Protected Area, 2016.

This report is made possible by the generous support of the American people through the United States Agency for International Development (USAID). The contents are the responsibility of The Nature Conservancy and its partner Sustainable Grenadines Inc. and do not necessarily reflect the views of USAID or the United States Government

Acknowledgments

This project was implemented through the Caribbean Marine Biodiversity Program overseen by The Nature Conservancy (TNC) with financial support from USAID.

Thanks to Sandy Island Oyster Bay Marine Protected Area staff and affiliates for their collaboration on this project. In particular, special thanks to Junior McDonald, Davon Baker, Senator Norland Cox, Aaron Bartholomew, Anique Coy and Akim Clement.

Much appreciation is extended to Newton Eristhe and Aden Forteau for their ongoing support. Thanks to the interviewed parties that shall remain nameless to maintain confidentiality and to all others that offered professional opinions (refer to reference list of personal communications).

Special thanks to Sustainable Grenadines Inc. for making this project possible.
In particular, special thanks to Orisha Joseph, Sonia Jind, Alba García Rodríguez, Krisma Moore, Kristy Shortte and James Lord for their professional support and encouragement.

Thank you to the Queen Elizabeth II Scholars Program for the training and financial support that allowed me to work on this project. Much appreciation is extended to Becky Field, Dr. Lucia Fanning and Dr. Claudio Aporta for their ongoing support.

Table of Contents

Executive Summary

Given the significance of tourism in the region, the marine protected areas (MPAs) of the Grenadines must aim to protect marine ecosystems while also supporting tourism activities. Yachting is the primary tourism activity occurring within the Sandy Island/Oyster Bay MPA (SIOBMPA). Anchor damage to coral reef and seagrass ecosystems is believed to be one of the key threats posed by yachts. In addition, anchors can act as a vector for the invasive seagrass *Halophila stipulacea*.

In order to reduce the threats of yachts, notably their use of anchors, the Caribbean Marine Biodiversity Program (CMBP) funded by USAID has provided resources to support the installation of additional fixed mooring systems within SIOBMPA, which is a CMBP core conservation site. The mooring systems should be strategically sited, adequately promoted, and sufficiently monitored and maintained in order to maximize the benefits of mooring systems. This Adaptive Mooring Management Plan is intended to guide the installation and management of new mooring systems and recommend approaches to monitor and mitigate the impacts of yachts mooring overnight in the MPA.

A graduate research study and internship with Sustainable Grenadines Inc. (SusGren) has supported the development of this management plan. The study assessed the current management regime, the existing mooring fields and historical visitation data. The research also investigated the potential threats of increasing the number of moorings within the SIOBMPA and explored possible approaches to mitigate the identified threats.

Historical visitation data from SIOBMPA were analyzed to provide insight on park usage (number of yachts, people per boat, time spent in MPA, size of boats, regulatory violations). Information from key stakeholders including charter yacht companies, MPA management staff and dive operators was incorporated into the management plan. Stakeholder input was key in determining the feasibility of proposed management approaches, including potential strategies to mitigate the threats associated with increased mooring systems. In-water assessments of the current mooring systems in SIOBMPA were conducted. The data (location, depth, system components, condition, bottom type) was used to create a mooring database. Google Earth was used to map the current locations and identify sites for the new mooring systems. The new sites were selected based on bottom type, depth, currents, and proximity to significant features. Seventeen sites for new yacht moorings and eleven sites for new small boat moorings were identified within L'Esterre Bay. South of Sandy Island, thirteen new yacht mooring sites and twelve small boat mooring sites were identified. Table 1 provides a summary of the mooring systems recommended for immediate installation.

Table 1: Number, location and design of the small boat and yacht mooring systems recommended for the Sandy Island Oyster Bed Marine Protected Area.

Type of Mooring System	Number to be installed	Location	Mooring Design
Small boat	11	Paradise Beach, L'Esterre Bay	Halas with concrete block anchor
	12	Sandy Island	
Yacht	17	Paradise Beach, L'Esterre Bay	Halas with concrete block anchor
	13	Sandy Island	Halas with manta and pin anchor
Dive boat	4	See Figure 14	Halas with concrete block anchor or drilled epoxied eyebolt (depending on site)
Demarcation buoy	5	Perimeter (see Figure 15)	Halas with concrete block anchor

The plan puts forth recommendations regarding mooring management best practices and recommends approaches to mitigate the threats of yachts. Sewage pollution was determined to be the most significant threat of yachts, as improper holding tank disposal or a lack of a holding tank leads to untreated sewage being directly discharged into the sea. It was recommended that the costs of mooring fees be increased; that sewage-waste mitigation measures be adopted; that sewage collection and treatment options be further explored; and that educational materials be developed and distributed.

The importance of evaluating and adjusting approaches in order to ensure efficiency was recognized and thus, the management plan was developed to be adaptable. The management a will be adapted as the management and regulatory context changes, and as information on the success of the recommended actions becomes available.

Water quality monitoring has been recommended as a method of monitoring the severity of improper waste disposal from yachts, and in combination with visitation and yacht characteristic data, is intended to enhance the understanding of the MPAs' yachting carrying capacity. This will be crucial in achieving a level of tourism that does not compromise the MPAs' ecosystem health or reduce the tourism appeal.

A more extensive, well maintained mooring system could contribute to the success of these MPAs since moorings reduce the threat of anchor damage, generate income and ensure safety to yachts. The recommended management and monitoring measures aim enhance the understanding of the MPA's carrying capacity. This will be crucial in achieving a level of tourism that does not compromise the MPA's ecosystem health.

1.0 Introduction

1.1. Marine Management in the Grenadines

In an effort to manage the multitude of pressures threatening marine ecosystems (e.g. climate change, overfishing, coastal development, etc.), marine protected areas (MPAs) are being created across the globe (Watson et al., 2015). The IUCN has defined an MPA as “Any area of intertidal or subtidal terrain, together with its overlying water and associated flora, fauna, historical and cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment” (Resolution 17.38 of the IUCN General Assembly, 1988, reaffirmed in Resolution 19.46 (1994).

Although MPAs are intended to safeguard marine ecosystem health, the areas must be managed effectively in order to meet conservation goals and promote the provision of ecosystem goods and services (Watson et al., 2015). The challenge of managing MPAs with limited resources available has been met with various strategies and approaches, which must be adapted to the context of the MPA of interest. It is becoming increasingly apparent that successful management of MPAs requires an understanding of their biological and physical processes, as well as their associated social and economic aspects (Thur, 2008). Adaptive Management approaches have emerged from the recognition of the importance of evaluating and adjusting approaches in order to ensure efforts are effective, efficient and appropriate given the current socio-ecological context.

The Grenadine Islands are a volcanic island chain located atop the Grenada Bank in the Caribbean Sea (Figure 1; Grenadines MarSIS, 2015). The northern islands are governed by St. Vincent and the Grenadines, while the southern islands belong to Grenada. The Grenada Bank supports the most extensive coral reef and related habitat in the southeastern Caribbean (CCA 1991a, CCA 1991b). Seagrass meadows, lagoons, mangroves, and a variety of patch, fringing and bank barrier reefs provide habitat for commercially important species (e.g. conch, lobster, reef fish), as well as ecosystem goods and services for coastal communities (Baldwin, 2012). Fishing, tourism and marine transport are the foundation of the economies and livelihoods of the region (Baldwin et al., 2006). The marine-based tourism sector includes charter yachts and cruise ships, onshore accommodation and restaurants (resorts, hotels, guesthouses, rental villas), and recreational water-based activities (e.g. SCUBA diving, snorkeling, sportfishing, day boat charters; Baldwin et al., 2006). It is well recognized that coastal and marine tourism often contribute to the decline of coastal ecosystems such as coral reefs, seagrass beds and mangroves (Davenport and Davenport, 2006). It is therefore essential that marine management includes the identification and mitigation of threats associated with coastal and marine tourism in the Grenadines.

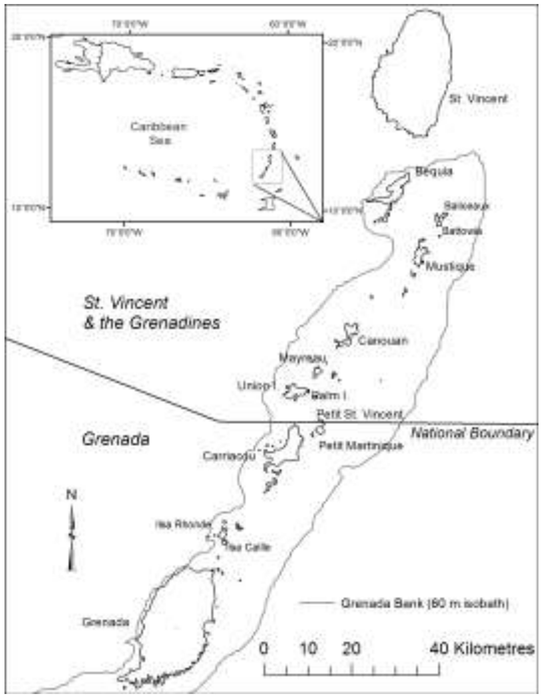

Figure 1. The Grenadine Islands of the Grenada Bank, Caribbean.

In response to the need for enhanced conservation efforts of coastal resources, both Grenada, and St. Vincent and the Grenadines have pledged to protect twenty-five and twenty percent, respectively, of the Grenada Bank by 2020. To ensure protected areas are more than just 'paper parks' created to meet percentage targets, marine managers must work to effectively manage the MPAs to meet specific, measurable objectives (Watson et al., 2015). Given the significance of tourism in the region, the MPAs must be managed to protect marine ecosystems while also supporting tourism activities. In 2011, the Grenadines Network of MPAs was established to promote trans boundary coordination and collaboration amongst MPAs in Grenada and St. Vincent and the Grenadines. The network aims to enhance management capacity in the region through meetings, training sessions, learning exchanges, and monitoring expeditions (SusGren, 2016).

The Sandy Island/Oyster Bed MPA (SIOBMPA) is one of the principal tourism destinations in the Grenadine Islands, and therefore, management must aim to maximize the benefits of tourism and mitigate the associated threats of visitation. Yachters are the most frequent users of the SIOBMPA. One of the key threats associated with these yachts is the potential for anchoring to damage coral reef and seagrass ecosystems. In order to reduce the threats posed by yachts, notably the use of anchors, the Caribbean Marine Biodiversity Program (CMBP) is providing resources to support the installation of additional fixed mooring systems within the MPA. This Adaptive Mooring Management Plan intends to guide the management of the moorings, which includes mitigating the threats associated with increasing the opportunities to accommodate yachts within the MPA.

1.2 Threats of Yachts to Marine Protected Areas

1.2.1 Carrying Capacity of Yachting Tourism

Yachting is a popular tourism activity, particularly in tropical waters like the Caribbean Sea. Yachting tourism involves staying and sailing on motor yachts or sailing ships. Since MPAs are often hotspots for yachting, management strategies are needed to ensure yachting does not compromise ecosystem health. Yachting boats can have negative impacts on marine health, as the use of anchors can cause physical damage to coral reef and seagrass ecosystems (Backhurst and Cole, 2000; Lloret et al., 2008). In addition, pollution from yachts, notably sewage disposal, can negatively impact marine ecosystem health (Lloret et al., 2008). At the same time, MPAs can employ strategies to gain benefits from tourism, such as implementing a user fee system (Thur, 2008). User fees can be a sustainable financing mechanism and also provides records of park usage patterns and rates that can be helpful in assessing the impacts of visitation (Thur, 2008). By monitoring the impacts of visitation, managers can establish a tourism carrying capacity for the area, which is the level of tourism activity that causes an acceptable amount of impact (Bell et al., 2011). Overcrowding of an MPA can reduce its tourism appeal and decrease safety; therefore, in addition to the environmental impacts of yachts, overcrowding should be considered when establishing the yachting carrying capacity of an MPA (Ashton and Chubb, 1972; Bell et al., 2011; Diedrich et al., 2011; Tseng et al., 2009; Lewis 1998).

1.2.2 Threats of Anchoring

As the popularity of water-based recreation continues to rise, the impacts associated with anchoring are increasingly threatening coastal habitats (Schlöder et al. 2013). Research has shown that coral reef ecosystems are highly susceptible to degradation from anchoring activities (Carilli et al. 2009; Dinsdale and Harriott 2004; Fava et al. 2009; Flynn, 2015; Glynn 1994; Goenaga 1991; Maynard et al. 2010; Rogers and Garrison 2001; Schlöder et al. 2013). Physical damage from boat anchors and their attached chains can dislodge, overturn and crush corals (Goenaga 1991; Glynn 1994; Dinsdale and Harriott 2004; Fava et al. 2009). Anchor damage to corals can cause shifts in community assemblage, leading to reef ecosystems dominated by non-coral taxa, commonly macroalgae (Carilli et al. 2009, Rogers and Garrison 2001, Schlöder et al. 2013, Maynard et al. 2010). When anchoring flattens areas of reef there is a loss of refugia, decreasing the availability and quality of reef habitat (Fava et al. 2009). For instance, Flynn (2015) found that highly anchored areas showed reduced cover of hard corals and sea fans, as well as lower species richness and fish densities compared to rarely anchored sites. Similarly, Lewis (1998) determined that anchor damage to coral reef patches led to the disappearance of coral-associated fishes. Carilli et al. (2009) suggested that chronic stress from anchoring reduces coral resilience to global climate change.

Boat anchoring also negatively impacts seagrass ecosystems (Creed et al., 2008; Milazzo et al., 2003; Montefalcone et al., 2008). Anchoring is one of the many anthropogenic activities contributing to the world-wide loss of seagrass ecosystems (Short and Wyllie-Ech- everria, 1996; Hemminga and Duarte, 2000), and is of particular concern in marine parks where tourism leads to the frequent use of anchors (Creed et al., 2008). The negative effects caused by anchors have been recorded at the individual plant level, as well as the population level (structure of the seagrass meadow; Montefalcone et al., 2008). The shoot density and rhizome baring of the seagrass were observed to be strongly impacted by anchors, especially in areas where the cover of the meadow was low (Montefalcone et al., 2008). Similarly, research on the effects of anchor damage on an algal dominated seagrass bed in Abrolhos Marine National Park, Brazil, indicated anchor use has created scars that fuse together and reduce seagrass cover and alter community composition (Creed et al., 2008). It is thought that the loss of seagrass structural complexity can have indirect detrimental effects on associated faunal assemblages (Garcia-Charon et al., 1993). These results highlight the imperative necessity to regulate boat-anchoring activities in areas with seagrass ecosystems.

1.3 Mooring Systems

1.3.1 Importance of Mooring Systems

Well-maintained mooring systems within an MPA can offer a range of benefits that contribute to management success, both in terms of conservation objectives and visitor satisfaction. Moorings can reduce the use of anchors, lessening the threat of anchor damage to benthic species and habitat, notably seagrass and coral reefs (Marbà et al., 2002). A study looking at the effectiveness of management measures to conserve seagrass meadows in Spain's Cabrera National Park found that regulation of mooring activities has improved the status of the meadows (Marbà et al., 2002). The research showed that after mooring regulations were implemented, seagrass patch formation and patch growth rates increased in active colonizing areas. In addition, leaf production was found to increase, while vertical rhizome growth decreased. The study indicates that mooring management can offer opportunity for seagrass meadows to recover from anchoring damage.

Revenue generated from mooring fees can be managed to sustainably finance MPA expenditures, such as mooring maintenance costs or patrol vessel expenses. Since the MPA is one of the top destinations for yachts touring the Grenadines, a substantial mooring fee can be collected if a high quality, well maintained mooring system is provided (S. Carey, personal communication, July 23, 2016).

Moorings can also serve to reduce overcrowding, promote the efficient use of space, and increase boater safety and well being (Diedrich et al., 2013). Dive moorings can offer a method of restricting the level of activity at popular sites. If park regulations require SCUBA divers to be accompanied by a dive master from a local dive operator, as is the case for the SIOBMPA, dive moorings can support this regulation by reserving access for local dive operators. In areas with strong currents, dive moorings may serve to assist SCUBA divers ascents or descents by providing a guideline from the surface buoy to depth. The mooring systems may also provide opportunities to monitor and control park access. For instance, if monitoring were to indicate that the MPA's carrying capacity is being exceeded, yacht moorings could be disassembled to decrease the number of sites available for yachts to berth.

1.3.2 Yacht Mooring Systems

Mooring systems consist of three primary components, (1) a permanent fixture on the seafloor, (2) a floating buoy at the surface, and (3) a series of lines attaching the bottom fixture to the surface buoy. The Halas principle of mooring design, which involves an anchor and a three part rope and buoy system (Figure 2), is widely used in marine parks due to its simple construction methods and practical maintenance costs (Fairhead and Baldwin, 2015). The downline connects the anchor to the buoy and surface lines, and often has a float near its base to keep the line from dragging across the bottom when slack. The through line is a shorter line that connects to the downline to the buoy, allowing for this section of the mooring to be replaced when worn without having to replace the entire length of downline. The pickup line is secured to the buoy, providing a reinforced loop that boaters can 'pick-up' out of the water and secure their lines through.

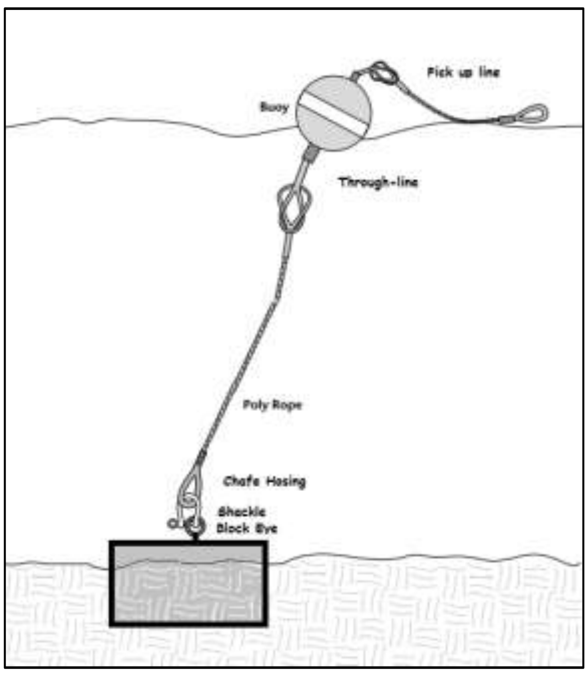

Figure 2. Typical Halas style mooring system (Fairhead and Baldwin, 2015).

The type of mooring system anchor deployed in an area is dictated by the seafloor characteristics (Breda and Gjerde, 1996). Block-type mooring systems are best suited for areas with shallow mud, sand, or gravel and are not recommended for areas with corals or seagrass (Breda and Gjerde, 1996). Block-type mooring systems typically consist of a heavy block anchor (e.g. concrete or engine block) with an attachment chain and floating buoy (Figure 2). The block anchor is not permanently fixed to the bottom so the system should be deployed on a level bottom to avoid shifting (Breda and Gjerde, 1996). Block-type moorings are often used because other types are more expensive and require more specific materials, equipment and expertise. Block-type moorings are also appropriate where the substrate dynamics do not allow for the use of in-substrate markers (e.g. Manta Ray). One of the drawbacks associated with using block-type anchors is that once the block is deployed it is difficult to move or remove. Block-type moorings also change the clearance available for boats to pass overhead so if a block is in a shallow area and not embedded in the sediment, collisions may occur.

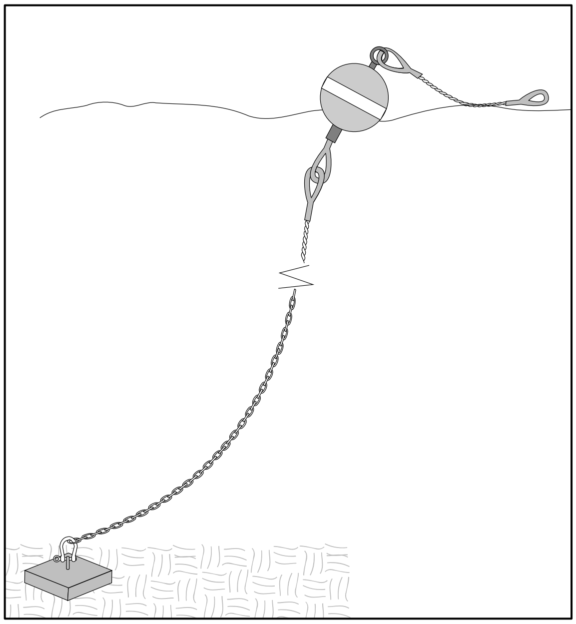

Figure 2. Block-type mooring system (Breda and Gjerde, 1996).

Manta and pin mooring systems utilize ‘manta ray’ embedment anchors to secure the system in areas of sand, coral rubble, or a combination of bottom-types (Figure 3). A utility anchor is driven into the seafloor (Figure 4) using a hydraulic underwater hammer. SCUBA divers then attach the down line to a thimble eye nut that is screwed to the anchor. The thimble eye nut should be welded to the anchor to keep the system from unscrewing. Manta systems can be deployed in approximately 30 minutes or less so labour costs are minimal (Breda and Gjerde, 1996).

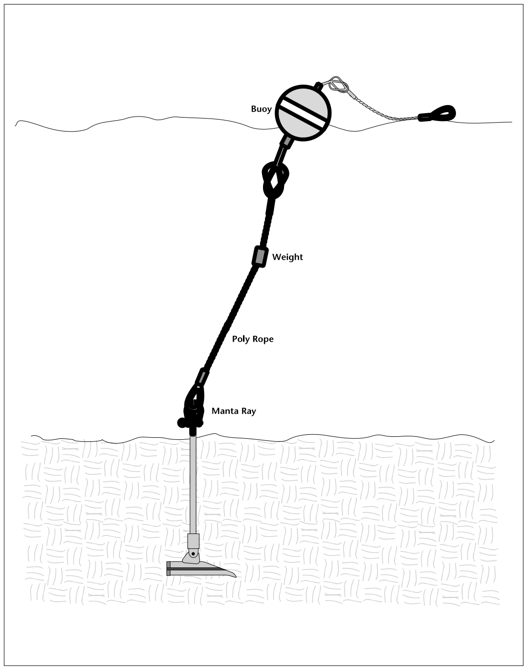

Figure 3. Manta and pin mooring system (Breda and Gjerde, 1996).

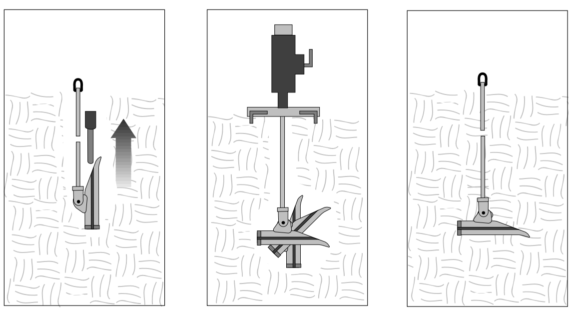

Figure 4. Manta anchor securement stages in seafloor (Breda and Gjerde, 1996).

2.0 Study Area Context

2.1 SIOBMPA Description

The Sandy Island/Oyster Bed Marine Protected Area (SIOBMPA) is located on the southwest coast of Carriacou, the largest of the Grenadine islands in Grenada (Figure 5). The volcanic island is inhabited by approximately 8 000 residents. The majority of local livelihoods rely on the agriculture or fisheries sectors. The primary activities that occur within the SIOBMPA are spear fishing, pot fishing, seine fishing, SCUBA diving, recreational use, water taxi use and charter craft usage (MCMPA, 2015).

The MPA boundaries encompass the mangroves of Lauriston Pt. in Hillsborough Bay, the shoreline through L'Esterre Bay, Pt. Cistern, and the north end of Tyrrel Bay (Figure 5). Islands within the MPA include Sandy Island, Mabouya Island, and the Sister Rocks.

Figure 5. Map showing the MPA boundary (red) of the SIOBMPA, Carriacou, Grenada (Google Earth, 2016).

The SIOBMPA is the largest and most biologically diverse MPA in the state of Grenada (MCMPA, 2015). Covering 6.59 km^2, the MPA has extensive reef development, mangroves, and seagrass beds. Several coral reef systems provide habitat for numerous species, offer coastal protection from high-energy waves and currents, and attract SCUBA dive and snorkel tourism to the MPA. With its postcard-ready white sandy beaches and turquoise waters, Sandy Island is a significant site that attracts locals and tourists to the MPA. Tourists SCUBA diving and snorkelling frequent coral reef systems off of Sister Rocks and Mabouya Island. The mangroves within the MPA are also significant, contributing a number of ecosystem goods and services including land-based sediment filtration, coastal protection and breeding grounds and nurseries for fish and shellfish (Moore, 2014). Along the north side of Tyrrel Bay, a dominant stand of Red Mangroves (*Rhizophora mangle*) serve as habitat for the Mangrove Oyster (*Crassostrea rhizophorae*), the Flat Tree Oyster (*Isognomon alatas*) and the Grenadian Bank Tree Boas (*Corallus grenadensis*; Moore, 2014). The tree boas are endemic to Grenada and the Grenadines (TNC GFD, 2007). A lagoon within the mangroves offers a safe haven for boats during tropical storms (TNC GFD, 2007).

2.2. SIOBMPA Management

The Nature Conservancy (TNC) developed a Draft Management Plan for the SIOBMPA in 2007. The management plan was developed in a participatory process that included a wide range of stakeholders (community members, government representatives, scientists; Harvey and Baldeo, 2013). TNC and the government of Grenada have a Memorandum of Understanding to work towards the implementation of the Programme of Work on protected areas in Grenada, hence TNC's ongoing support of the SIOBMPA. After the signing of a co-management agreement, the MPA was officially launched in July 2010. Co-management of the MPA was identified as the most appropriate management mechanism since the stakeholders and government agencies 'on the ground' were considered to have a better understanding of the context of the area (Harvey and Baldeo, 2013). It was anticipated that co-management could improve responsiveness and adaptability of the management interventions to evolving social and ecological conditions. Educational activities aimed at increasing local awareness regarding the intentions and associated opportunities of the MPA have been ongoing within the communities of Carriacou for over a decade.

The Fisheries Division of the Ministry of Agriculture, Lands, Forestry, Fisheries and the Environment is the main government agency responsible for the management of the SIOBMPA, as well as all other MPAs in Grenada. Under the auspices of the National MPA Committee and MPA Coordinator, a Stakeholders Board co-manages the SIOBMPA (Whyte, 2012). The Stakeholders Board members include representatives from the following agencies:

- Ministry of Carriacou & PM Affairs
- Carriacou Environmental Committee
- Carriacou Historical Society
- Water Taxi Association
- Fisher Folk
- Port Authority
- Carriacou Regatta Committee
- Carriacou Police
- Board of Tourism
- Grenada Scuba Dive Association

The Ministry of Carriacou and Petite Martinique Affairs (MCPM) play a clearinghouse role, employing four park wardens, two of which are trainees, and supporting patrol boat services and maintenance (Whyte, 2012). Currently, there is not an MPA manager for the SIOBMPA. A fisheries officer has been responsible for the MPA's managerial tasks in the interim between MPA managers.

The 2007 SIOBMPA Draft Management Plan was revised in 2015 through collaboration between The Ministry of Carriacou and Petite Martinique Affairs, The Gulf and Caribbean Fisheries Institute (GCFO), TNC, and the SIOBMPA Management Committee. The revised plan calls for better integrated management and operational planning.

The SIOBMPA is a founding member of the Grenadines Network of MPAs, which was established in 2011 to promote transboundary collaboration amongst MPAs in Grenada and St. Vincent and the Grenadines. Along with other member MPAs, the SIOBMPA has been involved in meetings, training, learning exchanges and monitoring expeditions that are coordinated by Sustainable Grenadines Inc. (SusGren, 2016).

3.0 Assessment Methods

3.1 Management Review

The SIOBMPA management plans, both the original and the version revised in 2015, were assessed to determine what conservation objectives and supporting activities were relevant to consider within this management plan. Discussions with park management staff provided insight on the current mooring management practices and suggestions for future mooring management. In 2007, Moor Seacure International Ltd. developed a Mooring Feasibility Report for SIOBMPA (Moir, 2007). The report was examined for technical advice, including mooring system and site recommendations. A mooring report on the installation of the mooring and demarcation buoy system for the SIOBMPA was also reviewed to provide information on mooring site characteristics and installation procedures (Laflamme, 2010).

Grenada's legislation was reviewed in order to identify relevant policies and determine the capacity for MPA regulations to be legally enforced. Relevant international agreements that Grenada has committed to were reviewed to reveal opportunities for recommended management measures to support such commitments.

3.2 Field Surveys

A field assessment of the existing mooring systems in the SIOBMPA was conducted to gather baseline data to inform the proposed management recommendations. Yacht moorings and small boat moorings were included in the field survey. Dive moorings were not included in the field survey because their current condition and GPS locations were known. In addition, an inspection of the dive moorings would have required the inspector to SCUBA dive, which would have added unnecessary costs to the project.

A snorkeler inspected all of the yacht and small boat mooring systems within the SIOBMPA boundaries. MPA wardens in the MPA patrol boat assisted the snorkeler. Once the mooring system was located, the snorkeler free dove to check all of the mooring system's components. The depth was measured with a measuring tape that the snorkeler unwound until the weighted end reached the seafloor next to the mooring anchor. The observations were called out to one of the wardens, who recorded the data in a field notebook. The warden also used a GPS to determine to mooring systems' locations. The snorkeler took photographs to document standard and abnormal features of the mooring systems and seafloor.

Google Earth was used to map the locations of the surveyed moorings.

3.3 SIOBMPA Visitation Data

The park management staff were requested to provide visitation and mooring data. The data requested included the following:

- Number of yachts that visit the park
- Number of people aboard the yachts
- How many yachts have used the available moorings
- Number of days spent on the mooring
- How many yachts have been charged for breaking park regulations, specially anchoring in no-anchoring areas and flushing holding tanks

An MPA warden transcribed the mooring fee records into an Excel spreadsheet, providing the figures on the number of moorings used and the number of days spent on each mooring. Since the mooring fees are higher for boats over 50 feet in length, it was possible to determine the percent of boats that overnighted in SIOBMPA that were over 50 feet in length.

3.4 Charter Yacht Company Interviews

Charter yacht companies and day trip operators from Grenada, Carriacou, St. Vincent and Union Island were requested to provide information on their perceptions regarding mooring systems within SIOBMPA. Interviews also covered questions relating to the characteristics of the charter yacht fleets, primarily relating to holding tanks, as well as perceptions of threats of yachts and the potential of management measures to mitigate these threats. Skype interviews allowed for this information to be collected. See Appendix A.1 for a copy of the interview questions.

3.5 SCUBA Dive Operator Interviews

Carriacou has three SCUBA Dive Centers – Lumba Dive, Arawak Dive, and Deefer Diving – that use the SIOBMPA. The operators of these dive centers have a vested interest in the success of the MPA, as healthy, productive marine ecosystems positively influence tourism interest in SCUBA diving within the MPA. All three dive operations use the dive moorings within the SIOBMPA. The dive centers' owners were interviewed to gain insight on their connections to the moorings (e.g. use, role in maintenance etc.), and their perception on the management of the moorings. See Appendix A.2 for a copy of the interview questions.

One of the interviewed dive operators provided GPS coordinates for the current dive moorings. The coordinates for sites where new or replacement dive moorings are desired were also shared. Both the current and desired dive moorings were added to the Google Earth map showing the park boundaries and yacht and small boat moorings.

3.6 Identification of Threats

In order to ensure the installation of additional mooring systems within the SIOBMPA does not have adverse impacts on the environment or safety and tourism appeal, the threats of increasing the number of moorings were identified. The author's background knowledge, literature, relevant MPA reports and discussions with stakeholders and marine conservation professionals contributed to the assessment of potential threats.

3.7 Siting New Mooring Systems

3.7.1 Siting New Yacht and Small Boat Moorings

The locations for new yacht mooring sites were selected to ensure the environmental impact of the mooring activities are as minimal as possible. Research on the potential environmental impacts of mooring systems was conducted to contribute to the site selection. In complement, the environmental characteristics of potential sites were assessed, including bottom type, proximity to key habitats, depth and prevailing current direction. The Grenadines Marine Resource Space-use Information System (MarSIS) data layers were uploaded to Google Earth in order to visualize the locations of shallow water habitats. Habitat layers from the CaribNode database were also downloaded and visualized in Google Earth (http://www.caribnode.org/layers/). Considering the habitat types and locations of existing mooring fields, potential sites for new mooring fields were determined. Nautical charts (https://webapp.navionics.com/#@12&key=stblAdiouJ) were then used to gather data on the depths and prevailing currents of the identified zones. The Mooring Feasibility Report developed for the SIOBMPA by Moor Seacure International Ltd. was used to determine the seafloor suitability of the sites identified as potential locations for the installation of additional mooring systems (Moir, 2007).

When selecting locations for additional moorings, boat safety and user satisfaction must also be considered. Overcrowding has been reported to decrease safety and user satisfaction, and thus, adequate spacing of moorings and a set capacity within anchoring zones are very important aims to achieve. Literature was reviewed to determine the recommended spacing of mooring systems within a mooring field, which depends on the size of the boat. A distance of 130 feet was deemed appropriate because if boats up to 65 feet use the moorings, there is at least double the length of the boat between moorings to allow for swing room. Using the Google Earth map with the current yacht, small boat and dive moorings marked, the ruler tool was used to identify yacht mooring sites at least 130 feet from any moorings or other obstructions. The same spacing protocol was used for small boat moorings, with at least 50 feet between each suggested site.

The proximity to MPA features of interest was also considered when determining where to site new moorings. For instance, Sandy Island is one of the key tourist attractions of the MPA, and therefore, moorings located nearby would likely entice boaters more than moorings elsewhere. It is important to take user desirability into account in order to encourage boats to berth, and thus pay mooring fees, within the MPA instead of at nearby locations outside of the MPA boundaries. The potential zones’ proximity to Paradise Beach and the Mangrove Lagoon were also considered. Paradise Beach has a number of restaurants, guesthouses, hotels and tourist shops. The Mangrove Lagoon is of interest as it is a natural attraction where visitors can enjoy snorkeling, kayaking, etc.

3.7.2 Siting New Dive Moorings

New dive sites were selected based on recommendations made by the three dive operators that use the MPA. One of the dive shop owners provided GPS coordinates for the suggested sites, some of which previously had dive moorings but now need to be replaced.

3.7.3 Superyacht Moorings

Historical park visitation data were used to determine the percentage of boats that are greater than 50 feet, which suggests the number of superyacht moorings that should be installed. This study did not involve the selection of superyacht mooring sites because of the associated engineering requirements and recommends a professional mooring company be hired to site and install superyacht mooring systems.

3.7.4 Demarcation Mooring Systems

There were demarcation buoys to mark the MPA boundaries in the past, but the mooring systems do not currently have buoys and need to be replaced. The GPS coordinates of five key sites requiring mooring systems for boundary demarcation buoys were obtained from Lumba Dive's records of previous mooring systems' locations.

3.8 Stakeholder Workshop

A workshop will be held with MPA managers, key representatives from charter yacht companies, dive shop operators and water taxi operators to present the draft Adaptive Mooring Management Plan. Working sessions will be directed to allow for stakeholders to brainstorm about potential challenges and mitigation strategies associated with the proposed mooring management system. The participants' input will help to further shape the design of the Mooring Management Plan for SIOBMPA.

Potential focus topics include the following:

- Mechanisms to communicate information to yacht crews and tourist yachters
    - mooring buoy locations
    - user registration
    - fee payment options
    - mooring methods/safety
    - mitigating environmental impacts (waste disposal protocol)

- Management requirements
    - siting mooring systems (map with MPA features of interest, areas/species at risk and associated threats, buoy locations)
    - greeting and payment collection protocol
    - monitoring threats of increased visitation (e.g. water quality monitoring program)
    - mitigating threats of increased visitation (e.g. boat inspections)
    - monitoring and maintenance of mooring systems, including dive moorings
    - potential of recommended waste management options

4.0 Results

4.1 Management Review

4.1.1 Policies Supporting Mooring Management in SIOBMPA

Grenada's national MPA legislation (The Grenada 2001 Fisheries (MPA) Regulations) prohibits anchoring within MPA boundaries unless there is a designated anchoring zone. Mooring systems are therefore required to provide boats with berthing options within the SIOBMPA, which only has a small anchorage zone. Prohibiting the use of anchors within the MPA, besides within the anchoring zone, aims to eliminate the threat of anchors causing damage to coral reefs and seagrass beds. The health of these key ecosystems is essential if the biodiversity of the area is to be conserved. In fact, stakeholders involved in developing the MPA's original management plan identified seagrass beds and coral reef ecosystems as two of the seven key resources that the SIOBMPA should serve to protect (TNC GFD, 2007). Damaging anchoring practices could indirectly impact sea turtles and livelihood security, which were also deemed key resources by MPA stakeholders. For instance, damage to coral reefs or seagrass beds could decrease the quality of habitat available to support commercially fished species, lessening the benefits of the MPA to the region's fishers. Since green turtles rely on seagrass beds for nutrition, a reduction in seagrass cover or quality could negatively impact green turtles, which are the most frequently observed species of sea turtles in the region, are culturally significant, and are an important tourism draw.

In addition to minimizing the threats associated with anchor damage to seagrass and coral reefs, mooring systems were considered as an approach to reduce pressures to mangroves by providing an alternative berthing for boaters that typically secure their vessels to mangroves.

This Adaptive Mooring Management Plan builds on a number of the MPA objectives that are included in the original management plan for the SIOBMPA (TNC GIF, 2007). Objective 7 is " to eliminate boat anchoring in seagrass beds, mangroves and coral reefs in the Park within one year" (TNC GFD, 2007). Objective 9 – "to regulate the number of vessels visiting Sandy Island at one time, based on carrying capacity within one year" – will be supported by the Strategic Actions of Objective 7. The strategic actions are as follows:

- Develop a mooring buoy program within the MPA that targets seagrass beds, mangroves and coral reefs using public consultation.
- Implement mooring buoy program within the Park.
- Establish regulations for anchoring within mangrove areas in the Park during emergencies.
- Develop and implement a public awareness campaign for the general public and targeted groups (fishermen, schools, beach vendors, boaters, etc.)

The revised management plan, which was submitted for MPA board approval in June 2016, highlights high priority and low priority actions that have not been achieved, a number of which are relevant to this Adaptive Mooring Management Plan. One of the identified high priority actions was to “maintain mooring buoys” through the implementation of adaptive management techniques. It was suggested that patrol guidelines be developed and that rangers be granted authority to issue tickets, notably for improper sewage disposal. Lower priority actions included the establishment a park monitoring protocol before operation of MPA (re. sewage disposal); the implementation of national legislation (re. sewage disposal); and establish regulations for anchoring within mangrove areas in the Park during emergencies.

4.1.2 History of Moorings at SIOBMPA

In 2009, Moor Seacure International completed onsite visits and underwater inspections together with seabed probes in order to determine the type and suitability of the seabed and make recommendations for the appropriate design of moorings for each area (Moir, 2009). The recommended sites do not currently have moorings and are too close to existing moorings to use as sites for additional installations. In 2010, a mooring systems installation project saw 25 yacht moorings of the manta ray type installed near Sandy Island. This brought the park closer to achieving Objective 7, as described above. Many of the moorings, however, were eventually removed or redone because of insufficient spacing, improper splicing, and incorrect lengths of pickup lines. The current moorings were installed last year under a CARIBSAVE project. This history of mooring installations emphasizes the need to follow a well-informed plan for new mooring installations.

4.1.2 Mooring Management Operations

South of Sandy Island there are nine operational yacht mooring systems, but twelve manta ray anchors are in place. An additional five moorings are located near to the park boundary in L’Esterre Bay. Yachts up to 50 tons can use the moorings during calm weather. When the wind reaches over 16 knots, yachts must be under 40 tons to use the moorings safely. If the yacht is too large to safely use the mooring system, the yacht must use an anchor is a specified area. From Sunday to Friday, a park patrol boat collects moorings fees in the morning. Yachts under 50 feet in length pay 25 Eastern Caribbean Dolalrs (XCD) or $10 USD for 24 hours. Yachts over 50 feet pay 50 XCD or $20 USD for 24 hours. The same fees apply to yachts anchoring within the designated anchoring zone. Charter yacht boats are also charged a snorkeling fee of $1 USD per person. Park wardens do not work on Saturdays so mooring or snorkeling fees are not collected. Water taxi operators (WTO) are not currently charged mooring fees. Dive operators using the moorings within the MPA do not pay fees; the potential for an annual user fee has been discussed, but never tabled.

4.2 Field Surveys

The snorkeler assessed a total of 17 yacht mooring systems within SIOBMPA, covering all of the existing mooring systems or partial mooring systems (ie. anchors missing lines). Two of the moorings were missing buoys or other components that rendered them unusable. Twelve yacht moorings south of Sandy Island were examined and mapped (Figure 6). Five yacht moorings and six small boat moorings were assessed near Paradise Beach in L'Esterre Bay (Figure 7). The yacht moorings have manta and pin style anchors and are in sandy patches amongst seagrass and corals. Data collected was used to map mooring locations and create a mooring systems database in Microsoft Excel for the SIOBMPA. Photographs taken to document standard and abnormal features of the mooring systems and seafloor are included in Appendix B to clarify observations noted during the assessments.

Figure 6. Current overnight yacht moorings located south of Sandy Island, SIOBMPA (Google Earth, 2016).

Figure 7. Current overnight yacht moorings (black and white rings) and small boat moorings (white diamonds) off of Paradise Beach, L'Esterre Bay, SIOBMPA, Carriacou (Google Earth, 2016).

4.3 SIOBMPA Visitation Data

The mooring fee records were assessed to determine the number of boats overnighting in the park each month. Since mooring fees for SIOBMPA are collected whether the boats anchor or use the mooring, data from mooring receipts indicates how many boats overnighted in the MPA. The data does not indicate whether the boats moored or anchored. Reciepts were available to indicate the number of boats that overnighted each month of 2014, except for June through September (Figure 8), and each month of 2015 (Figure 9). There is no data available for these months because the MPA patrol boat was not operating, and thus, mooring fees were not collected so no reciepts exist. Records from the eight months of 2014 in which fees were being collected indicate a total of 619 boats overnighted in the SIOBMPA. January and February were the busiest months of 2014, with 120 and 134 boats per month respectivly. March and December were the busiest months of 2015, with 140 and 133 boaters per month respectively. Comparing the eight months of data from 2014 with the data from the same eight months of 2015 shows a 18.70% increase in the number of boats overnighting in the MPA.

Since there is a higher fee for boats greater than 50 feet in length, the data showed the size class of the boats. The mooring fee records for 2014 indicate that 91.76% of the boats that paid the mooring fee were less than 50 feet in length. In 2015, mooring fee records indicate that 89.99% of the boats that paid the mooring fee were less than 50 feet in length.

It's important to note the there is no record of the number of moorings available for each month, which may have impacted the amount of boats overnighting in the MPA. There is also no indication of the number of days the wardens collected mooring fees so the unit effort is not accounted for in these results.

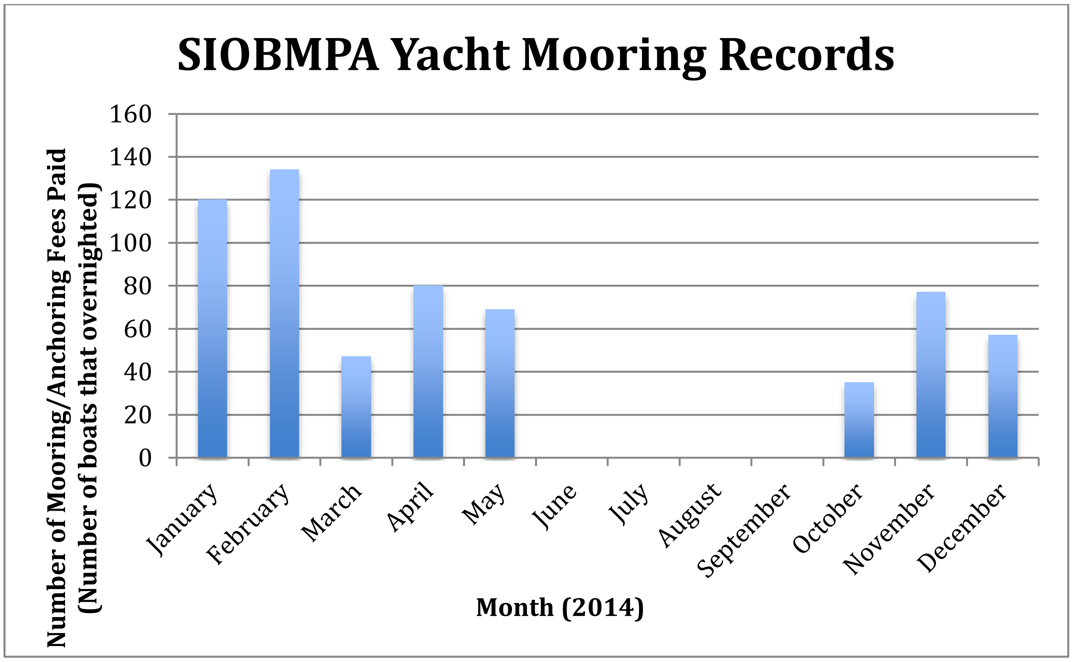

Figure 8. Graph showing number of boats that overnighted in SIOBMPA for each month in 2014, except for June-September when the patrol boat was out of service.

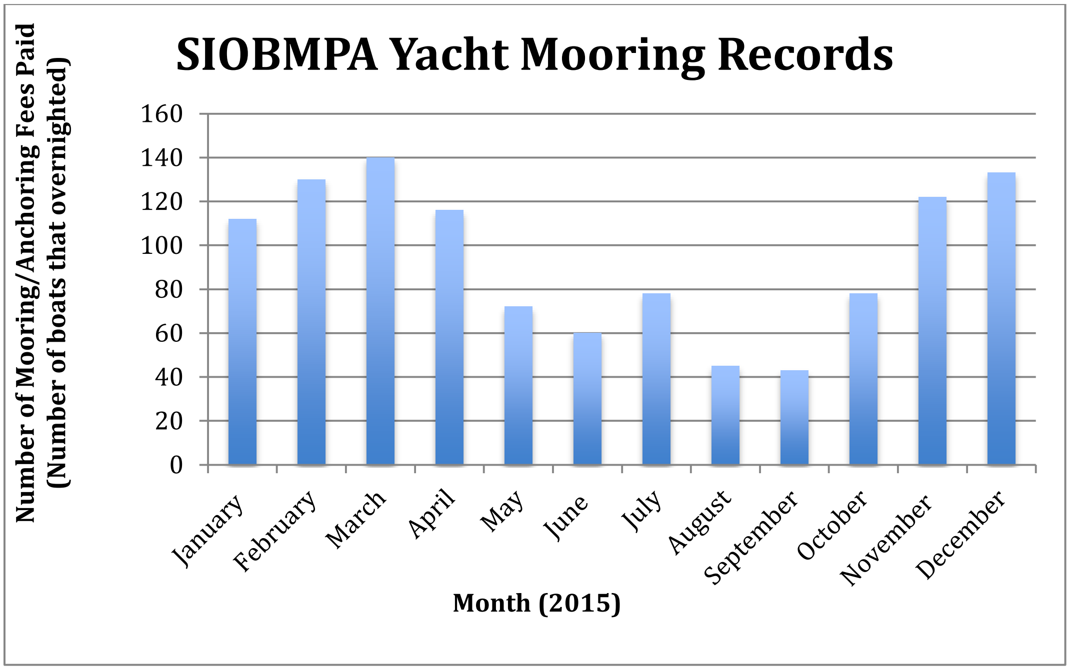

Figure 9. Graph showing number of boats that overnighted in SIOBMPA each month in 2015.

4.4 Charter Yacht Company Interviews

Interviews were conducted with seven charter yacht companies and one day-trip yacht cruise company that operate in the Grenadines. The interview responses are not explicitly stated in this document in order to safeguard the privacy of participants. The qualitative information provided by the interviews has been incorporated into the recommendations of this management plan. The interviewees were asked about both the Tobago Cays Marine Park, as well as SIOBMPA. The following quantitative results are presented as averages of the data provided by each of the eight interviews.

The interviewees estimated the percentage of their business that visits the SIOBMPA. The percentages were averaged, indicating that 28.14% of the represented yachts visit the SIOBMPA while sailing in the Grenadines. It was reported that 62.14% of these trips are crewed and 97.10% of the boats are less than 60 feet in length. Estimates indicated that an average of nine people stay on the charter yachts under 60 feet in length, while an average of 16 people stay on the super yachts.

Of the fleets represented in the interviews, an average of 66.63% of the boats were reported to have holding tanks on board. Volumes ranged from 10 to 200 gallons. Five participants stated that the holding tanks were used properly, whereas two admitted that the holding tanks were kept open to avoid issues with valves seizing shut. Two of the interviewees expressed the view that their companies were the only ones that properly used holding tanks while sailing in the Grenadines. The participants that reported holding tanks were properly used on their companies' boats specified that waste collected waste is emptied between islands, or close to or beyond three miles from land. It was noted that tourists do not want to detour solely to dump waste, and some are not comfortable sailing far from land.

It was reported that holding tanks are serviced at a range of intervals, from bi-weekly to annually. Some participants indicated that the products used to clean the holding tanks are not environmentally friendly, while one reported that vinegar and water is used because it is relatively benign and as effective as potentially toxic products. To encourage a reduction in the pollution generated by the charter yacht industry in harbours, the suggestion to use vinegar and water to clean holding tanks will be provided in the information package that will be distributed upon the adoption of this management plan.

When asked what threats yachting poses to the marine environment, interviewees identified a total of seven threats (Figure 10). It should be noted that the sample size of this question was seven, since once participant chose not to answer due to a lack of knowledge. Six of seven participants identified liquid waste pollution as a threat of yachting, indicating that it is the greatest perceived threat of yachting in the MPA. The reported causes of these threats included the limited use of holding tanks; not enough well maintained moorings; the accessibility of fish and lack of enforcement against illegal fishing; the lack of garbage facilities in the MPA; and a general lack of awareness. Suggested measures to mitigate these threats were (1) to designate an area for boats without holding tanks where dispersion is most effective, (2) implement holding tank regulations (3) ensure regulations are legally enforceable, (4) install more moorings, (5) provide more comprehensive briefings to visitors, (5) conduct more MPA patrols, and (6) promote the sale of reef friendly sunscreen.

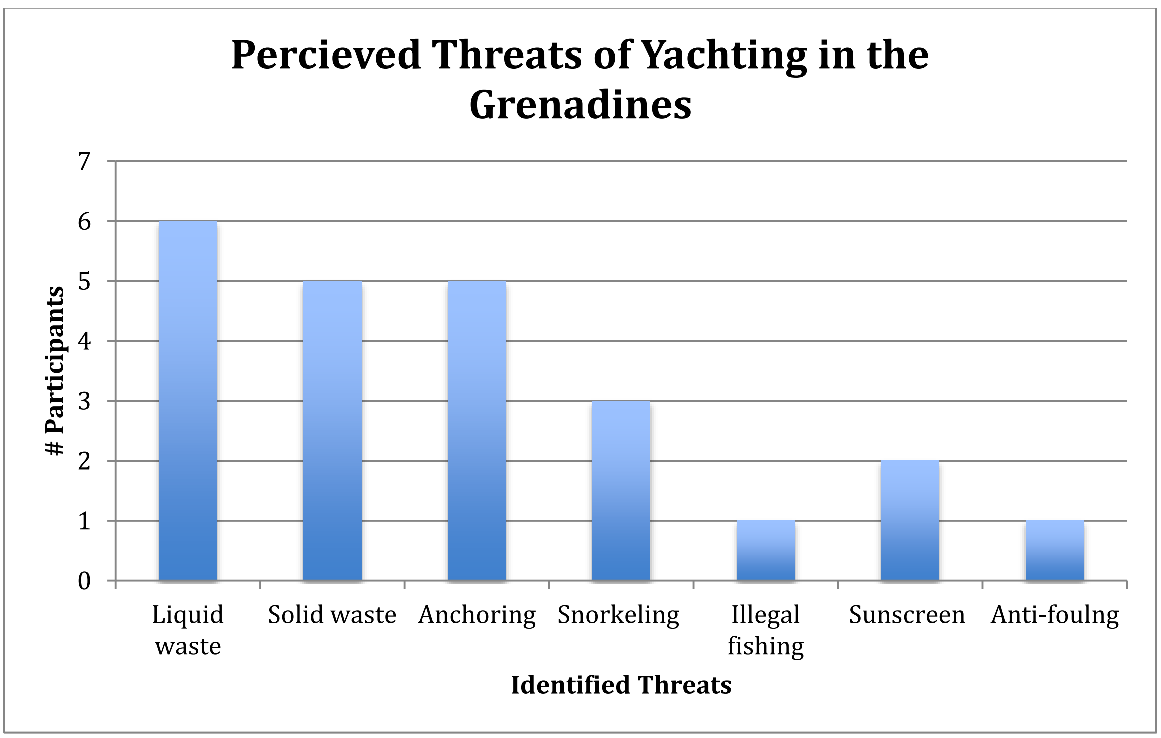

Figure 10. Bar graph showing the perceived threats of yachting to the marine environment and the number of interviewees that identified each threat.

Interview participants were asked about the feedback they receive from guests. It was recounted that overcrowding has not been reported as a concern. No guests have mentioned issues with the use of holding tanks, beyond the occasional note about the smell; however, it was told that guests have expressed their surprise in the lack of regulations associated with holding tanks and waste disposal within the MPAs. The most common complaint from charter yacht guests that visited SIOBMPA was that the moorings were not reliably maintained.

4.5 SCUBA Dive Operator Interviews

To ensure the privacy of the participants, the dive center operators' interview responses are not explicitly stated in this document. Alternatively, key information provided by the interviews has been incorporated into the recommendations of this management plan. The key stakeholder workshop will provide an opportunity for the diver operators and MPA staff to discuss a dive mooring management approach.

4.6 Threats of Yachts in MPAs

4.6.1 Identified Threats

In order to ensure the installation of additional mooring systems within the SIOBMPA does not have adverse impacts on the environment or safety and tourism appeal, the threats of increasing the number of moorings were identified (Table 2). It is assumed that the threat of anchor damage could be reduced by the addition of moorings, but that other threats associated with yachts may increase if the moorings attract more yachts to overnight in the MPA.

Table 2. Table showing potential threats of increasing the number of mooring systems available in the SIOBMPA if it were to lead to more yachts overnighting.

Threat	Identified in Management Plan	Highlighted by Management Staff	Identified in Stakeholder Interviews	Observed During Field Surveys
Improper sewage waste disposal	☑	☑	☑	☑ *in form of algal bloom
Anchoring	☑	☑	☑	-
Improper solid waste disposal	☑	☑	☑	☑ *bottles and trash
Sunscreen pollution	-	-	☑	-
Coral damage by snorkelers	-	-	☑	-
Anti-fouling	-	-	☑	-
Spear Fishing	-	-	☑	-

4.6.2 Threats of Improper Sewage Disposal

The issue of improper sewage disposal appears to be the most severe threat associated with yachts within MPAs. This management plan seeks to address this threat since the installation of new mooring systems may increase the amount of yachts overnighting within the MPA and mooring management offers opportunities to support better waste-management mechanisms.

The impacts of sewage from yachts depend on boater practices, such as holding tank usage, and on the flushing characteristics of the location (Hoggarth, 2007). Discharge of nutrient-containing wastewaters, such as sewage from yachts, can result in high nutrient levels and low oxygen levels in the ambient water. The effects of nutrients are related to the capacity of the receiving water to accept, dilute and disperse discharges (Hawker and Connell, 1989). Nitrogen and phosphorus levels are the major water quality parameters affected by sewage discharge (Hawker and Connell, 1989).

The primary stresses on a coral reef community associated with nutrient enrichment (eutrophication) are connected to increased attached algal growth, localized dissolved oxygen depletion and, in some instances, elevated concentrations of plankton in the water column (Hawker and Connell, 1989). Coral morbidity and mortality associated with sewage inputs are typically a result of competition with algae for space and light (Marszalek, 1981). Increases in inorganic nutrients and turbidity levels resulting from sewage disposal have been found to cause substantial ecological shifts in coral reef ecosystems (Hawker and Connell, 1989; Reopanichkul et al., 2009). For instance, increased inorganic nutrients and turbidity levels associated with wastewater disposal have been tied to substantial ecological shifts in the form of (i) increased macroalgal density and species richness, (ii) lower cover of hard corals, and (iii) significant declines in fish abundance (Reopanichkul et al., 2009). Similarly, Hawker and Connell (1989) found water nutrient enrichment in coral reef systems resulted in the loss of corals and a dominance of filter and detrital feeders such as sponges, sea cucumber, oysters and clams.

Since hypoxia, meaning low oxygen levels, narrows the thermal tolerance an organism by reducing its metabolic scope, reductions in oxygen availability can have detrimental impacts on marine ecosystems.

Eutrophication via waste disposal can also lead to sporadic phytoplankton blooms. Phytoplankton outbreaks can deplete oxygen and, in some cases, release toxins that cause filter feeders (e.g. mussels, clams, etc.) to be deadly to humans if consumed. These blooms, commonly known as ‘red tides’ have detrimental impacts on marine ecosystems and often negatively impact local fisheries and marine-based recreational activities.

4.7 Potential Sites for New Mooring Installations

4.7.1 Sandy Island

Thirteen potential new yacht mooring sites were identified south of Sandy Island (Figure 11). Measurements were taken in Google Earth to ensure spacing was at least 130 feet between moorings to allow for swing room. Twelve small boat moorings were sited, as depicted by the white squares. It is suggested that some small boat moorings be reserved for local use, while others be designated for dinghies.

The thirteen recommended sites in this report include yacht mooring sites identified in 2010 that do not conflict with current mooring sites (i.e. at least 130 feet from any mooring system accommodating yachts up to 65 feet). The 2009 study found suitable rocks for drilling and installing epoxied eyebolt mooring systems, which could accommodate dingy and small boats (e.g. water taxis). Table 3 summarizes the mooring locations, while Figure 11 displays their locations as well as the existing mooring systems near Sandy Island.

Table 3. Number, location, depth and bottom type of potential new yacht mooring systems south of Sandy Island, SIOBMPA.

N (yacht) NS (small boat)	N (Degrees Decimal Minutes)	W (Degrees Decimal Minutes)	Depth (ft)	Bottom Type	Components
N1	12° 29.066'N	61° 28.861'W	15	Sand Patch	Halas with concrete block
N2	12° 29.070'N	61° 28.883'W	13	Sand Patch	Halas with concrete block
N3	12° 29.046'N	61° 28.882'W	17	Sand Patch	Halas with concrete block
N4	12° 29.049'N	61° 28.904'W	10	Sand Patch	Halas with concrete block
N5	12° 29.030'N	61° 28.915'W	20	Sand Patch	Halas with concrete block
N6	12° 29.055'N	61° 28.935'W	28	Sand Patch	Halas with concrete block
N7	12° 29.035'N	61° 28.943'W	14	Sand Patch	Halas with concrete block
N8	12° 28.991'N	61° 28.952'W	25	Sand Patch	Halas with concrete block
N9	12° 28.967'N	61° 28.940'W	25	Sand Patch	Halas with concrete block
N10	12° 28.943'N	61° 28.950'W	25	Sand Patch	Halas with concrete block
N11	12° 28.948'N	61° 28.934'W	33	Sand Patch	Halas with concrete block
N12	12° 28.979'N	61° 28.851'W	45	Sand Patch	Halas with concrete block
N13	12° 29.000'N	61° 28.840'W	35	Sand Patch	Halas with concrete block
NS1	12° 29.120'N	61° 28.882'W	-	Rock/sand	Halas with epoxy embedded pin or small concrete block
NS2	12° 29.117'N	61° 28.894'W	-	Rock/sand	Halas with epoxy embedded pin or small concrete block
NS3	12° 29.118'N	61° 28.906'W	-	Rock/sand	Halas with epoxy embedded pin or small concrete block
NS4	12° 29.112'N	61° 28.920'W	-	Rock/sand	Halas with epoxy embedded pin or small concrete block
NS5	12° 29.107'N	61° 28.931'W	-	Rock/sand	Halas with epoxy embedded pin or small concrete block
NS6	12° 29.104'N	61° 28.943'W	-	Rock/sand	Halas with epoxy embedded pin or small concrete block
NS7	12° 29.099'N	61° 28.954'W	-	Rock/sand	Halas with epoxy embedded pin or small concrete block

NS8	12° 29.096'N	61° 28.968'W	-	Rock/sand	Halas with epoxy embedded pin or small concrete block
NS9	12° 29.092'N	61° 28.981'W	-	Rock/sand	Halas with epoxy embedded pin or small concrete block
NS10	12° 29.085'N	61° 28.995'W	-	Rock/sand	Halas with epoxy embedded pin or small concrete block
NS11	12° 29.080'N	61° 29.009'W	-	Rock/sand	Halas with epoxy embedded pin or small concrete block
NS12	12° 29.075'N	61° 29.021'W	-	Rock/sand	Halas with epoxy embedded pin or small concrete block

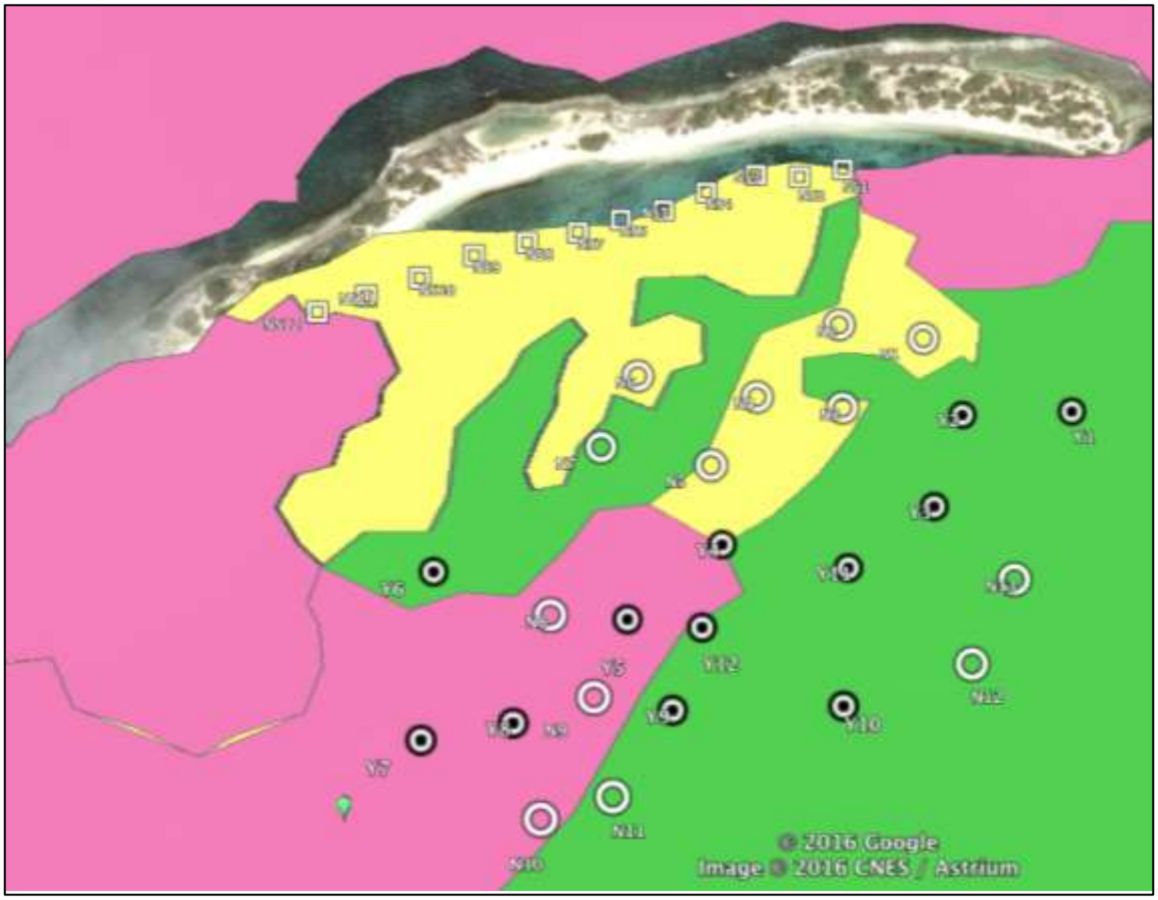

Figure 11. Map showing locations of current yacht moorings (black and white circles) and the potential sites for new moorings (white rings indicate yacht moorings; white square indicates small boat moorings) at Sandy Island, SIOBMPA, Grenada. MarSIS habitat layers show areas dominated by sand in yellow, seagrass in green and coral in pink.

4.7.2 Paradise Beach, L'Esterre Bay

The seabed probe and site inspection conducted by Moor Seacure in 2009 determined that hydraulic embedment anchors were not suitable for use near Paradise Beach, L'Esterre Bay. There were also no suitable rocks for Epoxied pin systems. The in-water inspection of the current moorings near Paradise Beach found that manta and pin moorings have been utilized for overnight yacht moorings and a variety of 'home-made' anchors are securing the small boat moorings. This assessment recommends that a combination of concrete block type anchors and manta and pin type anchors be used for future yacht mooring installations near Paradise Beach so their success can be compared. It is suggested that additional small boat moorings be installed and properly maintained, as was recommended by interviewed dive shop operators who stated that this would increase access to Paradise Beach services (e.g. restaurants, shops). Additionally, small boat moorings will decrease the threat of anchor damage close to shore, as well as reduce the incidence of boats tying to trees near the beach, which can cause breakage.

Seven potential sites for new yacht moorings and eleven small boat moorings have been identified in L'Esterre Bay off of Paradise Beach (Table 4; Figure 12). These locations are spaced with a minimum 130 feet between yacht moorings to accommodate vessels up to 65 feet in length. Prior to installation, an in-water inspection of these sites should identify an exact location where there is minimal seagrass coverage (i.e. the closest sand patch), and the exact depth of that location so the mooring system can be prepared with the appropriate length of downline (10 feet longer than depth at high tide). If the locations are altered to minimize the mooring system's impact on seagrass, the coordinates should be updated in the Google Earth map and the distance between mooring systems should be double-checked to ensure adequate spacing.

Table 4. Number, location, depth and bottom type of potential new yacht mooring systems north of Paradise Beach, SIOBMPA.

N (New yacht) NS (New small Boat)	Coordinate (Degrees Decimal Minutes)	Coordinate (Degrees Decimal Minutes)	Depth (ft)	Bottom Type	Components
N14	12° 28.408'N	61° 28.986'W	**>8**	Sand Patch	Halas with concrete block or manta and pin
N15	12° 28.431'N	61° 28.980'W	**>8**	Sand Patch	Halas with concrete block or manta and pin
N16	12° 28.413'N	61° 28.961'W	**>8**	Sand Patch	Halas with concrete block or manta and pin
N17	12° 28.438'N	61° 28.958'W	**>8**	Sand Patch	Halas with concrete block or manta and pin
N18	12° 28.420'N	61° 28.937'W	**>8**	Sand Patch	Halas with concrete block or manta and pin
N19	12° 28.380'N	61° 29.029'W	**>8**	Sand Patch	Halas with concrete block or manta and pin
N20	12° 28.385'N	61° 29.002'W	**>8**	Sand Patch	Halas with concrete block or manta and pin
N21	12° 28.388'N	61° 28.972'W	**>8**	Sand Patch	Halas with small concrete block or manta and pin
N22	12° 28.393'N	61° 28.946'W	**>8**	Sand Patch	Halas with small

					concrete block or manta and pin
N23	12° 28.407'N	61° 28.905'W	**>8**	Sand Patch	Halas with small concrete block or manta and pin
N24	12° 28.392'N	61° 28.887'W	**>8**	Sand Patch	Halas with small concrete block or manta and pin
N25	12° 28.455'N	61° 28.932'W	**>8**	Sand Patch	Halas with small concrete block or manta and pin
N26	12° 28.434'N	61° 28.917'W	**>8**	Sand Patch	Halas with small concrete block or manta and pin
N27	12° 28.466'N	61° 28.908'W	**>8**	Sand Patch	Halas with small concrete block or manta and pin
N28	12° 28.440'N	61° 28.894"W	**>8**	Sand Patch	Halas with small concrete block or manta and pin
N29	12° 28.418'N	61° 28.881'W	**>8**	Sand Patch	Halas with small concrete block or manta and pin
N30	12° 28.404'N	61° 28.858'W	**>8**	Sand Patch	Halas with small concrete block or manta and pin
NS13	12° 28.329'N	61° 28.964'W	**>8**	Rock/sand	Halas with small concrete block
NS14	12° 28.328'N	61° 28.953'W	**>8**	Rock/sand	Halas with small concrete block
NS15	12° 28.336'N	61° 28.929'W	**>8**	Rock/sand	Halas with small concrete block
NS16	12° 28.340'N	61° 28.909'W	**>8**	Rock/sand	Halas with small concrete block
NS17	12° 28.349'N	61° 28.881'W	**>8**	Rock/sand	Halas with small concrete block
NS18	12° 28.355'N	61° 28.871'W	**>8**	Rock/sand	Halas with small concrete block
NS19	12° 28.361'N	61° 28.861'W	**>8**	Rock/sand	Halas with small concrete block
NS20	12° 28.365'N	61° 28.851'W	**>8**	Rock/sand	Halas with small concrete block
NS21	12° 28.370'N	61° 28.841'W	**>8**	Rock/sand	Halas with small concrete block
NS22	12° 28.377'N	61° 28.832'W	**>8**	Rock/sand	Halas with small concrete block
NS23	12° 28.385'N	61° 28.823'W	**>8**	Rock/sand	Halas with small concrete block

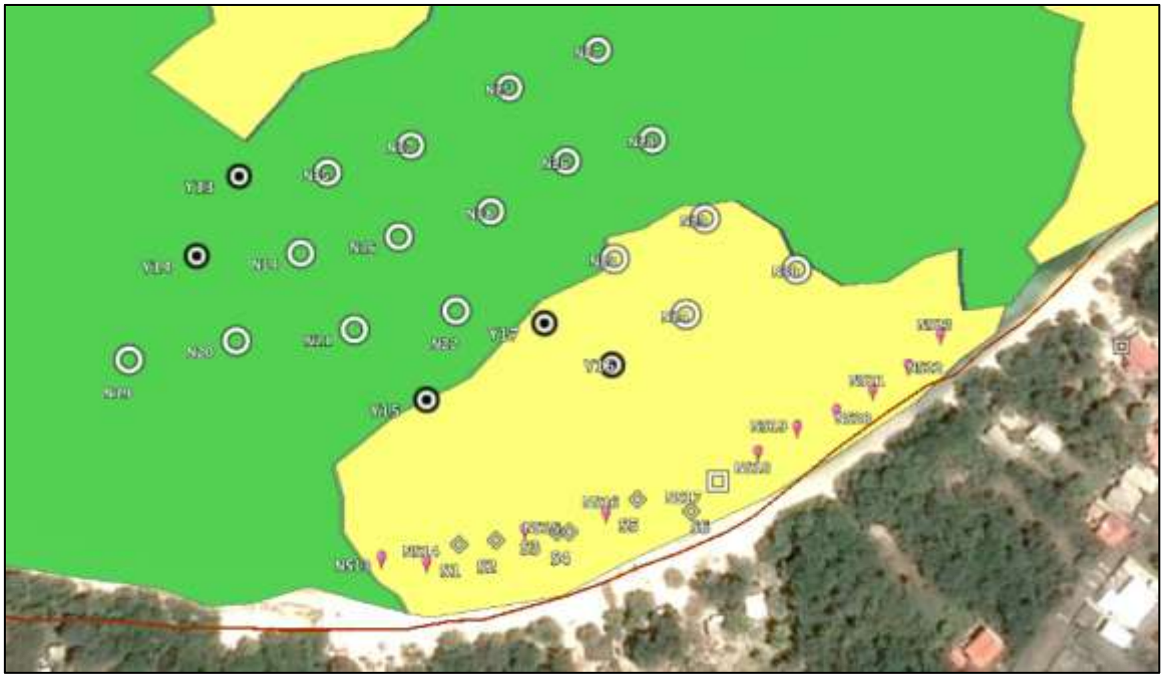

Figure 12. Map showing locations of current moorings (black and white circles indicate yacht moorings, white diamonds indicate small boat moorings) and the potential sites for new moorings (white rings indicate yacht moorings; white square indicates small boat moorings) at Paradise Beach, SIOBMPA, Grenada. MarSIS habitat layers show areas dominated by sand in yellow, seagrass in green and coral in pink.

4.7.3 Dive Moorings

Richard Laflamme and Diane Martino of Lumba Dive are currently managing and maintaining the dive moorings. When interviewed, they stated that they could continue to uphold these responsibilities if the appropriate materials and equipment would be provided. The stakeholder workshop wherein this draft management plan will be presented should include the three dive shops operating in the SIOBMPA. The dive shop representatives and MPA management staff will need to establish an arrangement regarding dive mooring management that is agreeable to all parties.

Dive mooring GPS coordinates were provided by Richard of Lumba Dive. Red dive flags indicate current moorings, while the four orange dive flags indicate sites requiring dive moorings (Figure 13, 14). The current anchorage zone is the area within the green placemarkers shown in Figure 13. This sandy area is where boats anchor that exceed the size limit of the mooring systems. It is recommended that a professional mooring company be contracted to site and install moorings for superyachts and small cruise ships.

Figure 13. Map showing current dive mooring sites (red flags) near Mabouya (left) and Sandy Island (right), as well the anchorage zone south of Sandy Island, SIOBMPA, 2016.


Figure 14. Map showing current dive mooring sites (red flags) and dive sites requiring mooring systems (orange) near Sister Rocks (top left) and around Cistern Point, SIOBMPA, 2016.

4.7.4 MPA Boundary Demarcation Moorings

From Lumba Dive's records of past mooring system locations, five key sites requiring mooring systems for boundary demarcation buoys were identified (Figure 15). These sites were identified based on the record's notes that indicated SIOBMPA staff had requested the removal of other demarcation buoys and the upkeep of the moorings at these five sites. SIOBMPA has demarcation buoys, which can be redeployed once the mooring systems have been installed at the five sites.

Figure 15. Map of SIOBMPA with suggested boundary demarcation mooring sites (purple flags).

5.0 Recommendations

5.1 Recommended Mooring Specifications

5.1.1 Mooring Design

The Halas principle of mooring design is recommended for new installations in SIOBMPA, as was recommended for the South Coast Marine Managed Area (Fairhead and Baldwin, 2015). A detailed description of the Halas mooring system design is provided in Appendix C.1.Three-ton concrete anchor blocks are the recommended anchor type for yacht moorings since the manta and pin type anchors require specialized equipment for installation, and have proven less suitable to dynamic sandy bottom conditions (B. Wilson, personal communication, May 24, 2016). Epoxy embedded pins can be used for small boat moorings where there are rocks suitable for secure the pin (Figure 17;Moir, 2009). Benefits of the Halas system are that it is user friendly, durable and easily maintained and repaired with locally available materials and resources. Mooring fabrication requires basic measuring and splicing skills.

The existing yacht moorings were installed in 2015 as part of a CARIBSAVE project. Their systems involve a Manta Ray anchor system, also called a Manta and Pin type system. This type of anchor can be very reliable, however, dynamic bottom-types such as shifting sands can lead to the anchors displacement. About a year after installation, the manta ray anchors on the moorings within SIOBMPA appear to be in their original, correct positions. Manta systems require specialized equipment and expertise to install, which SIOBMPA staff have because of the previous project. Concrete block-type anchor are less expensive than manta ray anchors and are relatively simple to build and install. The concrete blocks are only suitable for flat sandy bottom areas. It is recommended that a combination of these two anchor types be used for the new moorings, which will allow for comparison. This was the recommended approach for the mooring fields at South Coast Marine Managed Area in St. Vincent.

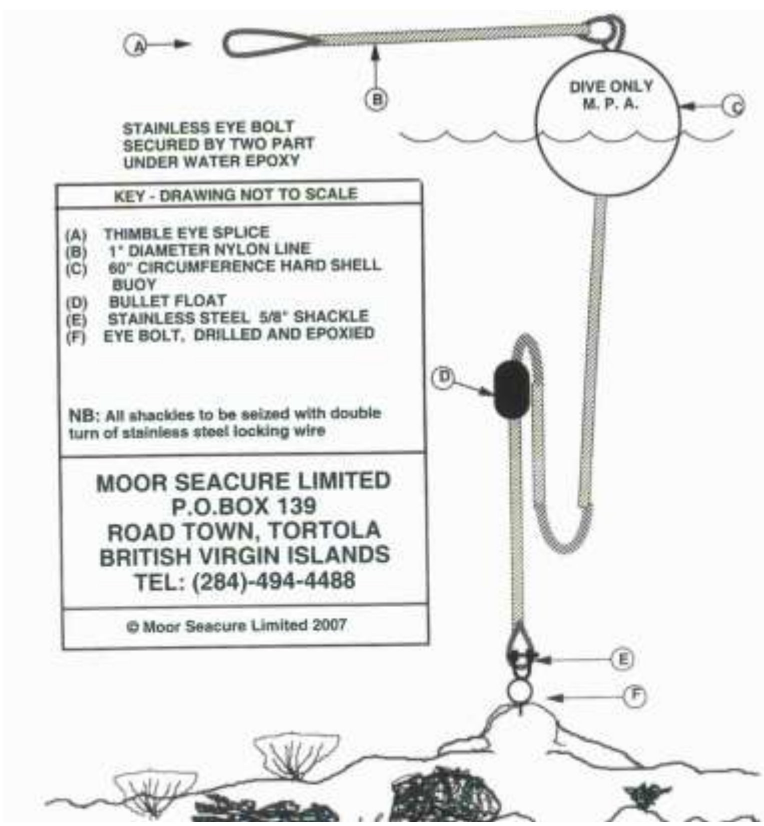

Figure 17. Epoxy embedded pin mooring system for small boats recommended by Moor Seacure Ltd. (Moir, 2009).

5.1.2 Yacht Mooring System Components

These yacht moorings are suitable for boats between 26-65 feet and less than 30 tons gross weight. For boats greater than 30 tons gross weight or 65 feet in length, larger mooring systems will be required. Directions to assemble the Halas Mooring System can be found in Appendix C.1.

The following parts will be required for each yacht mooring system:

- Buoy- 18 inch polyethylene ball buoys (white if suggested colour coding is followed)
- Anchor- 3 ton concrete block (3x3x3 or 3x4x3) with shackle and eye bolt (see Figure 1)
- Rope system typically uses ¾ inch 3-strand nylon combo rope or ¾ inch UV-treated polypropylene rope
- Downline- ¾ inch rope approximately 10 feet longer than the depth at high tide; reinforced hose or galvanized thimble (spliced into the loop at bottom of line to prevent abrasion).
- Through line- 12 feet of 7/8-inch line
- Pickup line- 15-18 feet of ¾ inch rope
- Galvanized shacked to connect downline to anchoring system
- Thimble or nylon reinforced hosing

5.1.3 Small Boat Mooring System Components

Small boat moorings will be suitable to accommodate dinghies and boats under 26 feet in length.

The following parts will be required for each small boat mooring system (as shown previously in Figure 2):

- eye bolt, drilled and epoxied
- stainless steel 5/8 inch shackle
- bullet float
- 60 inch circumference hard shell buoy (blue)
- 1 inch nylon line
- thimble eye splice

5.1.4 Power Boats/Super Yachts

These larger boats can cause significant anchoring damage, and therefore, moorings should be provided instead of creating an additional anchoring zone or utilizing the existing anchoring zone. I am looking into potential options and will provide those within the next week. They will be more costly, but the potential for mooring fees is also much greater for these types of superyachts.

5.1.5 Colour Coding of Moorings

It is recommended that the mooring buoys be colour-coded to communicate their intended use. The following code is used in the British Virgin Islands (BVI). Some of the interviewed charter yacht companies have commended the mooring system in the BVI so given this, and the popularity of yachting in the BVI, it is recommended that the same colour coding system be used at SIOBMPA.

- The mooring buoys are 13 inches in diameter and are colour-coded as follows:
  - Orange Buoys: Non-diving, day use only
  - Yellow Buoys: Commercial dive vessels only
  - Large Yellow Buoys: Commercial vessels or vessels over 55 ft.
  - White Buoys: Non-commercial vessels, for overnight use (in BVI, only day use because boats are not allowed to overnight within MPA boundaries)
  - Blue Buoys: For dinghy use only

5.2 Mooring Maintenance

5.2.1 Importance of Mooring Maintenance

Ensuring the mooring systems are properly maintained should be a principal priority of MPA management staff. Proper mooring maintenance promotes user safety, environmental protection and revenue generation. Poorly maintained mooring systems can lead to boater mistrust, which encourages anchoring and its associated threats. In fact, the majority of the interviewed charter yacht company representatives cited poorly maintained moorings as the main cause of anchoring within MPAs. Poor mooring maintenance may also lead to breakages that can result in a yacht being set adrift, vulnerable to collisions with other yachts or groundings that can damage the boat and degrade benthic habitat (e.g. coral reef, seagrass beds). Visitors will be more accepting of increased mooring fees if the mooring systems are well maintained.

5.2.2 Mooring Maintenance in SIOBMPA

The proposed mooring maintenance plan for SIOBMPA draws from the 'Standard Operating Procedures for Mooring Maintenance' (SOPMM), which was prepared as an output of the Grenada Bank MPA Network Learning Exchange to Mustique (Harvey, 2013). The report was developed to assist the MPAs within the Grenada Marine Protected Area (GMPA) system with maintenance of their fixed mooring systems. All staff working on mooring maintenance should be familiar with the SOPMM.

The supervision of maintenance should be assigned to one individual. This person will be responsible for designating responsibilities and ensuring a mooring maintenance schedule is kept (see Appendix C.2 for the recommended schedule). The schedule has been designed to be flexible so that the maintenance plan can adapt as local conditions and patterns of use change over time. The schedule has been added to the Grenada Bank MPA Network monitoring calendar.

As described in the SOPMM, mooring systems require maintenance to ensure that moorings are safe, reliable, and in an acceptable condition. The maintenance cycle includes three stages (1) inspection, (2) repair, and (3) onshore inventory management.

The cycle aims to:

- Maintain mooring systems to safely secure vessels for which they are rated
- Conduct maintenance in a consistent, timely and efficient manner
- Manage onshore mooring inventory to complement in-water activities

To implement the mooring maintenance cycle, 15 Standard Operating Procedures (SOP) have been identified (Table 5).

Table 5. List of Standard Operating Procedures for Mooring Maintenance (Harvey, 2013).

SOP 1	All personnel working within SIOBMPA must be familiar with the location and type of mooring infrastructure found in the MPA.
SOP 2	Each mooring must have a clearly marked unique identification number on the mooring buoy, which must be recorded on the official receipts.
SOP 3	All personnel working within SIOBMPA must be familiar with the size limitations of the MPA's moorings.
SOP 4	All personnel working within SIOBMPA must be familiar with proper mooring techniques.
SOP 5	Maintenance of SIOBMPA moorings must be carried out under the supervision of the MPA manager or other qualified expert appointed by the MPA Board.
SOP 6	Inspections of underwater moorings components using SCUBA must be carried out by buddy pairs.
SOP 7	Personnel who are required to use specialist tools for mooring inspection and maintenance must first be trained in their use
SOP 8	Visual inspection of surface components of the moorings must be made during all regular patrols, or at least weekly, and in response to public reports regarding moorings.
SOP 9	In-water inspection of underwater mooring components must be made at least twice (2) per month in the high season and at least once (1) per month in the low season, and in response to public reports regarding moorings
SOP 10	If there is any fraying in the down or pick-up lines, corrosion of more than 20% of the metal (i.e. chain or shackles) or signs of stress fractures, these components must

	be replaced immediately.
SOP 11	Equipment and supplies must be kept in good order and in ready, operating condition.
SOP 12	Condition of moorings must be punctually and truthfully recorded following inspections. A field log sheet (Appendix C.3) must be filled out for every mooring that is inspected and/or repaired.
SOP 13	All public reports about moorings must be followed-up and recorded in the warden daily log.
SOP 14	All mooring reports must be validated and signed-off on by the senior warden on duty and submitted to the manager.
SOP 15	In the event of a mooring failure or loss of a mooring, in addition to the mandatory incident report, a mooring failure report must be generated within one week and must include the details in the full SOP document (see Appendix C.4 for incident report log sheet).

To facilitate SOP 12 and SOP 13, a Mooring Management Binder should contain mooring maintenance log sheets, a space for incident and public reports, and maps of the mooring fields (Appendix C.5). The Mooring Management Binder should be taken to the field daily to ensure all maintenance activities and mooring related incidents are recorded.

In addition, a mooring maintenance pamphlet has been developed to provide a summary of the information from the SOPMM (Appendix C.6). This pamphlet should also be included in the field binder to provide reference materials that can guide maintenance and promote consistency.

An Excel Workbook has been developed for record keeping and has been provided to the designated mooring management supervisor. One spreadsheet should be used to keep track of the number of visitors/boats using the moorings, the size of boats, the length of stay, and the fees collected. One spreadsheet should be used to record the costs each maintenance activity (e.g. replacement mooring system components, SCUBA gear rental, etc.) and any costs associated with mooring management (e.g. printing of new maintenance log sheets). One spreadsheet should be used to record the expenditures associated with educational materials, which can be funded via revenue generated from mooring fees.

5.3 Protection of Mangroves within SIOBMPA

As many as 200 boats, both locally and foreign owned, seek shelter within the mangrove lagoon during storm events (G. Schmitt, personal communication, July 7, 2016). Boats drop anchors and use lines to secure their vessels to the mangroves. The SIOBMPA draft management plan (2007-2009) indicated the need to address the risk of mangroves being damaged during storm events as a result of vessel securement. The mooring feasibility study conducted in 2009 by Moor Seacure International recommended the installation of a ground chain mooring system within the mangrove lagoon to reduce this threat. Moor Seacure installed and currently manages a ground chain system in Paraquita Bay, British Virgin Islands. Given their knowledge of the area, the interviewed SCUBA dive operators were asked for their opinion on the proposed ground chain system. One of the three responses was negative and expressed doubt that the mooring system was feasible given the muddy bottom-type. The other two responses were positive, but the point was made that the money required for such a system might be better spent elsewhere considering the low frequency of storm events. Management staff agreed with the latter viewpoint and decided that this plan should not recommend the installation of the ground mooring system within the mangrove lagoon. An assessment of the mangroves' baseline condition could be conducted prior to any storm events so a post-storm assessment would be better able to gauge the impact that yachts are having when moored to the mangroves during storm events. This data would then be available to inform decisions regarding the use of the lagoon during storms and the need for an alternative mooring structure.

5.4 Mooring Fees

5.4.1 Mooring Fee Collection Procedure

The collection of moorings fees occurs on a daily basis within the SIOBMPA. It provides the opportunity for park wardens to greet and brief the visitors, collect the appropriate fees and ensure boats are properly secured to the appropriate mooring system. If boats need to anchor (e.g. if they are too large for the moorings), then the wardens should ensure the yacht anchors within the anchorage zone. It is recommended that this interaction between wardens and visitors be used to ensure that the boats are adhering to the holding tank regulations of the SIOBMPA. One of the wardens should board the boat and check that the holding tank is closed. Information on the boat and its stay should be recorded since it is an ideal opportunity to collect data that will be useful in terms of managing the mooring systems and in assessing the park's carrying capacity. The data should be transcribed into an excel spreadsheet every week by a designated SIOBMPA staff member. A checklist will be included in the Mooring Management Binder in order to ensure the wardens do not oversee any aspects of the recommended procedures. The checklist is as follows:

Mooring Fee Collection Checklist

- ✓ Boat name, size (gross tonnage and length), number of passengers, date, length of stay, mooring number and if the boat has a holding tank have been recorded
- ✓ Money has been collected and the amount recorded
- ✓ Mooring surface components have been checked
- ✓ Boat's connection to the mooring has been checked
- ✓ Boat's holding tank has been checked to ensure it is closed
- ✓ Visitors have been welcomed and briefed on park regulations and services
    - no-anchoring

- holding tank must remain closed
- speed limit
- proper garbage disposal
- no-touching or taking anything from the reef
- no fishing
- reef-friendly sunscreen
- contact information to report incidences (request that any issues with the moorings be reported; request that observations of other visitors breaking regulations be reported; offer assistance if anyone is harassing the visitor or theft occurs)

5.4.2 Mooring Fee Costs

Well-managed mooring systems can be a successful sustainable financing mechanism, particularly in MPAs that are popular yachting destinations. Multiple interviewed charter yacht companies noted that anchoring might be occurring because visitors want to avoid paying mooring fees, and therefore, it will be important to ensure that mooring fees continue to be collected from boats within the anchorage zone. It was also suggested that a higher mooring fee could be implemented if the moorings were high quality and well maintained. If the fees were to increase, the amount of overnighting yachts in the MPA might decrease, but the same amount of money could be generated as long as the decrease in users was not significantly reduced. For instance, in order to make 1000 XCD on mooring fees in one night, the park could accommodate 22 yachts paying 45 XCD or 13 yachts paying 75 XCD. There would need to be 9 yachts unwilling to pay the higher fee in order for less money to be generated. The SIOBMPA management board will need to agree upon a cost that is profitable, but not perceived as high enough to decrease visitation significantly.

The price should not be set higher than that of an overnight berthing fee at the marina that is currently under-going construction in Tyrell Bay. If moorings for large boats (i.e. super yachts or small cruise ships) are installed, as recommended by this management plan, the cost of overnighting on the mooring will need to be established. It is suggested that consideration be given to the average number of people aboard these large boats and the high costs of chartering superyachts. One of the interview participants advocated that the MPA should increase mooring fees as long as the mooring systems are well maintained, and set a high-price for super-yacht moorings. Alternatively, one interview participant expressed concerns that increasing mooring fees would negatively impact visitation rates and decrease the amount of tourism dollars being spent in the region. This person noted that since Mustique increased their mooring fees, tourists have been less willing to overnight at Mustique; however, MPA managers working at Mustique reported that visitation has not decreased since the new mooring fees were set at 185 USD for three nights (B. Little, personal communication, June 8, 2016). The set price should at least ensure the mooring fee profits are enough to fund the mooring systems' maintenance costs and the fee-collection patrols. Ultimately, the mooring fees agreed upon by the SIOBMPA management board will need to be proposed and approved by Grenada's MPA coordinator and put through cabinet.

An analysis of the spending patterns of yachters in Grenada indicated that in 2012, only 2% of the expenditures were on government fees, which includes MPA visitation and mooring fees (Henry, 2013). Considering the marine ecosystem's beauty and productivity greatly contribute to the yachting tourism appeal of the region, it can be argued that a greater portion of the money being spent by yachters should contribute to marine conservation and management costs. Out of an analysis of the economic opportunities of the yachting industry, Henry (2013) identified five recommendations that would promote the economic success of the industry; one of the recommendations was to strengthen management of Marine Protected Areas. These findings should be considered when making decisions regarding the costs of the MPA's mooring fees.

5.4 Sewage Waste Management Options

5.4.1 Sewage at Sea

Any boat with bathroom facilities on board requires a waste management system. Black water refers to toilet waste, while grey water is the term for wastewater from sinks and showers. Typically, grey water is flushed overboard without treatment. Many countries have adopted regulations that prohibit the direct discharge of black water into coastal or freshwater areas because of the threats of nutrient pollution, harmful pathogens, and reduced aesthetic appeal. The need to manage black water on board yachts can be addressed in a variety of ways, including the use of marine sanitation devices (MSDs), or recirculating, composting and incinerating toilets.

MSDs are systems that treat black water to reduce the amount of bacteria entering the sea upon waste disposal. Type 1 MSD involves the processing of sewage using chlorination or maceration. Type 2 relies on the bacteria present within the sewage to facilitate aerobic digestion. Type 3 refers to the storage of waste in containers, known as holding tanks, and the subsequent disposal of the collected waste.

Cruise ships commonly use MSDs, but their effectiveness varies and depends on the type of MSD used. A study conducted by the Alaska Department of Environmental Conservation found that 55% of black water treated by MSDs, mainly Type 2, on cruise ships contained fecal coliform about the federal standard of 200 fecal coliform per 100 milliliter (EDEC, 2000). As such, the SIOBMPA should adopt a regulation to prohibit the release of MSD treated black water within the MPAs' boundaries.

Almost all new yachts are built with holding tanks (T. Segond, personal communication, July 18, 2016). Also termed 'black water tanks', holding tanks are storage containers that connect to toilets on yachts and other vehicles. There are different designs of holding tanks that vary in complexity (See Figure 16-18).

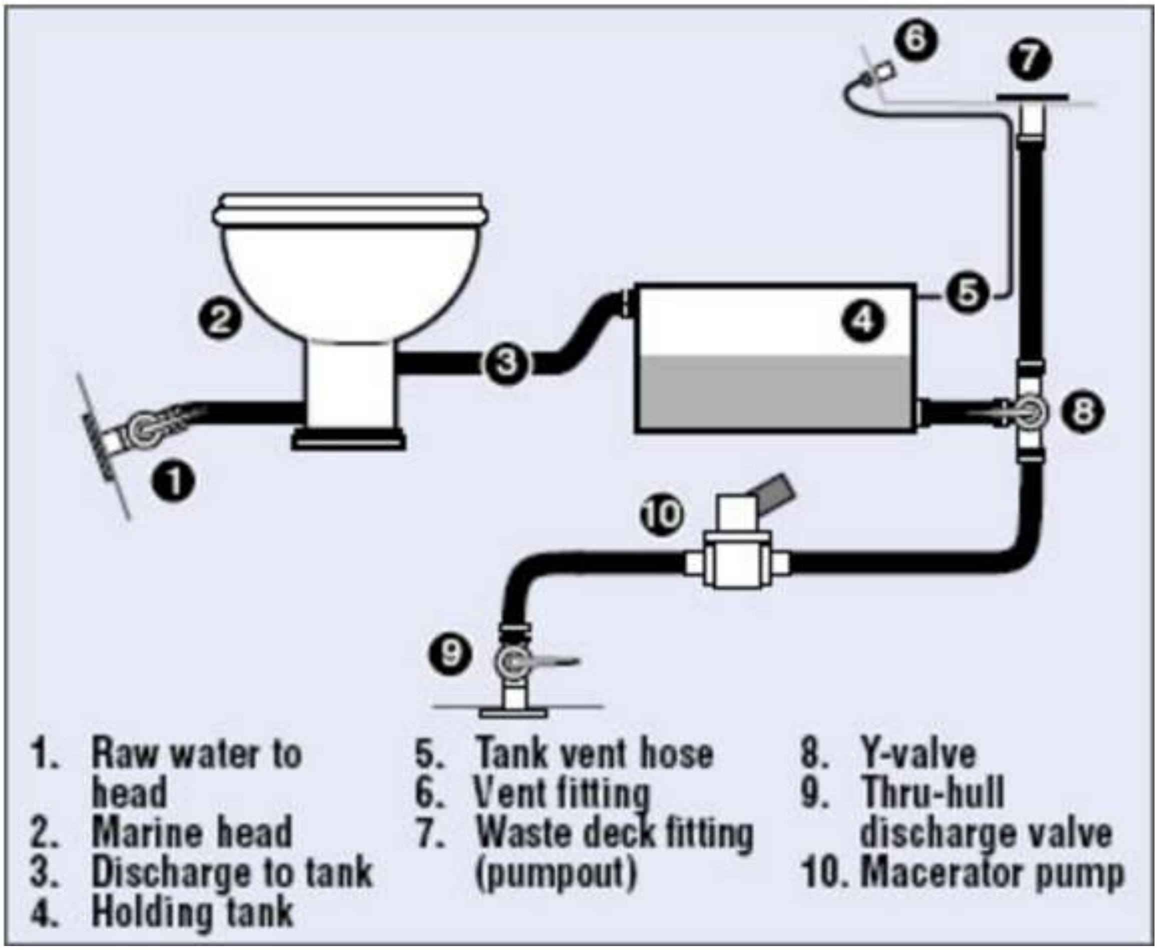

Figure 16. Diagram showing a holding tank system with multiple discharge options (Burden, 2016).

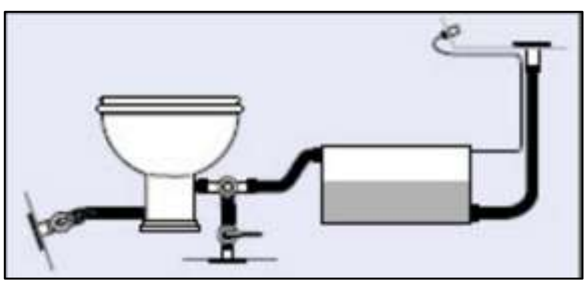

Figure 17. Holding tank with optional overboard discharge (Burden, 2016).

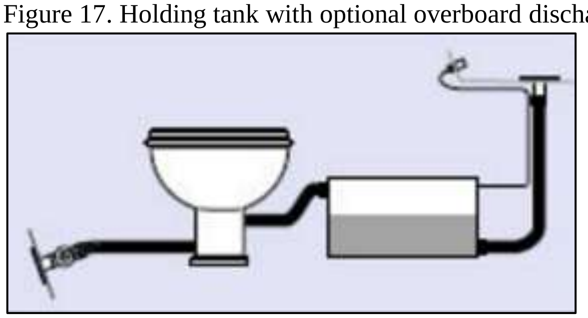

Figure 18. Holding tank without self discharge option (Burden, 2016).

Some designs are built with an optional overboard discharge mechanism (see Figure 16-17), while others do not give the boater the option to discharge the sewage directly into the sea (Figure 18). It has been reported that many of the charter yachts operating within the SIOBMPA position the Y valve in a position that facilitates the direct disposal of black water into the sea. This practice is done to avoid the risk of the Y valve seizing shut, which apparently occurs frequently in older holding tank systems and causes unpleasant issues that can detract from the guests' experience (anonymous personal communication). An interviewed charter yacht company representative expressed the opinion that holding tank systems, especially newer systems, do not have this issue if they are regularly maintained.

5.4.2 National and International Regulations on Sewage Disposal at Sea

Holding tanks, also termed 'black water tanks', are storage containers that connect to toilets on yachts and other vehicles. Black water refers to toilet waste, while grey water is the term for waste from sinks and showers. Because black water is high in nutrients and often contains harmful bacteria and viruses, many Coastal States' have regulations that prohibit holding tank disposal in defined areas. The International Convention for the Prevention of Pollution from Ships (MARPOL) provides a global set of protocols relating to ship pollution, including regulations regarding the discharge of sewage from ships (Annex IV). The regulations address the ships' equipment and systems for the control of sewage discharge, the provision of port reception facilities for sewage, and requirements for survey and certification. Annex IV, which was revised in 2004 and adopted in 2005, apply to ships certified to carry 15 or more passengers, or that exceed 400 gross tonnages. Regulations prohibit the discharge of sewage into the sea within a specified distance from the nearest land. Ships may discharge comminuted and disinfected sewage at a distance of more than three nautical miles, while sewage that is not comminuted or disinfected may be discharged at a distance of more than 12 nautical miles from the nearest land. Governments committed to MARPOL are required to ensure the provision of adequate reception facilities at ports and terminals for the reception of sewage. Grenada subscribes to MARPOL, however, supporting national legislation is lacking (Jeco Caribbean, 2011).

Ideally, all boats entering an MPA should be required to have functioning holding tanks to ensure no black water is flushed into the marine park. Although this may seem extreme, many countries now have national legislation that prohibits the discharge of untreated sewage anywhere within 12 nautical miles of land (i.e. their territorial waters). Countries such as Finland, Greece, Turkey and the Netherlands have adopted this regulation, making holding tanks or on-board marine sanitation devices (MSDs) mandatory. Other countries have this regulation, but have defined characteristics of boats that qualify their exception from the regulation. For instance, Denmark allows boats built prior to January 1980 to discharge sewage when two nautical miles from the shore; boats built between 1980 and January 2000 that are either less than 10.5m LOA or have a maximum beam of less than 2.8m do not require a holding tank and can discharge sewage when two nautical miles from the shore; and boats built after January 2000 must have a holding tank that can be emptied via a deck fitting.

5.5.3 Regulating Holding Tanks in the SIOBMPA

Interviews with charter yacht company representatives determined that 66.63% of the companies' charter yachts have holding tanks and that almost all new yachts have holding tanks. It was commonly reported that holding tank valves often seize open or shut; if it seizes open, waste will go directly through a macerator pump, which breaks the waste up and passes it out via the through-hull discharge valve into the ocean; if it seizes shut, sewage will not be able to be disposed of once the holding tank becomes full (Figure 16).

Because of the threats posed by sewage disposal within the SIOBMPA, including nutrient pollution from yachts, the release of harmful bacteria, and a decrease in tourism appeal, regulations that encourage the proper use of holding tanks are required.

There may be resistance to the adoption a regulation that prohibits all boats without functioning holding tanks from overnighting in the SIOBMPA because it could be perceived as a deterrent to visitation. Given the importance of tourism to the region's economy, the fear that stricter regulations will decrease tourism is understandable. It is vital, however, to consider the risk visitation poses to the tourism industry if visitors to the SIOBMPA cause detrimental impacts that decrease the tourism appeal of the MPA. It is the author's opinion that if conservation of the marine ecosystems within the SIOBMPA is held as the top priority, the park will be capable of sustaining tourism over the long-term. Regulations that help to ensure the MPA remains rich in life and encourages stakeholders to view the park (e.g. mooring systems) as well managed, will increase the tourism appeal and thus, revenue potential of the SIOBMPA.

To ensure that regulations are supported, implemented and enforced, awareness of the intent and importance of the regulations must be promoted, and the feasibility of the regulations must be considered. It is therefore recommended that the initial regulations relating to sewage-pollution do not completely ban boats without functioning holding tanks from the park, but rather encourage boat owners to consider upgrading their sewage facilities. As incentive, boats that do have functioning holding tanks should receive a discounted mooring fee. This will incentivise charter yacht companies and pleasure craft owners to install or upgrade holding tanks. If water quality monitoring indicates that sewage waste pollution is occurring at a level that could compromise the health of the marine ecosystems, the regulation can be modified to restrict access to boats without functioning holding tank facilities.

Furthermore, it is recommended that boats without functioning holding tanks should overnight at specific moorings. A flow mapping study would be required in order to identify which mooring locations would be the most appropriate to designate for boats without holding tanks. Non-toxic biodegradable fluorescent dyes can be used to map the flow characteristics. Sites should be selected if the water flow indicates that disposed sewage would be dispersed via currents into deeper waters away from the shallow coral reef and seagrass ecosystems.

Fluorescent dye tablets can also be used to discourage improper waste disposal by placing tablets in vessel holding tanks so the water will be coloured if the holding tank is emptied. The colour degrades via solar radiation in a matter of days. Marinas use this technique to ensure vessels are not releasing sewage waste within the harbour (Geosyntec, 2016). If this practice was adopted by SIOBMPA, park wardens must be responsible for ordering a supply of dye tablets. Tablets could be placed in holding tanks when mooring fees are collected. It is recommended that two tablets be used per holding tank (Ben Meadows, 2016). The cost of dye tablets will limit the frequency at which this method could be applied, as the cost of 200 tablets is around 45.00 USD (Ben Meadows, 2016). Given the cost, it is recommended that the tablets be used on vessels that have large holding tanks because they pose a greater threat than holding tanks that contain small volumes of waste.

5.5.4 Sewage Waste Collection and Treatment

One of the two most important factors in preventing sewage pollution from vessels is to ensure that sewage pump-out facilities are adequate and reasonably available (Geosyntec, 2016). The other significant aspect of preventing improper sewage disposal at sea is boater education, specifically promoting awareness about no-discharge zones and the rationale behind their designation (Geosyntec, 2016).

Sewage pump-out facilities allow for waste to be transferred from the holding tanks of vessels to on-land containers or sewage systems. There are three types of pump-out facilities. Fixed-point collection systems involve a centrally located pump-out station, typically at a fueling pier so boats can refuel and pump-out simultaneously. Slipside systems continuously collect wastewater and are used by live-aboard vessels in marinas. Portable systems include a pump and storage tank, allowing for the system to be moved as needed. The portable system's storage tank is emptied into the municipal sewage system or can be removed by a septic tank pump-out service.

In order to encourage the proper use of holding tanks, there must be pump-out facilities available near to the MPA. It must be convenient for boaters to have their holding tanks emptied in order to incite boaters to choose to use a pump-out facility instead of disposing the waste into the sea. The creation of a pump-out facility could be an alternative livelihood project associated with SIOBMPA. Funding support would be needed to purchase the equipment and provide training, but pump-out fees would be collected to generate income over the long-term.

It is crucial to consider what will happen to the waste once it is collected. The treatment and strategic disposal of the collected sewage is required in order for the effort of collecting the sewage to be worthwhile. If the collected sewage is pumped untreated into the coastal zone, it will likely cause more adverse impacts than if it had been disposed of while the vessel was at sea where dispersion is more significant. Since there is no municipal sewage treatment facility on Carriacou, a waste treatment system would need to be established to deal with the waste collected from vessel holding tanks. A conversation with the Permanent Secretary of Carriacou indicated that an anaerobic digestion facility would be of interest (B. Sylvester, personal communication, June 9, 2016).

Anaerobic digestion of sewage waste involves the use of bacteria to breakdown the organic material in the absence of oxygen. The process produces biogas and digested slurry. A biogas-biofertilizer plant, as shown in Figure 19, utilizes anaerobic digestion to degrade organic wastes, such as sewage, wastewater, animal waste, and plant waste, over a period of approximately 30 days (CEHI, 2004). Biogas-biofertilizer plants are widely used in the Caribbean and are featured within the Directory of Environmentally Sound Technologis for the Integrated Management of Solid, Liquid and Hazardous Wastes for Small Island Developing States in the Caribbean Region (CEHI, 2004).

As the bacteria break down the organic material, biogas comprised of methane and carbon dioxide is produced and collects in the dome of the digester. An outlet pipe connects to PVC pipelines that transport the gas to be scrubbed and provided to various energy consuming devices (e.g. refrigerators, stoves, diesel engines). When the capital and operating costs of a digester were considered against the cost of conventional fuels, the comparisons showed that biogas may be a feasible alternative when (1) biogas can replace a conventional fuel, (2) the conventional fuel is more expensive than the biogas, and (3) all of the produced biogas is used (Homan, 2016). It is recommended that further research be conducted to determine the use potential of biogas on Carriacou.

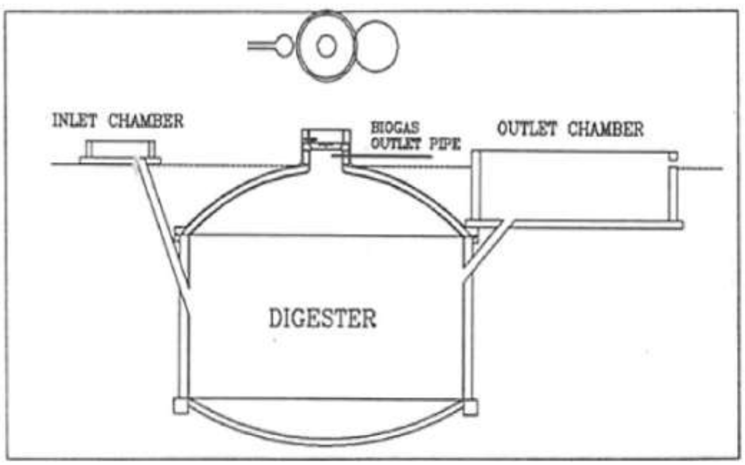

Figure 19. Diagram of a biogas-biofertilizer plant showing inlet chamber, digester, biogas outlet pipe and outlet chamber (CEHI, 2004).

Digested slurry is contained in the system's outlet chamber until it is piped to fields or dried and transported to the point of use. The slurry is a great fertilizer because it is rich in organic nutrients and typically does not contain harmful pathogens (CEHI, 2004; Jenkins, 1999). This technology does not work well with only human waste because it contains too much nitrogen and not enough carbon to adequately sustain the microorganisms (Jenkins, 1999). The system would therefore require a carbon-based material, such as plant cellulose, to be incorporated. Kitchen food-scraps, weeds, straw, hay, and leaves are sources of carbon that can be added to the system to achieve a beneficial carbon/nitrogen ratio. The need for carbon-based material could instigate the development of a composting system for the island. Since the fertilizer produced could be marketed to farmers and gardeners, profits from fertilizer sales could support a compost collection service.

It is recommended that further discussion between relevant government agencies and involved NGOs consider the viability and requirements of the aforementioned sewage collection and treatment options. Project grants may be attainable to cover initial costs, but the systems must be integrated in a manner that ensures their long-term use is feasible.

5.6 Raising Awareness

5.6.1 Promoting Mooring Systems

Various strategies have been implemented to reduce the impacts of anchors on seagrass and coral reef ecosystems (Milazzo et al., 2003). In the last decades, approaches have involved anchoring bans, limitations on the size and number of boats, and the provision of boat moorings.

In order for mooring systems to be an effective management measure, moorings must be available and boat operators must be willing to use the mooring buoy and pay the associated fees. Given the limited legal capacity and resources of many MPAs, however, enforcing anchoring bans and providing well-maintained moorings can be challenging. In such situations, the self-regulatory approach based on educating and informing boaters on anchoring threats may be more effective in terms of mitigating anchor damage (Antonini and Sidman, 1994). For instance, Diedrich et al. (2013) investigated how the attitudes and beliefs of boat operators influences their willingness to use mooring buoys as opposed to anchors. The study showed a positive relationship between attitudes associated with perceptions of safety, space, and minimizing impacts on sensitive habitat, and boaters' willingness to use buoys and pay mooring fees. Awareness regarding the need to minimize negative impacts on sensitive habitat, in this case seagrass (*Posidonia oceanica*), positively influenced boaters' perceptions regarding mooring buoys, while crowding in the study site had a very minor influence. Antonini and Sidman (1994) found a similar positive relationship between boater perception and the use of moorings. A field-tested guidebook with large-scale maps (illustrating sensitive habitats and shore features and services) was found to influence more than 50% of boaters' decisions on where to anchor, indicating the potential of informed voluntary decisions to reduce anchoring threats (Antonini and Sidman, 1994).

Adopting the self-regulatory approach necessitates the development and distribution of site-specific educational materials. In the case of SIOBMPA, informative materials are needed to raise awareness on the threats of anchoring. It will be important to ensure that sailors are aware of the opportunities to use the moorings, the best-practices for mooring use, the mooring fees and payment methods, and the MPA regulations (e.g. no-anchoring unless in anchoring zone, no waste/holding tank disposal). There are already brochures for the SIOBMPA, which could be updated to include the aforementioned topics, and printed and distributed. Charter yacht companies could ensure each yacht has a laminated version and could review it during their safety briefs. Having laminated copies would cut down on printing resources. Tourism bureaus, customs offices, dive shops and hotels could have copies of the brochure available. Publications targeted at sailors, such as Caribbean Compass should also provide this information. This information, as well as maps with the mooring fields, anchoring zones and park boundaries, should also be available on the MPAs' websites or social media accounts (SIOBMPA does not currently have a website, but has Facebook). Additionally, it is recommended that navigational companies be approached to include MPA regulations, updated anchoring zone and mooring field locations and information on waste pump-out facilities. One interviewed charter yacht company has on-board electronic tablets with a range of information available for the passengers, which could include information on moorings and waste impacts and disposal options. It has been emphasized that there is a need to have educational information available in multiple languages, notably English and French.

To encourage the use of the moorings, there must also be evidence regarding the moorings' maintenance available for interested visitors. It is recommended that the Mooring Management Binder be taken on all fee-collection patrols so that the mooring maintenance records and incident reports can be used to promote a positive perception of the moorings.

5.6.2 Awareness-raising to Mitigate Yachting Impacts

In addition to providing the aforementioned information to promote the use of moorings, the suggested site-specific educational materials should contain information about waste disposal regulations and available pump-out facilities. Making this information prevalent will not only promote regulatory compliance, but it is likely to improve the tourism appeal of the SIOBMPA. Multiple interviewed charter yacht company representatives noted that guests have remarked on the lack of waste disposal options in the park and have been concerned about the water quality. The majority of the interviewed charter yacht companies expressed support for enforced holding tank regulations within the SIOBMPA and all were willing to provide educational materials to their guests if the information was sent to them.

Sailors that travel on their own boat, commonly called 'yachties', are a stakeholder group that will require attention when promoting awareness regarding waste disposal. Outreach may be more challenging relative to park visitors sailing in charter yachts because there is not the opportunity of briefing visitors prior to the beginning of their trip. If navigational applications agree to provide information on MPAs, information on waste disposal protocol and pump-out facility locations could also be included. The information should also be available online and at the Customs Office so people entering the country can be informed prior to visiting the MPA.

It is recommended that a fact-sheet on eco-friendly yacht practices and products should be electronically distributed to the charter yacht companies operating in the Grenadines and posted online. Some of the interviewed charter yacht representatives shared on their efforts to reduce the environmental impacts of their business. For instance, vinegar was suggested as a replacement for the potentially toxic chemicals that are often used to clean holding tanks. Additionally, an interviewee recommended a microbe-based antifouling agent that is more eco-friendly and cheaper than conventional antifouling agents because it lacks heavy metals.

5.6 Carrying Capacity

The Grenadine Islands’ picturesque volcanic islands, sandy beaches and turquoise waters have been attracting yachters for decades. The carrying capacity of yachting within the SIOBMPA refers to the amount of yachts that the MPA can accommodate without the yachts having significant impacts on the environment or on the visitors’ experience. To-date, there has not been a carrying capacity established for SIOBMPA. The development of this management plan involved research aimed to ensure that the addition of mooring systems within the park does not lead to an exceeded carrying capacity. Primary consideration was given to the environmental threats associated with yachts visiting the park, mainly sewage pollution, as well as the issue of overcrowding.

Desktop research and meetings and interviews with key stakeholders confirmed that improper sewage waste disposal poses a severe threat to the health of marine ecosystems within the SIOBMPA. This mooring management plan, therefore, prescribes that water quality monitoring be conducted to ensure the level of pollution is adequately controlled by the proposed waste mitigation methods. If water quality data indicates that liquid waste pollution from yachts is having deleterious impacts, the MPA manager must decide whether access to moorings should be restricted to lessen the ecological pressure, or whether alternative waste management options should be pursued.

Interviewed charter yacht company representatives did not report overcrowding as a complaint issued by guests that had visited the SIOBMPA. The historical records did show an 18% increase in the number of boats overnighting from 2014 to 2015. If the moorings are used and only boats too large for the moorings anchor in the anchorage zone, overcrowding should not be an issue in SIOBMPA even if the number of overnighting yachts continues to increase.

This management plan stipulates that records of moorings include the mooring buoy identification number and whether or not the yacht has a functioning holding tank. Analysis of these records will reveal usage patterns that could provide insight into the level of the pressures placed on specific areas within the SIOBMPA. Subsequently, this knowledge could be used to inform access restrictions. For instance, if water quality monitoring indicates waste pollution is significant near Sandy Island, records can be assessed to determine if more yachts without functioning holding tanks are overnighting there compared to near Paradise Beach. Access restrictions could then be implemented to ensure that yachts without holding tanks do not overnight near Sandy Island.

6.0 Conclusion

This research has determined that a more extensive, well-managed and maintained mooring system could contribute to the SIOBMPA as follows:

- Decrease the threats of anchoring to seagrass and coral reef ecosystems
- Ensure that the spacing between vessels is adequate to prevent collisions and overcrowding
- Generate profits from mooring fees that can be used to cover maintenance costs and patrol boat expenses, as well as to support conservation activities
- Provide an opportunity for data collection of yacht characteristics and use patterns
- Promote awareness amongst visitors via briefings during mooring fee collection and boundary demarcation buoys

In order to maximize on the benefits of mooring systems and mitigate the threats of yachts beyond anchoring, the study put forth a number of management recommendations. It was recommended that the costs of mooring fees be increased; that sewage-waste mitigation measures be adopted; that sewage collection and treatment options be further explored; and that educational materials be developed and distributed. It was determined that as management strategies are applied and evaluated, monitoring data is collected and interpreted, and policies or regulations are implemented, aspects of the management approach will need to be adapted. Water quality monitoring has been recommended as a method of monitoring the severity of improper waste disposal from yachts, and in combination with visitation and yacht characteristic data, is intended to enhance the understanding of the MPA's yachting carrying capacity. This will be crucial in achieving a level of tourism that does not compromise the MPA's ecosystem health or reduce the tourism appeal.

7.0 References

Antonini, G., Zobler, L., Sheftall, W., Stevely, J., & Sidman, C. (1994). Feasibility of a non-regulatory approach to bay waternftnchorage management for sustainable recreational use.

Ashton, P. G., & Chubb, M. (1972). A preliminary study for evaluating the capacity of waters for recreational boating1. JAWRA Journal of the American Water Resources Association, 8(3), 571-577. doi:10.1111/j.1752-1688.1972.tb05179.x

Backhurst, M., & Cole, R. (2000). Biological impacts of boating at kawau island, north-eastern new zealand. Journal of Environmental Management, 60(3), 239-251.

Baldwin, K., D. Gill, A. Cooke, T. Staskiewicz, D. Lizama, R. Mahon, P. McConney and H.A. Oxenford. 2006. A socio-economic and space-use profile of Grenadine marine resource users. Centre for Resource Management and Environmental Studies (CERMES) technical report. University of the West Indies, Cave Hill Campus, Barbados. 116 pp.

Bell, C., Needham, M., & Szuster, B. (2011). Congruence among encounters, norms, crowding, and management in a marine protected area. Environmental Management, 48(3), 499-513. doi:10.1007/s00267-011-9709-1

Ben Meadows. (2016). BRIGHT DYES Biodegradable Dye Tracers. Retrieved from http://www.benmeadows.com/bright-dyes-biodegradable-dye-tracers_36816829/

Breda, A., & Gjerde, K. (1996). Types of Mooring Buoy Systems. PADI Mooring Buoy Guide. PADI Project Aware, USA. 92 pp.

Caribbean Conservation Association. (CCA:1991a). Grenada: Country environmental profile. Grenada: Country environmental profile () CCA.

Caribbean Conservation Association. (CCA;1991b). St. vincent and the grenadines: Country environmental profile. St. vincent and the grenadines: Country environmental profile () CCA.

Caribbean Environmental Health Institute (CEHI; 2004). A Directory of Environmentally Sound Technologies for the Integrated management of Solid, Liquid, and Hazardous Waste or SIDS in the Caribbean Region. Retrieved from http://www.cehi.org.lc/index.php/publication-a-info/2-uncategorised/53-waste-management-documents.

Carilli, J. E., Norris, R. D., Black, B. A., Walsh, S. M., & McField, M. (2009). Local stressors reduce coral resilience to bleaching. Plos One, 4(7), e6324.

CITES. 2002. Index Nesting Beach Survey Protocol fo Caribbean Hawksbills. Second CITES wider Caribbean hawksbill turtle dialogue meeting Grand Cayman, Cayman Islands. 21–23 May 2002. Retreived from https://cites.org/eng/prog/hbt/dialogue2/E-HT2-8.doc.

Creed, J. C., & Amado Filho, G.,M. (1999). Disturbance and recovery of the macroflora of a seagrass (halodule wrightii ascherson) meadow in the abrolhos marine national park, brazil: An experimental evaluation of anchor damage. Journal of Experimental Marine Biology and Ecology, 235(2), 285-306. doi:10.1016/S0022-0981(98)00188-9

Davenport, J., and Davenport, J. L. 2006. The impact of tourism and personal leisure transport on coastal environments: A review. Estuarine, Coastal and Shelf Science, 67(1), 280-292.

Diedrich, A., Balaguer Huguet, P., & Tintoré Subirana, J. (2011). Methodology for applying the limits of acceptable change process to the management of recreational boating in the balearic islands, spain (western mediterranean). Ocean and Coastal Management, 54(4), 341-351. doi:10.1016/j.ocecoaman.2010.12.009

Diedrich, A., Terrados, J., Arroyo, N. L., & Balaguer, P. (2013). Modeling the influence of attitudes and beliefs on recreational boaters' use of buoys in the balearic islands. Ocean & Coastal Management; Modeling the Influence of Attitudes and Beliefs on Recreational Boaters' use of Buoys in the Balearic Islands, 78, 112-120.

Dinsdale, E. A., & Harriott, V. J. (2004). Assessing anchor damage on coral reefs: A case study in selection of environmental indicators. Environmental Management, 33(1), 126-139.

Eckert, K. L., & Doyle, E. (2010). Sea Turtle Assessment – Tobago Cays Marine Park, St. Vincent and the Grenadines. Global Environment Facility (GEF) and Wider Caribbean Sea Turtle Conservation Network (WIDECAST) Project.

Espeut, P., 2006 (March). Opportunities for Sustainable Livelihoods in One Protected Area in Each of the Six Independent OECS Territories, for the OECS Protected Areas and Sustainable Livelihoods (OPAAL) Project. OECS Contract Number OECS/121/05. 160pp.

Fairhead, B. & Baldwin, K. (2015). Moorings plan for the South Coast Marine Park, St. Vincent. Prepared for the CATS 2 Project. 1-35.

Fava, F., Ponti, M., Scinto, A., Calcinai, B., & Cerrano, C. (2009). Possible effects of human impacts on epibenthic communities and coral rubble features in the marine park of bunaken (indonesia). Estuarine, Coastal and Shelf Science, 85(1), 151-156.

García Charton, J. A., Bayle-Sempere, J. T., Sánchez-Lizaso, J. L., Chiesa, P., Llaurado, F., Pérez, C., & Djian, H. (1993). Respuesta de la pradera de posidonia oceanica y su *ictiofauna asociada al anclaje de embarcaciones en el parque nacional de port-cros (francia).*

Geosyntec. (2016). Massachusetts Nonpoint Source Pollution Management. Sewage Pumpout Facilities Fact Sheet. Retrieved from http://bit.ly/2egzpz1

Glynn, P. W. (1994). State of coral reefs in the galápagos islands: Natural vs anthropogenic impacts. Marine Pollution Bulletin, 29(1), 131-140.

Goenaga, C. (1991). The state of coral reefs in the wider caribbean. Interciencia.Caracas, 16(1), 12-20.

Harvey, O. 2013. Standard Operating Procedures for Mooring Maintenance.

Harvey, O., Baldeo, R. 2013. Stakeholder Led Co-management Governance Regimes: The New Paradigm for Marine Protected Areas in Grenada, West Indies. Grenada Fisheries Department, Melville Street, St. George 's, Grenada.

Hawker, D., & Connell, D. (1989). An evaluation of the tolerance of corals to nutrients and related water quality characteristics. International Journal of Environmental Studies, 34(3), 179-188. doi:10.1080/00207238908710526

Heeney, E. (2015). Connection and understanding: The basis of a positive mutual gaze between residents of a small island developing state and a community of multinational ocean cruisers. World Leisure Journal, 57(2), 118-130. doi:10.1080/16078055.2015.1034342

Hemminga, M. A., & Duarte, C. M. (2000). Seagrass ecology Cambridge University Press.

Henry, A., V. (2013). The Marine and Yachting Sector in Grenada Economic Impact Assessment Final Report. Ideas to Business Limited, Trinidad and Tobago. Grant No. GA 38/GRN

Hoggarth, D. (2007). Tobago Cays Marine Park 2007-2009 Management Plan. Prepared for: Organization of Eastern Caribbean States (OECS) Environment and Sustainable Development Unit (ESDU), St. Lucia. 100 p.p

IUCN (2016). IUCN Red List of Threatened Species. Retrieved from http://www.iucnredlist.org/details/6494/0.

Jenkins, J., C. (1999). The Humanure Handbook: A guide to composting human manure. Chelsea Green Publishing, Grove City, PA 16127.

Joachim and Associates Ltd. (2008). Socioeconomic Value and Cost Benefit Analysis of Alternative Livelihoods Sub-Projects in the Tobago Cays Marine Park. TCMP Contract No: 09 2008

Lewis, A. R. (1998). Effects of experimental coral disturbance on the population dynamics of fishes on large patch reefs. Journal of Experimental Marine Biology and Ecology, 230(1), 91-110.

Laflamme, R. (2010). Installation of a Mooring and Demarcation Buoy System for the SIOBMPA. Presented to The Nature Conservancy and the National Fish and Wildlife Foundation. Project number FY10-C-NFWF-VI-LUMBADIVE.

Lloret, J., Zaragoza, N., Caballero, D., & Riera, V. (2008). Impacts of recreational boating on the marine environment of cap de creus (mediterranean sea). Ocean and Coastal Management, 51(11), 749-754. doi:10.1016/j.ocecoaman.2008.07.001

Marbà et al., 2002*, R. L. (2015). Boat anchoring contributes to coral reef degradation in the british virgin islands.*

Marszalek, D., S., (1981). Effects of sewage effluents on reel corals. 4th International Coral Reef Symposium Manila. Vol. 2, 15-20.

Mayreau Environmental Development Organization (MEDO; 2003). A Management Proposal for the Tobago Cays Marine Park, St. Vincent and the Grenadines.

MDDNR. 1991. A Guidebook for Marina Owners and Operators on the Installation and Operation of Sewage Pumpout Stations. Maryland Department of Natural Resources, Boating Administration, Annapolis, MD.

Milazzo, M., Badalamenti, F., Ceccherelli, G., & Chemello, R. (2004). Boat anchoring on posidonia oceanica beds in a marine protected area (italy, western mediterranean): Effect of anchor types in different anchoring stages. Journal of Experimental Marine Biology and Ecology, 299(1), 51-62.

Ministry of Carriacou and Petite Martinique Affairs. (MCMPA; 2015). Sandy Island/Oyster Bed Marine Protected Area Management Plan 2015-2025.

Moir, D., J. (2007). Mooring Feasibility Report Sandy Island Oyster Bay Marine Protected area, Carriacou, Grenada. Provided by Moor Seacure International Ltd. Commissioned by The Nature Conservancy. Contract number EC-041707007.

Moore, G. E. (2004). Assessment of the mangrove ecosystem of tyrrel bay, carriacou (grenada) west indies. The Nature Conservancy, Eastern Caribbean Program, Christiansted, St.Croix,

Montefalcone, M., Chiantore, M., Lanzone, A., Morri, C., Albertelli, G., & Bianchi, C. N. (2008). BACI design reveals the decline of the seagrass posidonia oceanica induced by anchoring. Marine Pollution Bulletin, 56(9), 1637-1645.

Reopanichkul, P., Schlacher, T. A., Carter, R. W., & Worachananant, S. (2009). Sewage impacts coral reefs at multiple levels of ecological organization. Marine Pollution Bulletin, 58(9), 1356-1362. doi:10.1016/j.marpolbul.2009.04.024

Rogers, C. S., & Garrison, V. H. (2001). Ten years after the crime: Lasting effects of damage from a cruise ship anchor on a coral reef in st. john, US virgin islands. Bulletin of Marine Science, 69(2), 793-803.

Schlöder, C., O'Dea, A., & Guzman, H. M. (2013). Benthic community recovery from small-scale damage on marginal caribbean reefs: An example from panama. Bulletin of Marine Science, 89(4), 1003-1013.

Short, F. T., & Wyllie-Echeverria, S. (1996). Natural and human-induced disturbance of seagrasses. Environmental Conservation, 23(01), 17-27.

State of Alaska Department of Environmental Conservation. (2000). Cordell Bank National Marine Sanctuary, Management Plan. Retrieved from http://bit.ly/2dwCgiE

The Nature Conservancy and Grenada Fisheries Division (TNC GFD; 2007). Sandy Island/Oyster Bed Marine Protected Area, Management Plan, USVI

Thur, S. M. (2010). User fees as sustainable financing mechanisms for marine protected areas: An application to the bonaire national marine park. Marine Policy, 34(1), 63-69. doi:10.1016/j.marpol.2009.04.008

Tobago Cays Marine Park (TCMP; 2014). Sea Turtle Monitoring Presentation 2014.

Tseng, Y., Kyle, G., Shafer, C., Graefe, A., Bradle, T., & Schuett, M. (2009). Exploring the crowding– satisfaction relationship in recreational boating. Environmental Management, 43(3), 496-507. doi:10.1007/s00267-008-9249-5

Caribbean Environmental Health Institute (CEHI; 2004). A Directory of environmentally sound technologies for the integrated management of solid, liquid and hazardous waste for SIDS in the Caribbean Region. United Nations Environment Programme (UNEP). Retrieved from http://bit.ly/2e6aWNa

Whyte, B. 2012. Grenada SIOBMPA Business Plan. Gulf of Caribbean Fisheries Institute.

United Nations. (2014). Proposed areas for inclusion in the SPAW list. Annotated format for presentation report for: Tobago Cays Marine Park, Saint Vincent and the Grenadines (United Nations Environment Program) 38 pp.

List of Referenced Personal Communication

Aaron Bartholomew: Park Warden, Sandy Island Oyster Bay MPA
Simon Carey: Former director of Tui Marine
Emma Doyle: Gulf and Caribbean Fisheries Institute
Marina Fastigi: Carriacou coordinator for KIDO Nesting Sea Turtle Monitoring, affiliated with WIDECAST
Berris Little: Mustique Marine Conservation Area
David Robin: Director of Maritime Administration, St. Vincent and the Grenadines
George Schmitt: Owner and operator of Arawak Dive, Tyrell Bay, Carriacou
Theirry Segond: Mechanical Engineer, Techniservicemarine
Bernadette Sylvester: Permanent Secretary, Ministry of Carriacou and Petite Martinique Affairs
Benjamin Wilson: Park Ranger, Tobago Cays Marine Park
Kenneth Williams: Park Manager, Tobago Cays Marine Park

APPENDIX A: Stakeholder Interview Questions

Appendix A.1 Charter Yacht Company Interview Questions

1. Approximately what percentage of your business involves trips to the TCMP or SIOBMPA?
2. Approximately how many of these trips are crewed?
3. What is your perception on the management of moorings in the SIOBMPA?
4. What percentage of the time do your boats use moorings vs anchoring?
5. Why would you choose to anchor instead of use the moorings?
6. Do you have any suggestions about where you would like to have new yacht or dingy moorings within the TCMP or SIOBMPA?
7. What are the dimensions of the boats in your fleet and how many boats are there in total?
8. How many people can stay on each vessel?
9. How frequently do you perform vessel cleaning and engine maintenance?
10. How many of the vessels have holding tanks?
11. What is the capacity of the holding tanks?
12. Can you approximate how often the holding tank needs to be released given a certain number of users?
13. Are the holding tanks used (not propped open to avoid clogging)?
14. Where are the holding tanks flushed?
15. How often are the holding tanks maintained?
16. What topics are covered in your safety briefing (e.g. park regulations)?
17. What are guests told in relation to the holding tanks and flushing practices?
18. Is there any information on the boat to communicate holding tank use and disposal?
19. Do you know of regulations for holding tank disposal within the MMAs?
20. Do you know of regulations for holding tank disposal outside of the MMAs?
21. In your opinion, what are the threats of yachting to the marine environment in the TCMP or SIOBMPA?

22. In your opinion, what are the causes of these threats?

23. What are some potential measures to mitigate these threats?

Do you collect reviews from the guests?
If yes,
a) Have guests mentioned issues with overcrowding within the MMAs?

b) Have guests mentioned issues with holding tank disposal?

c) What is the most common complaint of guests that have visited the MMAs?

24. Would you be willing to modify holding tank protocols and practices in order to comply with MMA regulations?

25. Would you put up a best practices information card or poster in your vessels with information on mooring use and holding tank practices?

26. Would you be willing to provide your guests with an information pamphlet about the MPAs and their significant features and regulations?

27. Do you have any further comments regarding mooring management or the management of the threats of yachts, such as sewage pollution?

Appendix A.2 SCUBA Dive Company Interview Questions

1. What is your perception regarding the current management of moorings within the SIOBMPA?

2. Do you/have you played a role in siting, installing or maintaining the dive moorings?

3. In the future, would you prefer to play a role in maintaining the dive moorings?

4. Do you pay a mooring fee to use the dive moorings?

5. Would you like there to be more dive moorings within the SIOBMPA? If so, where?

6. Do you think more dive moorings would increase the risk of crowding at dive sites?

7. Do you think more dive moorings would increase pressures associated with human use at these sites?

8. Do you notice other boats using their anchors within the SIOBMPA?

9. If so, do you think anchoring is causing damage?

10. Do you think anchors are being used because of a lack of moorings or because people do not trust the current moorings?

11. In order to protect the mangroves, we will be looking into alternatives for people to secure their boats to during storms. Do you ever use the mangroves during storms?

12. The mooring feasibility report suggested a ground chain, storm protected system within the sheltered lagoon at the head of Tyrell Bay. Would you use a ground chain, storm protection system is there was one available and do you think the system is feasible?

APPENDIX B: Photographs of Mooring Systems

Photographs were taken during the in-field assessment of the mooring systems within the SIOBMPA. The following photos display typical and notable features and conditions of the mooring system components.

Figure 20. Image showing a single manta pin anchor with downline attached, surrounded by seagrass and green algae (Reed, 2016).

Figure 21. Image of downline with moderate fouling (Reed, 2016).

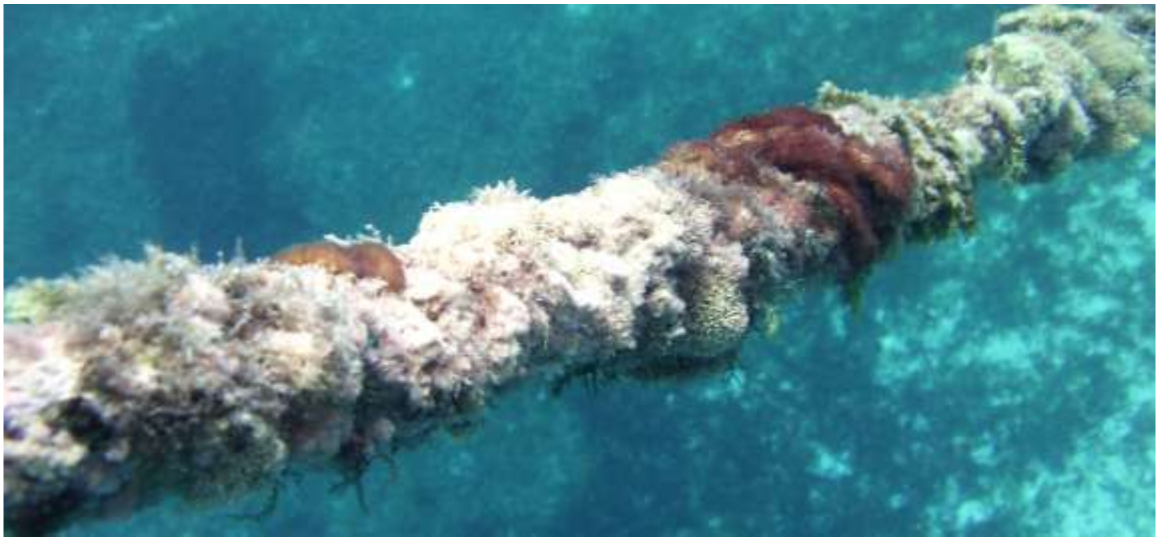
Figure 22. Image of downline with significant fouling (Reed, 2016).


Figure 23. Image of the standard pick-up line with spliced rope loop reinforced with plastic piping to reduce abrasion from vessel lines (Reed, 2016).


Figure 24. Image showing scouring of seagrass from anchor chain without a float (Reed, 2016).


Figure 25. Image showing concrete block anchor with chain and float that is preventing scouring of the surrounding seabed (Reed, 2016).

Figure 26. Image showing a yacht anchor and chain that is damaging a seagrass bed (Reed, 2016).

Figure 26. Image showing chain from yacht anchor lying on top of a seagrass meadow next to a conch (Reed, 2016)


Figure 27. Image of a pickup line made with a spliced rope loop reinforced with steel (Reed, 2016).

APPENDIX C: Mooring Systems Management Materials

Appendix C.1: The Halas Mooring System

Excerpt from Fairhead and Baldwin, 2015

The Halas system of mooring design (Figure 1) has become very popular worldwide in marine parks areas due to its simple construction methods and practical maintenance costs. The Halas system generally uses a commercial 18-inch diameter buoy constructed from polyethylene plastic filled with polyurethane foam and treated with UV inhibitors. Embedded in the buoy is a PVC pipe through which a 3/4-inch buoy through-line can pass.

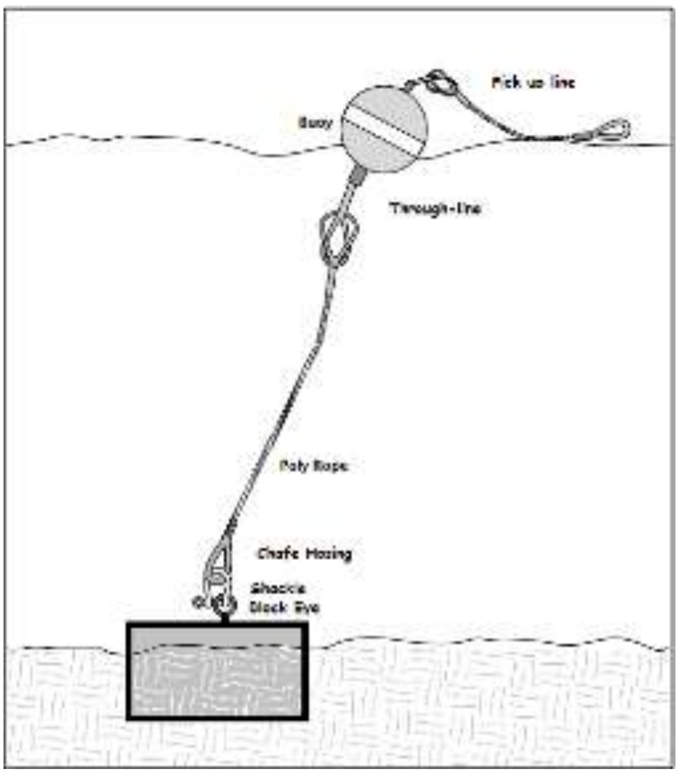

Figure 1. Typical "Halas" style mooring setup

Most of the materials used are easily sourced, simple to work with and local operators can become experienced enough to engage in regular and effective maintenance and repairs with very little training. Although the moveable mooring components generally remain the same for moorings using the Halas design, the anchoring system varies considerably, depending on the nature of the seabed and intended use of the mooring (maximum vessel size limits etc.). Anchoring systems would typically be comprised of large concrete anchoring blocks in areas of sand and mud (silt), square shaft single or multi-helix sand screws in areas of deep sand, "Manta Ray" anchors in areas of sand or areas with a fairly hard composition and finally eye bolts that are drilled and epoxied into areas of hard coral or rock.

The Halas system is unique in that it uses a three-part rope system (Figure 2) instead of one continuous rope. One line leads from the anchoring system's eye at the bottom to the buoy at the surface. A second line runs though the buoy and is attached with a loop to the anchor line at one end, and at the other end is attached with a loop to the third "pickup" line. This three-part rope system eliminates the need for shackles and thus decreases maintenance time and cost of the system. Maintenance is made easier because sections of the system can be replaced or repaired as needed without detaching the entire down line.

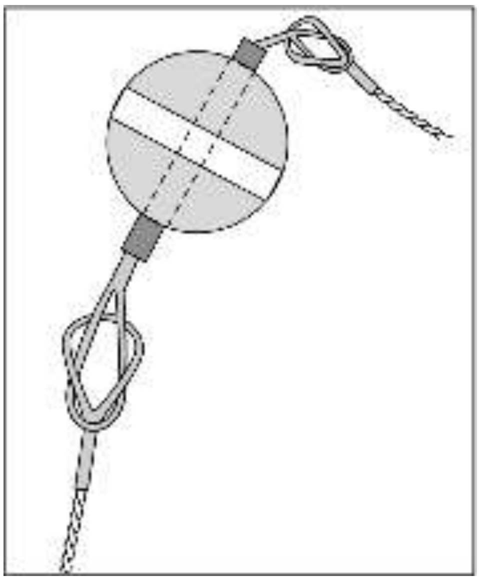

Figure 2. "Halas" 3-part system illustration

UV-treated polypropylene rope as well as 3-strand nylon "combo" rope is used for the three-part rope system. 3/4-inch rope is typically used for the down line and pickup line and 7/8-inch rope for the buoy through line, but vessel size limits would generally dictate the rope sizes required. A 3/4-inch nylon line, approximately 10 feet longer than the depth of the water at high tide serves as the down line. The length of the down line would be adjusted for water depth and local tide conditions. At the bottom of the line a nylon reinforced hose or galvanized thimble is spliced into the loop to prevent abrasion and chafing from the bottom. This loop attaches with a shackle to the anchoring system's eye. The pin of the shackle is softer than the eye bolt so that the shackle wears out before the anchor's eye. An eye splice at the upper end interlocks with the eye splice of the buoy through-line. In some places tides and currents can twist the line and cause wrapping. This can be avoided by adding swivels to the bottom of the line.

The buoy through-line allows the buoy to be removed for repair without removing the entire down line. Twelve feet of 7/8-inch line is passed through the one-inch PVC buoy pipe. One loop is spliced into each end of the line; at the bottom end a 24-inch diameter loop large enough for the buoy to pass through, and at the top end, a small 6-inch diameter loop for attaching the pickup line. The splices should be as tight as possible to the buoy to prevent excess movement and wear on the line.

The 3/4-inch pickup line should only be long enough for a vessel to pick up and attach an additional line to it, approximately 15 feet of line for a 65-foot vessel. Additional line adds scope and resiliency to the system and, therefore, direct attachment of the pickup line to the boat should be discouraged. In other words, users should pass their own mooring line through the eye and pay out sufficient scope.

A galvanized shackle is used to connect the down line (and thus entire mooring system) to the anchoring system. Once attached, shackles should be properly tightened and seized. As mentioned above, various options are available for anchoring the mooring system to the bottom and these are generally determined by the nature of the seabed at the specific mooring site.

It is important to note that modifications to this system are acceptable and personal preference regarding the use of thimbles instead of the nylon re-enforced hosing, using a higher diameter line and eliminating the need for a pick-up line should be accounted for when setting standards for stakeholders to comply with.

Appendix C.2 Mooring Maintenance Schedule

The following maintenance schedule was recommended by Fairhead and Baldwin (2015) in the mooring management plan for the South Coast Marine Managed Area, St. Vincent and the Grenadines, which is a fellow member of the Grenadines MPA Network.

Weekly**:**
- Visual inspection of surface components of the moorings must be made during all regular patrols, at least weekly, or in response to public reports regarding moorings.

Monthly:
- Inspect all buoys and pick up lines.
- Clean pick-up lines of growth or replace if necessary.
- Clean, wax and polish buoys, check for cracks and replace where needed.
- Inspect and clean exposed portions of buoy through-line and replace if needed.

Quarterly:
- Inspect mooring down lines and chafe hosing for wear/damage and replace if needed.
- Inspect shackles for wear and damage, especially the contact area on the block’s eye.

Bi-annually:
- Replace buoy through-lines.
- Replace mooring pick-up lines.
- Check for signs of anchor system movement/positional shifting.

Annually:
- Replace shackle pin.

Every 2 years:

- Replace entire down line if necessary.

C.3 Log Sheet for Mooring Inspection or Repair

The following is a template of the log sheet recommended for use to document the results of each inspection or repair of a mooring system within an MPA (Harvey, 2013).

Mooring Log Sheet

Inspection ________________ Repair ___________________

Please use the following initial in the boxes provided to indicate the conditions of components and the work done on the specific date:

Good Condition (G) Needs Attention Soon (N) Replaced (R)

Date	**Mooring No.**	**Pick-up Line**	**Buoy**	**Down Line**	**Shackle**	**Lock Wire**	**Anchor**	**Remarks**

Note: Use the "Remarks" box to document any anomalies observed or document if and why a mooring was removed/abandoned.

Personnel Involved:
____
____

____

Officer in Charge

Appendix C.4 Mooring Incident Report Log Sheet

It is recommended that the following log sheet be used to document incident reports.

Date	Reported To (Name)	Reported By (Name)	Moo ring ID	Reported Incident or Issue	Signature of Mooring Supervisor

Appendix C.5 Mooring Management Binder Contents

Mooring Binder Contents:

- ✓ Maintenance report log sheets (see C.3)
- ✓ Map of moorings including ID numbers (see Figure 11 and Figure 12)
- ✓ Incident report log sheets
- ✓ Mooring Fee Collection Checklist (see pg.37)
- ✓ Maintenance procedures summary

Appendix C.6 Summary of Standard Operating Procedures for Mooring Maintenance

The following summary was developed with the intent that it be included in the Mooring Management Binder to provide a reference material that can guide maintenance and promote consistency. The Standard Operating Procedures for Mooring Maintenance (Harvey, 2013) and the Moorings Plan for South Coast Marine Managed Area, St. Vincent and the Grenadines (Baldwin and Fairhead, 2015) were used to inform this summary.

Mooring maintenance involves a three stage cycle that ensures moorings are safe, reliable and in satisfactory condition. The main requirements of each stage are highlighted below.

Stage 1: Mooring Inspection

- ✓ Vessel is secured properly to mooring
    - o boat's bow line should run through pick-up line and both ends of bow line should be cleated to the bow of the boat
    - o pick-up line should not be tied directly to the boat
    - o line should be lengthened on rougher days or if the buoy is pulled underwater and the line is horizontal
    - o add an extra line during rougher conditions
- ✓ Vessel does not exceed the size or weight limit of the mooring system

    - small boat moorings accommodate dinghies and small boats under 25 feet
    - overnight yacht moorings accommodate yachts under 65 feet and less than 30 gross tons
    - only dive operator vessels should be secured to dive moorings
- ✓ Mooring system surface components are in good condition and ID number is attached
    - weekly inspection of every mooring
    - check for fraying, breakage or other issues and remove bio-fouling
- ✓ In-water inspections are conducted by specially trained personnel only, in pairs if SCUBA diving
    - twice per month in high season
    - once per month in low season
    - clean ropes of biofouling, which could be masking damage
    - check for fraying, breakage, corrosion >20% on metal components (chains, shackles)
- ✓ Inspection Log Sheet is filled out and submitted to mooring supervisor
- ✓ A formal report is completed with each round of inspections and approved by Mooring Management Supervisor

Stage 2: Mooring Repair

- ✓ Repairs are conducted by specially trained personnel
- ✓ Repair activities are documented on a log sheet
- ✓ Changes to mooring supply inventory are recorded to ensure supplies used are re-stocked and funds are appropriately managed