A GEOSPATIAL FRAMEWORK TO SUPPORT ECOSYSTEM BASED MANAGEMENT AND MARINE SPATIAL PLANNING FOR THE TRANSBOUNDARY GRENADINE ISLANDS

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ABSTRACT

Marine resources are of vital importance to the people of the transboundary Grenadine Islands, but increasing pressures from tourism development and the non-sustainable use of these resources are making the planning and management increasingly complex. Marine spatial planning and management (MSPM) is a strategic way of improving decision-making and delivering an ecosystem-based management (EBM) approach to managing human activities in the marine environment. Notwithstanding the central role of human agency in the concepts of EBM and MSPM, it is recognised that many times marine management has not been effective in part due to a failure to use all available sources of information and knowledge, particularly the local knowledge of the resources' users.

We propose the application of a participatory GIS approach as a sound basis for practically incorporating EBM within MSPM initiatives. The benefits of using a systemised spatially referenced multi-knowledge participatory GIS (PGIS) database for MSPM includes: (1) effectiveness in data management and the identification of information gaps; (2) the promotion of spatial thinking including increased understanding or spatial relationships; and (3) definition of areas of importance for conservation, human activity and threat. These can provide the basis for a scientifically appropriate and socially acceptable marine space-use plan.

Keywords: *ecosystem-based management, marine spatial planning, participatory GIS*

1 INTRODUCTION

Marine resources are of vital importance to the people of the transboundary Grenadine Islands, but increasing pressures from tourism development and the non-sustainable use of these resources are making the planning and management increasingly complex. Heavy reliance on marine resources and increasing numbers of marine resource users calls for an integrated ecosystem-based approach (Convention of Biological Diversity's Malawi Principles, 1998) to the management of the Grenada Bank. It is recognised that in order to address the uncertainties associated with complex, diverse and dynamic systems, this approach should be adaptive, address issues of multiple scales, allow for inter-sectoral cooperation and promote broad stakeholder participation (Armitage *et al.*, 2008; Crowder and Norse, 2008; Mahon *et al.*, 2008). Despite this appreciation, it is increasingly clear that governments and stakeholders lack the practical tools needed to make ecosystem based management (EBM) operational, particularly in the marine environment (Douvere and Ehler, 2009; Tallis *et al*., 2010).

Marine spatial planning and management (MSPM) offers a strategic way of improving decision-making and delivering an ecosystem-based approach to managing human activities in the marine environment (Ehler and Douvere, 2007). Notwithstanding the central role of human agency in the concepts of EBM and MSPM, the scope of 'human dimension' information included often falls short relative to its actual importance and complexity (St. Martin and Hall-Arber, 2008). Likewise, it is recognised that marine management has often been ineffective in part due to a failure to use all available sources of information and knowledge, particularly the local knowledge of the resource users (Johannes, 1998; Anchiracheeva *et al.*, 2003; Berkes *et al.*, 2001; Folke, 2004). Despite the known value of these types and sources of information, they are often not appropriately incorporated in MSPM (Berkes, 1999; St. Martin and Hall-Arber, 2008).

We propose the application of a participatory GIS (PGIS) approach as a sound basis for practically incorporating an ecosystem approach within MSPM initiatives. Including stakeholders in the development of a technical representation of spatial knowledge can allow for improved understanding of the social characteristics of marine use patterns (Aswani and Lauer, 2006; St. Martin and Hall-Arber, 2008; De Freitas and Tagliani, 2009; Dalton *et al*., 2010). This not only demonstrates the relevance of information provided by stakeholders, but also supports EBM by using multi-discipline and multi-knowledge information sources in MSPM initiatives. A further tenet of a PGIS approach is that information is created in a format which is understandable and accessible to stakeholders thereby facilitating an equitable, transparent and collaborative decision-making environment (McCall, 2003; Corbett *et al*., 2006).

This paper demonstrates how the application of a collaborative geospatial approach can be of use for improved understanding and planning marine resource use. A PGIS, the Grenadines Marine Resource and Space-use Information System (MarSIS), was developed to provide a framework for ecosystem-based MSMP by integrating, analysing and sharing interdisciplinary and multi-knowledge information in a practical and comprehensible manner. We illustrate the potential of a PGIS to improve MSPM, specifically the various ways in which information can be brought together, visualised and analysed to create practical baseline inventories on marine resources and associated human activity that can be used to prepare a marine space-use plan for the transboundary Grenadine Islands.

2 METHODS

The focus of this paper is on aspects of the research involved in the collaborative development of the MarSIS geodatabase (including the data collection, geoprocessing and management); as well as the use of these data to conduct GIS analyses relevant for an ecosystem approach to MSPM, specifically those that define and analyse the existing location of marine resources and associated space-use patterns which occur on the Grenada Bank. The main steps in this overall procedure are described below.

2.1 DATA COLLECTION AND DEFINITION OF GEODATABASE STRUCTURE

The geodatabase design was driven by the need to understand the environment and the influence of human activities to support an ecosystem approach to transboundary MSPM in the Grenadine Islands. Information was collected from all available sources (using both scientific and local knowledge systems) and data gaps were filled to create a baseline of the distributions of marine resources, physical environmental features, human activities and jurisdictional boundaries. The Grenadines MarSIS as a personal geodatabase was created using ESRI's ArcInfo version 9.3 software package. All data were imported, geoprocessed and standardised using ArcMap, ArcCatalog and ArcToolbox standard tools along with the Spatial Analyst and 3D Analyst extensions. To start, all data within the Grenadines MarSIS were grouped under the three broad categories of: ecological, human use and jurisdictional data. Data were further organised into feature datasets or similar 'themes', each of which contain a number of respective feature classes categorised by geometry, data source and geoprocessing performed (Table 1).

2.2 DATA COMPILATION, STANDARDISATION AND INTEGRATION

Much of the collected data required additional geoprocessing and preparation of thematic layers. The main steps required to compile the Grenadine MarSIS geodatabase are described below.

All imagery, topographic maps and nautical charts were scanned and the 'Georeferencing' toolbar was used to assign spatial reference information to each image. Data on the boundaries of jurisdictional areas were either downloaded, as in the case of exclusive economic zone, created by measuring a set distance from the coastline (using the Buffer tool) as in the case of territorial seas, or digitised by importing (x,y) global positioning system (GPS) coordinates, as in the case of marine protected areas. Information on infrastructure were incorporated either by digitising features from maps or remote-sensed imagery, or by importing (x,y) GPS coordinates. Corresponding attribute information for the infrastructure features were obtained using informational pamphlets (*e.g.* tourism guides, port statistics guides), phone calls, informal conversation and personal observation and referenced accordingly in the metadata.

In order to enhance existing bathymetric data (FAO, 2005), sonar data points (x,y,z) were collected during field surveys and used to improve the resolution of the seafloor topography of the Grenada Bank less than 60 metres in depth (Baldwin, 2011 in prep). The 3D Analyst extension (Topo to Raster tool) was used to create a digital elevation model (DEM) from the enhanced bathymetry dataset. Next, a triangulated irregular network (TIN) three-dimensional model of the Grenada Bank seafloor was produced using the Spatial Analyst extension (Raster to TIN tool) to allow for 3D visualisation of information in ArcScene. From the TIN, bathymetry isolines (20 m and 100 m) were created (using the Contour tool).

A marine habitat map was created in two main parts (Baldwin, in prep 2011). One was a vector coastal shallow-water polygon habitat map derived using conventional remote sensing and ground-truthing to model the shallow-water habitat (less than 20 m) in detail. The other was a deep-water habitat map created by taking direct field observations using a 3 km^2 sampling grid and remote video to collect point observations which were used to interpolate marine habitat for the deep-water portion (20-60 m depth) of the Grenada Bank. Although two marine habitat maps were created initially; these two maps were merged into a seamless mapping surface (using the Union Analysis tool). To eliminate the sliver polygons (or 'No Data' speckles) which resulted from merging the two habitat datasets of various scales together, the 'Boundary Clean' tool was used. To prepare the data for analyses, the Grenada Bank polygon vector habitat map was converted to a habitat raster (using the Polygon to Raster Conversion tool).

Marine field survey instruments were designed to collect local knowledge of fishing knowledge as point data. An additional 12 fishing-related raster mapping surfaces were interpolated from the fisher 'judgement' of fishing suitability (species, gear type and ground quality) information (Baldwin, in prep 2011). Raster surfaces were created for each target species (conch, lobster, reef fish); each type of fishing gear (line, net, fish trap, SCUBA, spear gun); the apparent quality of the fishing ground (poor, okay, good, very good); and fishing preference (whether the fisher would choose to fish at the site or not)(yes, no). Spatial Analyst (Weighted Overlay tool) was used to identify areas of importance for multiple fish species and fishing gears (spatial overlap). This resulted in the production of two density surfaces (one for fishery type and one for fishing gear).

Participatory research methods were used to solicit and incorporate spatially-based local knowledge within the geodatabase and to fill information gaps on human use including socio-economic surveys, mapping exercises, marine field surveys. A socioeconomic marine resource-use assessment, comprising semi-structured interviews and surveys together with a series of mapping exercises, was undertaken to develop qualitative spatial information on socio-demographics, livelihood strategies, resources and use patterns (temporal and spatial), threats as well as environmental practices (Baldwin, in prep 2011). Spatial information derived from participatory mapping exercises was scanned as .tif images, imported into ArcGIS and features of interest (Table 1) were digitised. Corresponding attributes (collected as part of socio-economic assessment surveys) were first entered as tables into MS Excel and subsequently connected (using a table join) to relevant spatial datasets.

All vector feature classes within the datasets for infrastructure, marine resources, marine resource users, space-use patterns and threats were converted to raster surfaces for use in subsequent spatial analyses. For most marine and coastal activities, little was known about the geographic extent of impact beyond the location of the activity. To model spatial extent, buffers were applied to all point and line vector feature classes (as specified in Table 1) to represent all data as polygon feature classes. Next, all of the polygon feature classes were mapped onto a raster surface (using the Polygon to Raster tool). Given that all marine activities do not affect the marine environment equally, a measure of the impact at the location of the occurrence can be incorporated to each of the features. Since ranking impacts can be contentious (Ban *et al*., 2010); and the analyses carried out in this study are for demonstration purposes; no weighting was applied to the rasters. Instead all features were considered to have an equal impact as determined by a simple measure of presence or absence. To accomplish this, all rasters were further processed using Spatial Analyst (Is Null and CON tools) in order to create raster surfaces in which a value of '0' indicated absence and '1' indicated presence of a variable within the study area.

2.3 VISUALISATION, ANALYSES AND MSPM APPLICATIONS

The application of GIS to integrate information and the ability to display, query and analyse this information is widely recognised as a valuable tool for decision support and ecosystem-based MSPM (DeFreitas and Tagliani, 2009; Elher and Douvere, 2009). Basic requirements for an ecosystem-based management approach and the preparation of a marine space-use plan include an inventory of important ecological areas, current human activity and the identification of conflict or threat among and between uses and the environment (Crowder and Norse, 2008; Douvere and Elher, 2009; Tallis *et al*., 2010). To illustrate, the Grenadines MarSIS geodatabase is used to demonstrate some practical GIS applications that serve to define and analyse the existing environmental conditions of the Grenada Bank.

3 RESULTS

The process of collecting data as well as the creation and conversion of data from disparate sources, scales and participatory research methods (e.g. surveys, mapping exercises, field surveys) was an iterative process of data collection, data sharing and collaborative review to identify and fill information gaps. It took about 18 months initially, yet was on-going throughout the remainder of the research (an additional 36 months). All data included in the MarSIS required geoprocessing and preparation into thematic layers. Ultimately the Grenadines MarSIS geodatabase consisted of 11 feature datasets comprising 81 feature classes (e.g. 49 vector, 31 raster and 1 annotation). Fifty-four feature classes (63% of the geodatabase) were derived in part, based on the use of local knowledge sources, making MarSIS a PGIS (Table 1).

Understanding the amount and distribution of ecosystem structure and function is essential in the implementation of an ecosystem approach and MSPM (Elher and Douvere, 2009). The Grenada Bank study area consists of a total of 190,985 hectares; of which 38% is reef, 41% is mixed live-bottom, 12% hard bottom, 7% sand and 2% is seagrass. Seventy one percent (or 135,782 hectares) belongs to the country of St. Vincent and the Grenadines, and the remaining 29% (55,209 hectares) to Grenada.

GIS can be used to provide resource managers and decision-makers with tools to monitor a country's progress towards achieving marine conservation targets. To illustrate this, a number of spatial summary statistics were calculated to evaluate the habitat composition for each of the two designated no-take marine protected areas (MPAs) (Table 2). In terms of size alone, the TCMP consists of 6,201 hectares and is seven times larger than SIOBMPA which comprises a total area of 888 hectares. Likewise within the Grenada Bank study area, the TCMP (within St. Vincent and the Grenadines) renders 4.6% of the country's total marine area as protected; whereas the SIOBMPA (or Grenada Grenadines) only protects 1.6% of its' total marine area. Notwithstanding the size of the MPAs, in terms of protecting a higher proportion of representative reef ecosystem habitat (e.g. mangrove, reef and seagrass); SIOMPA may be more effective than TCMP. Within the boundaries of SIOBMPA, 19% of the marine park is comprised coral reef, 7% mangrove and 26% is seagrass. The TCMP on the other hand hosts less than one percent mangrove habitat, 6% seagrass and 22% coral reef habitat. These straightforward analyses exemplify the ability of GIS as a tool to easily summarise spatially-based data into useful information to evaluating the effectiveness of MSPM initiatives.

With regard to fisheries, lobster and reef fish fishing grounds are found to have a greater spatial extent (74% and 83% respectively) than conch fishing grounds (25%) across the Grenada Bank. Lobster and reef fish fishing grounds tend to be located in reef and reef-related (mixed live-bottom) habitats (91% and 89% respectively); whereas conch grounds are split mixed live bottom (45%), reef (23%) and hard bottom (20%) habitats. Three quarters of the Grenada Bank is identified to be of high quality (very good or good) fishing habitat. Likewise areas that fishers indicate as being of very good (98%) and good (80%) fishing quality consist primarily of reef and reef-related (mixed live bottom) habitats. Despite the presence of 142,252 hectares of identified high quality fishing habitat, fishers prefer to fish in only 10% (20,027 hectares) of the Grenada Bank. Overlaying the location of high quality (very good and good) fishing grounds and the location of preferred fishing areas can provide insight on human-environment interactions and patterns of space-use on the Grenada Bank. When fishing preference information is viewed spatially, some interesting distribution patterns become apparent (Figure 2). It becomes obvious that fishers prefer to fish close to shore in shallow water. This pattern could be explained as a result of several factors: economic (cost of fuel and time of travel); physical (limitation of depth and current relating to the deployment of gear and diving); and perhaps safety. Understanding the distribution of fishing preferences can have several important implications for conservation and marine space-use planning. To start, there may be a certain degree of 'natural or environmental' protection of habitats and resources taking place by virtue of the limitations of fishing methods and vessels that are currently in use. Depletion may be local, rather than of the entire resource. Additionally, this information may be of use in the determination of feasible conservation or 'no-take' areas by aiding the selection of areas which are not high priority for fishing. These types of analyses can contribute to MSPM through the identification of potential conservation zones in areas with low use by fishers, and therefore little resistance from or impact upon them resulting in greater management acceptance and compliance.

GIS can be applied to integrate information to explore the interactions among human activities and marine resources to prioritise MSPM initiatives. Cumulative impact overlays can also be useful in the development of spatial management scenarios to identify hotspot areas of human activity and threat as well as areas of importance for conservation. To this end, three cumulative impact mapping surfaces were created based on the feature classes listed in Table 3. Each cumulative impact mapping surface, represents the locations of raster cells where resources or activities of interest co-occur (using the SUM overlay of the Cell Statistics geoprocessing tools) thus indicating areas of importance. Next these surfaces were compared to underscore areas of overlapping or conflicting use and to develop scenarios to assist in the evaluation of trade-offs for MSMP decision-making.

A closer examination of the three cumulative impact surfaces for the island of Carriacou (Figure 3) reveals some interesting patterns. Figure 3a is a composite conservation map of Carriacou in which priority areas for conservation are highlighted; Figure 3b is a composite map of human activity of the same area which draws attention to areas identified to be important for marine-based livelihood (i.e. social well-being) of the island's communities; and Figure 3c depicts overlapping areas of identified threat. One interesting finding is that all three cumulative impact surfaces share a similar hotspot located in Tyrell Bay adjacent to the town of Harvey Vale. The Oyster Bed mangrove is identified as an area of high (five overlapping features) conservation priority. In addition Tyrell Bay hosts a number of human activities important to the livelihoods of the surrounding communities. Tyrell Bay is a major seaport in the island of Carriacou being heavily used by tourists as a preferred yachting anchorage. Finally, there are several identified threats in the area including mangrove cutting, artificial coastal structures and dredging that are a result of the construction of a marina in Tyrell Bay. These types of finding can be utilised in MSPM, particularly as the location of high threat and human activity hotspots border the boundary of the SIOBMPA. Essentially, the high amount of threat and human activity identified may not be consistent with the conservation action and could serve to weaken the ultimate effectiveness of this newly established MPA. This information in turn, could be used to assist in the development of management priorities and help to guide management in order to limit the number of impacts within the area.

4 CONCLUSION

The types of GIS analyses presented in this paper can make a valuable contribution towards understand the extent and distribution of resources and their relationship to coastal livelihoods. They support the assessment of trade-offs between uses and management action so as to determine the spatial allocation of the sea in a way that maximises societal benefits and mitigates possible conflicts. These types of multi-disciplinary spatial analyses can support integrated and holistic ecosystem-based decision-making and MSPM by adressing complexity of marine ecosystems in a practical manner. This includes identification of real or potential conflicts between human uses and the environment.

The usefulness of integrating interdisciplinary multi-knowledge information for ecosystem-based management and marine spatial planning is well documented (De Freitas and Tagliani, 2009; Dalton *et al.*, 2010; Tallis *et al.*, 2010). However, as previously outlined, the actual framework and practical methodologies for developing a holistic information platform for MSMP is lacking (Crowder and Norse, 2008; Douvere and Elher, 2009; Tallis *et al.*, 2010). We found that utilising a PGIS approach aided the collection, integration and understanding of multi-knowledge interdisciplinary information and presents significant opportunities for realising ecosystem-based MSPM on the Grenada Bank. The majority (63%) of information in the geodatabase was derived from local knowledge, in particular information on human activities. Additionally, the application of GIS (in terms of information integration, summarisation, and visualisation) proved beneficial in that it easily allowed for spatially-based ecosystem-level analyses of the Grenada Bank to be conducted and presented in ways that could be expected to increase stakeholder understanding of information generated thus support interactive governance.

The benefits of using a systemised spatially-referenced multi-knowledge PGIS database for MSPM include: (1) effectiveness in data management and the identification of information gaps; (2) the promotion of increased spatial thinking and understanding; and (3) definition of existing areas of importance for conservation, human activity and threat. These can provide the basis for a scientifically appropriate and socially acceptable marine space-use plan.

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Table 1. The geodatabase structure of the Grenadines MarSIS listed by type, feature dataset, layer name, geometry, source and geoprocessing applied.

Type	Feature dataset	Layer name	Geometry	Source	Geoprocessing
Ecological	Bathymetry				
		Grenada Bank - 200 meter contours	Line	FAO	Spatial Analyst (Contour)
		Grenada Bank - 10 meter contours	Line	FAO	Spatial Analyst (Contour)
		DEM Grenada Bank – 50 m	Raster	FAO & field measurement	3D Analyst (Topo to Raster)
		Grenada Bank TIN	TIN	FAO & field measurement	3D Analyst (Raster to TIN)
	Infrastructure				
		Coastlines	Line	Digitised from imagery	None
		Roads	Line	The Nature Conservancy	None
		Hotels	Point	Remote sensing	Digitised from imagery
		Airports	Point	Remote sensing	Digitised from imagery
		Seaports	Point	Remote sensing	Digitised from map; Analysis (500 m Buffer)
	Imagery/ Basemaps				
		Digital Globe (< 1 m resolution)	Image	Purchased	Georeferenced
		IKONOS (4 m resolution)	Image	FAO	Georeferenced
		LandSat (30 m resolution)	Image	Internet	Georeferenced
		Google Earth (varies from 1 - 4 m resolution)	Image	Internet	Georeferenced
		Aerial photos - black and white (SVG only)	Image	Government	Georeferenced
		Nautical charts (4)	Image	3 Imary and 1 US Navy	Georeferenced
		Topographic maps (1:25,000) - Grenadine Islands (6)	Image	Land and Survey departments	Georeferenced
	Marine Habitats				
		Shallow water marine habitat	Polygon	Remote sensing & field measurement	Digitised from imagery
		Deep water marine habitat (2) - Scientist and Fisher	Raster	Field measurement	Spatial Analyst (IDW)
		Habitat cover (high, medium, low)	Raster	Field measurement	Spatial Analyst (IDW)
		Reef geomorphology	Polygon	Coral Reef Millennium Mapping Project	Analysis (Clip)
		Upwelling of the Grenada Bank	Polygon	The Nature Conservancy	None
		Shoreline type	Polygon	The Nature Conservancy	None
	Marine Resources				
		Aquaculture	Point	Mapping exercises	Digistised from map; Analysis (200 m Buffer)
		Baitfish bays	Polygon	Mapping exercises	Digistised from map
		Sea turtle nesting beaches	Point	Mapping exercises	Digistised from map; Analysis (200 m Buffer)
		Seabird nesting areas	Polygon	West Indian Seabird Atlas (EPIC)	Digisited from survey data
		Iguanas	Polygon	Mapping exercises	Digistised from map
		Nursery areas	Polygon	Mapping exercises	Digistised from map
		Oyster beds	Polygon	Mapping exercises	Digistised from map
		Shipwrecks	Point	Mapping exercises	Digistised from map; Analysis (200 m Buffer)
		Whelks	Line	Mapping exercises	Digistised from map; Analysis (100 m Buffer)
Human Use	Marine Resource Users				
		Day-tour operators	Point	Socio-economic surveys	Digitised from imagery; Join related tables
		Water-taxi operators	Point	Socio-economic surveys	Digitised from imagery; Join related tables
		Ferry operators	Point	Socio-economic surveys	Digitised from imagery; Join related tables
		Dive shops	Point	Socio-economic surveys	Digitised from imagery; Join related tables
		Fishers	Point	Socio-economic surveys	Digitised from imagery; Join related tables
		Ships	Point	Socio-economic surveys	Digitised from imagery; Join related tables
		Yacht companies	Point	Socio-economic surveys	Digitised from imagery; Join related tables
	Space-use Patterns				
		Anchorages	Polygon	Mapping exercises	Digistised from map
		Shipping lanes	Line	Mapping exercises	Digistised from map; Analysis (500 m Buffer)
		Dive sites	Polygon	Mapping exercises	Digistised from map
		Fish landing sites	Point	Socio-economic surveys	Digitised from map; Analysis (200 m Buffer)
		Recreational areas	Point	Mapping exercises	Digistised from map; Analysis (200 m Buffer)
		Historical sites	Point	Mapping exercises	Digistised from map; Analysis (200 m Buffer)
		Vending aites	Point	Mapping exercises	Digistised from map; Analysis (200 m Buffer)
		Shipbuilding sites	Point	Mapping exercises	Digistised from map; Analysis (200 m Buffer)
	Fishery				
		Conch (yes/no)	Raster	Field measurement	Spatial Analyst (IDW)
		Lobster (yes/no)	Raster	Field measurement	Spatial Analyst (IDW)
		Fish (yes/no)	Raster	Field measurement	Spatial Analyst (IDW)
		Presumed fishing quality (VG, G, OK, Poor)	Raster	Field measurement	Spatial Analyst (IDW)
		Fishing preference (yes/no)	Raster	Field measurement	Spatial Analyst (IDW)
		Weighted fishery overlay (density)	Raster	Modelled surface	Spatial Analyst (Weighted Overlay)
	Fishing gear				
		Tank	Raster	Field measurement	Spatial Analyst (IDW)
		Spear gun	Raster	Field measurement	Spatial Analyst (IDW)
		Fish trap	Raster	Field measurement	Spatial Analyst (IDW)
		Net	Raster	Field measurement	Spatial Analyst (IDW)
		Line	Raster	Field measurement	Spatial Analyst (IDW)
		Weighted fishing gear overlay (density)	Raster	Modelled surface	Spatial Analyst (Weighted Overlay)
	Threats				
		Artificial structures	Polygon	Mapping exercises	Digistised from map
		Sand-mining	Polygon	Mapping exercises	Digistised from map
		Landfills	Point	Mapping exercises	Digistised from map; Analysis (200 m Buffer)
		Illegal dumping sites	Point	Mapping exercises	Digistised from map; Analysis (200 m Buffer)
		Quarries	Polygon	Mapping exercises	Digistised from map
		Land-based sources of pollution	Point	Mapping exercises	Digistised from map; Analysis (200 m Buffer)
		Desalination outfalls	Line	Mapping exercises	Digistised from map; Analysis (200 m Buffer)
		Dredging	Polygon	Mapping exercises	Digistised from map
		Goats	Polygon	Mapping exercises	Digistised from map
		Mangrove cutting	Polygon	Mapping exercises	Digistised from map
Jursidictional	Other				
		Marine protected areas	Polygon	GPS coordinates	Digistised from points
		Exclusive economic zone	Polygon	VLIZ Maritime Boundaries	Analysis (Clip)
		Territorial seas	Polygon	Modelled from coastline	Analysis (3 km Buffer)
		Local name - coastal features	Annotation	Mapping exercises	Digistised from map
		Scope Grenada Bank	Polygon	Modelled from bathymetry	Analysis - (Selection of 60 m bathymetry contour)

Table 2. Area (in hectares) of each habitat type contained within the Tobago Cays Marine Park (TCMP) and Sandy Island Oyster Bed Marine Protected Area (SIOBMPA) as well as summarised as a percentage of overall habitat protection for each respective country. *(SVG – St. Vincent and the Grenadines; GND – Grenada)*

	TCMP			SIOBMPA		
Class	Area (ha)	Proportion of MPA	Percent SVG total	Area (ha)	Proportion of MPA	Percent GND total
Coral reef	1,370	22.1	3.2	166	18.7	0.5
Mangrove	4	0.1	6.0	66	7.4	68.0
Mixed live bottom	1,585	25.6	< 0.1	223	25.1	2.2
Hard bottom	2,137	34.5	15.7	168	18.9	2
Salt pond / swamp	5	0.1	16.2	1	0.2	8.5
Sand	734	11.8	6.7	37	4.1	1.2
Seagrass	365	5.9	25.7	227	25.5	15.0
Total	6,201			888		

Table 3. A list of the feature classes used to create three cumulative impact surfaces; one each for conservation, human use and threat.

Cumulative Overlays		
Conservation	Human use	Threat
Reefs	Anchorages	Artifical structures
Mangroves	Aquaculture	Desalinisation outfalls
Seagrass	Baitfish bay	Dredging
Nursery grounds	Dive sites	Illegal dumping sites
Oyster beds	Landing sites	Land based sources of pollution
Sea turtle nesting beaches	Recreation areas	Landfills
Sea bird nesting sites	Seaports	Mangrove cutting
Historical sites	Ship building sites	Sand mining
Whelks	Ship wrecks	
	Vending sites	

Figure 1. The geographic scope of the transboundary study area. The study area includes the Grenadine Islands and the Grenada Bank (extending to 60 m isoline). The locations of the two designated MPAs are also shown. The inset map shows the extent of the EEZs of each country.

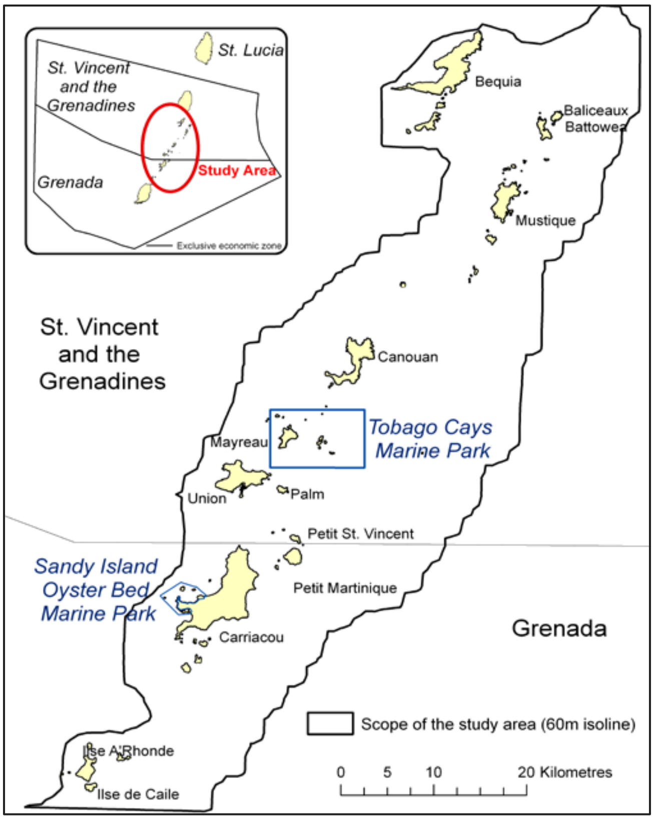

Figure 2. A map of the spatial distribution of preferred fishing areas and the location of high quality (very good and good) fishing grounds.

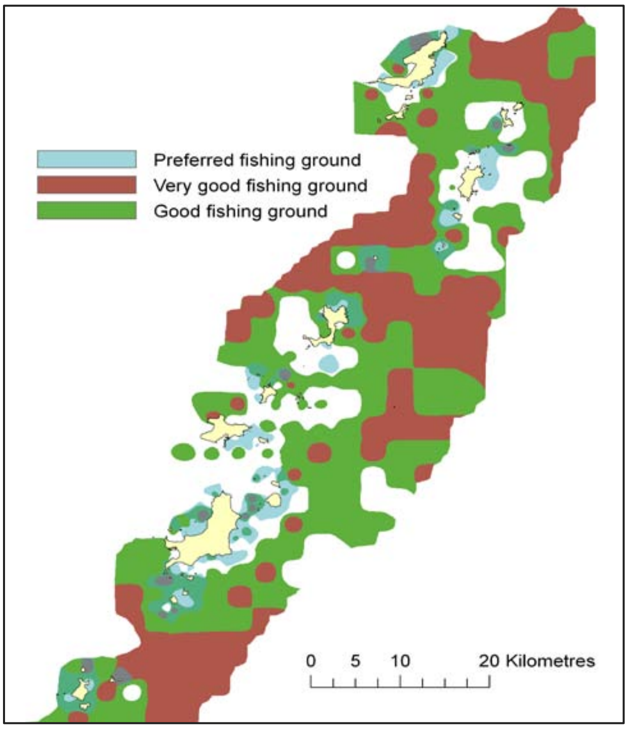

Figure 3. Cumulative impact surfaces (conservation, human use and threat) and identified hotspots of space-use overlap for the island of Carriacou, Grenada.