A PARTICIPATORY MARINE RESOURCE AND SPACE-USE INFORMATION SYSTEM FOR THE GRENADINE ISLANDS:

AN ECOSYSTEM APPROACH TO COLLABORATIVE PLANNING FOR MANAGEMENT OF TRANSBOUNDARY MARINE RESOURCES

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ABSTRACT

A PARTICIPATORY MARINE RESOURCE AND SPACE-USE INFORMATION SYSTEM FOR THE GRENADINE ISLANDS:AN ECOSYSTEM APPROACH TO COLLABORATIVE PLANNING FOR MANAGEMENT OF TRANSBOUNDARY MARINERESOURCES

Kimberly Elaine Baldwin

The application of a comprehensive strategy using multiple sources of information to address complex socio-ecological problems is recognised as essential for an ecosystem approach to marine governance. With a heavy reliance on marine resources and increasing numbers of resource users in the transboundary Grenadine Islands, there is a clear need for ecosystem-based marine resource management and a framework to support informed decision-making.

This dissertation details the ways in which stakeholders were engaged to develop a participatory geographical information system (PGIS) entitled the Grenadines Marine Resource and Space-use Information System (MarSIS). This included both the research approach (process) and the final geodatabase (product). Participatory processes were utilised to: (a) obtain and include the best available information from all possible sources; (b) increase inter- and intra-stakeholder understanding of interdisciplinary marine resource information; and (c) promote stakeholder ownership and use of the information produced. In order to demonstrate its potential for marine spatial planning and management, the MarSIS is used and evaluated as a framework for an ecosystem approach to managing the transboundary Grenada Bank marine resources.

This research found clear benefits in utilising a PGIS approach. These included more complete socio-ecological understanding of the human uses of marine resources in relation to conservation and to the livelihoods of the Grenadine people. Additionally, the processes employed in implementing a PGIS not only allowed for the production of locally-relevant and useful information, but also: (a) built stakeholder capacity in the understanding of the marine environment and related human uses; (b) provided legitimacy to the local knowledge of marine resource users; (c) increased confidence in and ownership of information produced; and (d) demonstrated to other practitioners the role stakeholders can and should play in marine governance. This study found that the collaborative development of the Grenadines MarSIS provided a practical mechanism to implement ecosystem-based management and strengthen interactive governance within the Caribbean.

Keywords*:* participatory geographic information system (PGIS), ecosystem-based management (EBM), interactive governance, marine spatial planning (MSP), the Grenadine Islands, Grenada Bank, transboundary marine resources

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DEDICATION

To my mother and my grandmother –

The two most inspirational women I have ever known.

Table of Contents

ACRONYMS

CARICOM	Caribbean Community
CBD	Convention on Biological Diversity
CCA	Caribbean Conservation Association
CD	Compact Disc
CERMES	Centre for Resource Management and Environmental Studies
CRFM	Caribbean Regional Fisheries Mechanism
DEM	Digital Elevation Model
DVD	Digital Versatile Disc
DVR	Digital Video Recorder
EA	Ecosystem Approach
EBM	Ecosystem-based Management
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
ESRI	Environmental Systems Research Institute
FAO	Food and Agriculture Organisation
GEF	Global Environment Facility
GDP	Gross Domestic Product
GIS	Geographic Information System
GND	Grenada
GNI	Gross National Income
GPS	Global Positioning System
HDI	Human Development Index
ICA	Institute of Cultural Affairs
IDW	Inverse Distance Weighted
IIRR	International Institute of Rural Reconstruction
kHz	Kilohertz
LED	Light-emitting Diode
MarSIS	Marine Resource and Space-use Information System
MDG	Millennium Development Goals
MPA	Marine Protected Area
MRU	Marine Resource User

MSP	Marine Spatial Planning
MSPM	Marine Spatial Planning and Management
NEMS	National Environmental Management Strategy
NGO	Non-governmental Organisation
NOAA	National Oceanic and Atmospheric Administration
OECS	Organisation of Eastern Caribbean States
PGIS	Participatory Geographic Information System
PM	Petit Martinique
PSV	Petit St. Vincent
PVC	Polyvinyl Chloride
SGD	St. George's Declaration of Principles for Environmental Sustainability
SGP	Small Grant Programme
SIDS	Small Island Developing States
SIOBMPA	Sandy Island Oyster Bed Marine Protected Area
SusGren	Sustainable Grenadines Project / Sustainable Grenadines, Inc.
SVG	St. Vincent and the Grenadines
TCMP	Tobago Cays Marine Park
TIN	Triangulated Irregular Network
TNC	The Nature Conservancy
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UTM	Universal Transverse Mercator
WGS	World Geodetic System
3D	Three Dimensional

GLOSSARY OF GIS TERMINOLOGY

Adapted from ESRI’s GIS dictionary (www.esri.com)

ArcGIS - is a geographic information system software product produced by ESRI. ArcGIS operates using a Windows interface and consisting of three main components: ArcMap, ArcCatalog and ArcToolbox.

ArcGIS is licensed under three functionality levels:

- **ArcView** - allows one to view spatial data, create layered maps and perform basic spatial analysis;
- **ArcEditor** - adds to the functionality of ArcView by including more advanced tools for manipulation of shapefiles and geodatabases;
- **ArcInfo -** provides for the full capabilities for data manipulation, editing, and analysis.

ArcMap - is the main component of the ArcGIS suite. It is used primarily to view, edit, create and analyse geospatial data. ArcMap allows the user to explore data within a data set, symbolise features accordingly and create maps.

ArcCatalog - is a geodatabase administration application in ESRI's ArcGIS suite. It provides a central place to access GIS information and view of all the data files, databases, ArcGIS documents and remote GIS web services. ArcCatalog allows the user to: browse and find geographic information; record, view, and manage metadata; define, export, and import geodatabase data models and datasets; search for and discover GIS data on local networks and the Web; and create and manage the schemas of geodatabases.

ArcToolbox –is a user interface in the ArcGIS suite used to access, organise, and manage a collection of geoprocessing tools, models, and scripts.

ArcScene - is a part of the Spatial Analyst extension and is an application that allows you to view your GIS data in three dimensions.

Attribute – is non-spatial information about a geographic feature in a GIS, usually stored in a table and linked to the feature by a unique identifier number.

Buffer – is a zone created around a map feature (represented as a polygon) that is measured out to a specified distance.

CON – is a geoprocessing tool that performs a conditional (if/else) evaluation on each of the input cells of an input raster.

Coordinates – are a set of values that define a position within a spatial reference represented by the letters (x,y) and optionally (z) for elevation data. Coordinates are used to represent locations in space relative to other locations.

Coordinate system – is a reference framework consisting of a set of points, lines and/or surfaces, and a set of rules used to define the positions of points in space in either two or three dimensions. The Cartesian coordinate system and the geographic coordinate system are the two coordinate systems used to reference GIS data.

Density surface - shows where point, line or polygon features are concentrated.

Digital elevation model – is the representation of continuous elevation values over a topographic surface by a regular array of z-values referenced to a common coordinate system. DEMs are typically used to represent terrain (i.e. bathymetry) relief.

Domain – is a mechanism for enforcing data integrity in a geodatabase. Attribute domains define what values are allowed in a field in a feature class or non-spatial attribute table. If the features or non-spatial objects have been grouped into subtypes, different attribute domains can be assigned to each of the subtypes.

Extension - an optional software module that adds specialized tools and functionality to ArcGIS. ArcGIS Spatial Analyst, ArcGIS 3D Analyst and Habitat Digitizer are examples of ArcGIS extensions used in this study.

Feature – is a cartographic representation of a real-world object on a map. A feature can be represented as a point, line or polygon in a vector data model or as a grid cell in a raster data model.

Feature class – is a collection of geographic features with the same geometry type (such as a point, line or polygon), the same attributes and the same spatial reference. Feature classes can be stored in geodatabases, shapefiles, coverages or other data formats. Feature classes allow homogeneous features to be grouped into a single unit for data storage purposes.

Feature dataset - is a collection of feature classes stored together that share the same spatial reference (i.e. they share a coordinate system) and their features fall within a common geographic area. Feature classes with different geometry types may be stored in a feature dataset.

Geometry - is used to represent the spatial component of geographic features as points, lines or polygons.

Geoprocessing – is a GIS operation used to manipulate GIS data. A geoprocessing operation takes an input dataset, performs an operation on that dataset and returns the result of the operation as an output dataset. Common geoprocessing operations include geographic feature overlay, feature selection and analysis, raster processing and data conversion. Geoprocessing allows for definition, management, and analysis of information to be used to form decisions. Geoprocessing tools are located in ArcMap and ArcToolbox.

Georeferencing – is the process of aligning geographic data and assigning it to a known coordinate system so it can be viewed, queried, and analysed with other geographic data.

Geographic information system – is an integrated collection of computer software and data used to view and manage information about geographic places, analyse spatial relationships, and model spatial processes. A GIS provides a framework for gathering and organizing spatial data and related information so that it can be displayed and analyzed.

IsNull – is a Spatial Analyst extension geoprocessing tool that determines which values from the input raster contain ‘NoData’ on a cell-by-cell basis. A value of ‘1’ is returned to an output raster if the input value is ‘NoData’ and ‘0’ for cells that are not.

Join - appends the fields of one table to those of another through an attribute or field common to both tables. A join is usually used to attach more attributes to the attribute table of a geographic layer.

Layer – is the visual representation of a geographic dataset in any digital map environment. Conceptually, a layer is a slice or stratum of the geographic reality in a particular area, and is more or less equivalent to a legend item on a paper map. In ArcGIS, a layer is a reference to a data source, such as a shapefile, feature class or raster that defines how the data should be symbolized on a map.

Personal geodatabase – is a database or file structure used primarily to store, query, and manipulate spatial data. Geodatabases enforces data integrity by storing geometry, a spatial reference system, attributes and behavioral rules for data. Various types of geographic datasets can be collected within a geodatabase including feature classes, attribute tables and raster datasets.

Query – is a request to select geographical features or attribute records from a database. A query is often written as a structured language query (SQL) statement or logical expression.

Raster – is a spatial data model that defines space as an array of equally sized grid cells arranged in rows and columns. Each cell contains an attribute value and locational coordinates. Unlike a vector structure, which stores coordinates explicitly, raster coordinates are contained in the ordering of the matrix. Groups of cells that share the same value represent the same type of geographic feature.

Remote sensing - is the small or large-scale acquisition of information of an object by the use of either recording or real-time sensing device(s) that are wireless, or not in physical or intimate contact with the object (such as by way of aircraft, spacecraft, satellite, buoy, or ship).

Spatial extent – is the limit of the geographic area of a data source represented by a minimum bounding rectangle defined by coordinate pairs (x min, y min and x max, y max). All coordinates for the data source must fall within this boundary.

Spatial reference – is the coordinate system, tolerance, and resolution used to store a spatial dataset.

Spectral signature - the specific combination of reflected and absorbed electromagnetic radiation at varying wavelengths which can uniquely identify an object.

Subtype – is a subset of features in a feature class or objects in a table that share the same attributes and are further categorised in a geodatabase. For example, a ‘roads’ feature class could be categorised into three subtypes: primary roads, secondary roads and tertiary roads. Creating subtypes can be more efficient by making the editing of data faster and more accurate because default attribute values and domains can be set up.

Triangular irregular network (TIN) – is a vector data structure that partitions geographic space into contiguous, non-overlapping triangles. The vertices of each triangle are sample data points with x, y and z-values. TINs are used to store and display surface models.

Union – is a standard ArcGIS geoprocessing overlay tool that merges two or more polygon spatial datasets that preserves all features that fall within the spatial extent of either input dataset (i.e. all features from both datasets are retained) and extracted into a new polygon dataset.

Vector – is a coordinate-based data model that represents geographic features as points, lines or polygons. Each point feature is represented as a single coordinate pair, while line and polygon features are represented as ordered lists of vertices. Attributes are associated with each vector geographic feature, as opposed to a raster data model which associates attributes with grid cells.

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

1.1 STRUCTURE OF THE DISSERTATION

This dissertation is structured in chapters that address different aspects of the work undertaken. The introductory chapter first gives a brief background to coastal marine resource management; justifies the research problem; further develops the research rationale and sets out two propositions for the study; reviews key concepts and provides a description of the study area. The next three chapters report upon the major components of the research (each with its own introduction, methods, results and discussion sections). Thus, the second chapter reviews the ways in which stakeholders were engaged to develop a participatory geographic information system (PGIS) in terms of both the research approach (process) and the produced information (product). The third chapter describes how marine habitat maps were developed by accessing the knowledge of stakeholders and combining this with the conventional technical habitat definitions and extant maps for the Grenada Bank in order to produce locally relevant marine habitat maps and other mapping products (marine space use). The fourth chapter summarises the development of the marine resource and space-use information system (MarSIS) geodatabase structure and examines some of the ways in which a collaborative geospatial approach (i.e. PGIS) can be applied to understanding, planning and managing marine resources in an integrated manner within a transboundary Caribbean context. To demonstrate its potential for marine spatial planning and management (MSPM), the MarSIS framework is used to provide a baseline picture of current conditions in the Grenadine Islands. The MarSIS is also used as a demonstration tool to show other practitioners the ways in which multi-knowledge information on coastal and marine resources and human activities can be brought together, analysed and used in scenario development as a starting point for collaborative MSPM. A concluding chapter synthesises the research with regard to the research propositions and evaluates them in light of the findings. This chapter concludes with a discussion of how the application of PGIS can serve as a practical mechanism to improve interactive marine governance. It provides recommendations for sustaining the project, and examines the implications for transboundary MSPM and further research.

1.2 BACKGROUND TO COASTAL MARINE RESOURCE MANAGEMENT

Coastal marine ecosystems consist of complex interacting habitats. They provide numerous ecological, economic, cultural and aesthetic benefits and are considered among the most productive and dynamic of ecosystems (Connell 1978, Moberg and Folke 1999, Aswani and Vaccaro 2008, Wilkinson 2008, Yang 2008). Despite this understanding, increasing coastal populations and development has resulted in threatened and degraded marine ecosystems (Sayer and Campbell 2004, Mora 2008, Wilkinson 2008, Gibbs and Cochran 2009). The severity of these impacts can be seen in a variety of ways including: the destruction of habitats; over-exploitation of resources; coastal pollution and erosion, all of which undermine food security as well as threaten biodiversity and coastal livelihoods. In the Caribbean, nearly two-thirds of the region's coral reefs are already threatened by human activities on or near the coasts (Gardner et al. 2003, Burke and Maidens 2004, Paddack et al. 2009) and most coastal resources are considered to be overexploited (FAO 1998, Mahon 2002). As both the scale of ecosystem exploitation and the extent of anthropogenic impacts have increased, fisheries management has also become more complex (Appeldoorn 2008, Paddack et al. 2009). If current trends in coastal marine ecosystem degradation continue, economic losses will be substantial for many of the Caribbean's small island developing states (Moberg and Folke 1999, Burke and Maidens 2004). Due to the significant ecological links among coastal and marine ecosystems, their long-term sustainability will require a holistic and regional approach to the control of human-related stressors occurring in the Caribbean region (Moberg and Folke 1999, Rogers and Beets 2001, Mora 2008, Paddock et al. 2009, Ogden 2010, Fanning et al. 2011).

Conventional top-down management approaches have failed to achieve the goals of sustainable development and have been insufficient to respond to the complex nature of the social, economic, political and environmental challenges of marine resource management (Maine et al. 1996, Grenier 1998, IIRR 1998, Sayer and Campbell 2004, Pomeroy et al. 2004, Wiber et al. 2004, Christie and White 2007; Ogden 2010). Historically, management of Caribbean marine resources and human impacts on coastal and marine areas have occurred on a sectoral basis, and have not been integrated among disciplines, knowledge systems or nations (Chakalall et al. 2007, Fanning et al. 2011). This segregated management approach has been ineffective in preventing environmental degradation of Caribbean marine ecosystems (Rogers and Beets 2001, Pomeroy et al. 2004: Agard et al. 2007, Mora 2008). Emerging perspectives on marine management suggest that an inclusive, multi-sector, strategic, multi-scaled and adaptive approach is required for effective marine resource management (Garcia et al. 2003, Folke 2004, Chakalall et al. 2007,Christie and White 2007, Armitage et al. 2008, Mahon et al. 2008, Agardy 2010, Ogden 2010, Tallis et al. 2010).

A paradigm shift which embraces a comprehensive strategy, or an ecosystem approach (EA), composed of both natural and human elements, is becoming increasingly recognised as an appropriate direction in marine governance (Garcia et al. 2003, Folke 2004, Bavinck et al. 2005, Chakalall et al. 2007, Ostrom et al. 2007, Armitage et al. 2008, Mahon et al. 2008, Chuenpagdee and Jentoft 2009, Agardy 2010, Tallis et al. 2010). The EA, as defined by the Malawi Principles of the Convention of Biological Diversity, is 'a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way.' In this manner the application of an EA builds on the concept of integrated management, but also requires that management be adaptive, carried out at multiple scales, and allow for inter-sectoral cooperation and broad stakeholder participation (Christie and White 2007, Douvere and Ehler 2009). Moreover, socio-cultural considerations are considered to play a central role in an EA as human interactions and (direct or indirect) uses of marine ecosystems take place in the context of socio-ecologic systems (Berkes and Folke 1998, Garcia et al. 2003, Chuenpagdee and Jentoft 2009, McConney and Salas 2011). Efforts that have ignored local circumstances and knowledge systems have wasted time and resources (Grenier 1998, Tripathi and Bhattarya 2004, Aswani and Lauer 2006b); whereas those that have incorporated local ecological and popular knowledge systems with traditional scientific approaches report having been able to fill important information gaps, identify potential problems and focus management priorities accordingly (Johannes 1989, Walters et al. 1998, Berkes 1999, Balram et al. 2004,Christie et al. 2005, Aswani and Lauer 2008, Castello et al. 2009). Not only is the incorporation of practical knowledge together with conventional scientific information considered to produce cost-effective, scientifically valid and locally relevant information, it is alleged to be an important tool for learning and understanding the linkages between marine resources and human communities required for EA to management (Berkes 1999, Berkes et al.2001, Chuenpagdee and Jentoft 2009, De Freitas and Tagliani 2009).

An effective EA will therefore require measures that can conceptualise, rationalise and control the spatial and temporal development of human activity occurring in the coastal and marine environment (Crowder and Norse 2008, Douvere and Ehler 2009). Despite this realisation, it is increasingly clear that governments and stakeholders lack the necessary tools to make EA to management operational and achieve sustainable development, particularly in the marine environment (Crowder and Norse 2008, Douvere and Ehler 2009, Tallis et al. 2010, Fanning et al. 2011, Agardy et al. 2012). Marine spatial planning and management (MSPM) is a science-based planning approach that offers a constructive means to deal with complex, diverse and dynamic systems. This model recognises the heterogeneous distribution of marine organisms, habitats and human activities, and thus the place-based spatial nature of resources and resource use. MSPM develops a plan for a given area in which ecological, economic and social objectives can simultaneously be accommodated to attain sustainable development (Crowder and Norse 2008, Douvere and Ehler 2009). By focusing on the distinctive features of an individual location and tailoring management to the local circumstance through an adaptive learning cycle, MSPM has the potential to offer a multidisciplinary framework to assist the implementation of EBM principles (Young et al. 2008).

As marine resource management has a spatial component and requires the integration of information from a variety of sources at multiple scales, geographical information systems (GIS) have gained wide acceptance for environmental management and planning applications. GIS has been broadly applied to participatory and collaborative approaches, as it allows for the aggregation of multi-scale information and ability to analyse a large number of attributes from different sources; thereby facilitating data sharing and the generation and comparison of alternative management scenarios (Yigitcanlar 2000, Quan et al. 2001). In recent years the use of GIS as a tool coupled with participatory and collaborative approaches has emerged as a novel science known as participatory GIS (PGIS) (Chambers 2006, Corbett et al. 2006, Rambaldi et al. 2006b). A focus on the application of a GIS in terms of the development of demand-driven, user-centred products has been emerging in the PGIS practice. By promoting the engagement of stakeholders in the development of a technical representation of spatial knowledge, PGIS can allow for a comprehensive understanding of the social aspects of natural resource use patterns (Quan et al. 2003, Balram et al. 2004, Chuenpagdee et al. 2004, Aswani and Lauer 2006, St. Martin and Hall-Arber 2008, Dalton et al. 2010). Thus PGIS can support the production and incorporation of a wide range of information, including local knowledge and stakeholders' perspectives to be systematically merged with conventional biophysical and jurisdictional information (Corbett et al. 2006, De Freitas and Tagliani 2009). Furthermore, collaborating with stakeholders to determine and produce appropriate (e.g. locally-relevant) information is a central tenet of PGIS. This process not only demonstrates the relevance of information provided by stakeholders, but supports an EA by promoting the collection and utilisation of local knowledge together with conventional scientific knowledge, hence allowing for a broader understanding of human-environment interactions (Balram et al. 2004, Chuenpagdee et al. 2004, Aswani and Lauer 2006, Dalton et al. 2010). As such, stakeholder engagement throughout the PGIS process can build capacity for effective participation in governance (e.g. Friedlander et al. 2003, Smith 2003, Pomeroy and Douvere 2008, Scholz et al. 2008, De Freitas and Tagliani 2009).

1.2.1 The Grenadine Islands

The transboundary Grenadine Island chain (atop the Grenada Bank) provides a good locality to evaluate the application of PGIS and assess its implications for governance within a complex coastal marine management environment. Marine resources and their use (including marine-based tourism, fishing and transportation) are of vital importance as they provide food security, livelihoods and social identity for the small coastal communities of the Grenadine Islands (Jardine and Straker 2003, Sustainable Grenadines Project 2005, Baldwin et al. 2006). Management thus far has primarily taken a conventional top-down approach guided by standard, non-specific, regional management plans and based on limited biophysical information. Furthermore, marine management of the Grenada Bank has not been integrated amongst disciplines, between nations or knowledge systems. This segregated management approach has not been effective and has failed to prevent the environmental degradation of the Grenada Bank.

To address the complex nature of multi-scale and multi-level transboundary marine resources of the Grenada Bank, there is a clear need for an integrated ecosystem approach, including access to holistic information to support informed decision-making for adaptive management and the provision of sustainable development. The need for such a holistic and integrated marine information system was broadly identified in 2002 by a transboundary NGO, the Sustainable Grenadines Inc. (better known as SusGren). The principles of interactive governance may provide a holistic theoretical approach to contend with complex social-ecological problems currently facing resource management; yet the development of practical mechanisms to provide for its implementation are yet to be fully realised (Folke et al. 2002).

1.3 RESEARCH AIMS AND OBJECTIVES

This study explores the requirements for an EA to marine governance, focusing in particular on the development of a participatory decision-making framework within a marine spatial planning context. Thus the intention of this research was to apply a PGIS approach and explore its usefulness as a practical mechanism to provide easy and equitable access to multi-knowledge marine resource information. PGIS was also tested as a tool to strengthen aspects of marine governance and support ecosystem-based transboundary marine spatial planning and management across the Grenada Bank. This PGIS system is referred to as the Grenadines Marine Resource and Space-use Information System (MarSIS).

1.3.1 The rationale for the research

Located in the Eastern Caribbean, the transboundary Grenadine Island chain lies on the Grenada Bank which extends more than 100 km in length between two countries, Grenada, and St. Vincent and the Grenadines (Figure 1-1). There are over 30 islands, islets and cays, of which nine have permanent settlements. Marine-based activities are the foundation of the economies of the Grenadine Islands in which fishing, tourism and inter-island transportation are the major sources of employment (Adams 1996; Baldwin et al. 2006). Although coastal and marine resources are of vital importance to the people of the Grenadines, increasing pressures from tourism development and the non-sustainable use of these resources are making the planning and management of marine resource use on the Grenada Bank increasingly complex (Mahon et al. 2004). The situation is further complicated by the transboundary nature of the resources and their users.

To date, management of the Grenada Bank marine resources has primarily been focused on the fisheries sector using a conventional top-down approach with a limited information base from which to make management decisions (FAO 1990, Culzac-Wilson 2003, Mahon et al. 2004, Daniel 2005, Joseph 2006, FAO 2007). There is little integration across sectors, between nations or among knowledge systems (i.e. conventional scientific and local ‘tacit’ knowledge). This approach

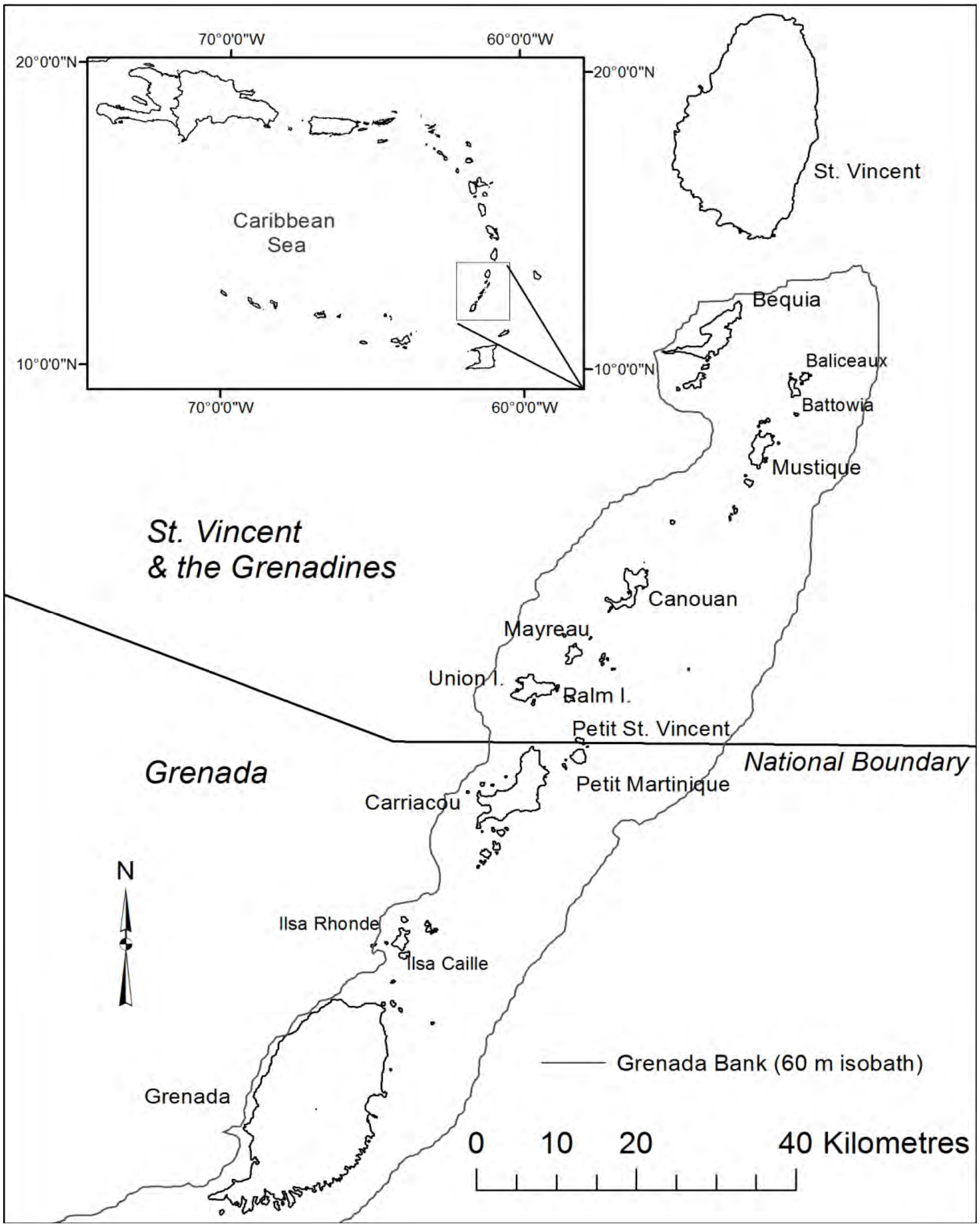


Figure 1-1 Geographic location of the countries of St. Vincent and the Grenadines and the tri-island state of Grenada and detail of the Grenadine Islands of the transboundary Grenada Bank (60 m isobath).

has failed to prevent environmental degradation within the Grenadine Island chain (CCA 1991a, CCA 1991b, Culzac-Wilson 2003, ECLAC 2004). The general lack of marine resource and space-use management together with the on-going environmental degradation provides an opportunity for applying an integrated EA to the transboundary management of the Grenada Bank marine resources.

The need for holistic and integrated marine resource information for the Grenada Bank was broadly identified in 2002 (CCA-CAMP 2002). This assessment also determined that in the Grenadine Islands, due to limited capacity and organisation, civil society stakeholders were the least able stakeholder group to contribute to bringing about equitable and lasting change (CCA-CAMP 2002). A project was subsequently developed with the overarching objective of promoting the sustainable integrated development and biodiversity conservation in the Grenadine Islands by fostering the capacity of all major stakeholders (including governments, private sector and civil society) to participate in governance (Mahon et al. 2004). The Sustainable Grenadines Project (better known as SusGren) started in 2004 and ended in December 2010 when it transitioned into a transboundary NGO, Sustainable Grenadines Inc. (still known as SusGren). SusGren's overarching objective today remains the same as that of its founding project.

An underlying perspective of SusGren is that progress towards an objective is more likely to be made when stakeholders are well informed, able to offer meaningful input and work from a common set of goals, principles and information. In order to enable such an environment, SusGren has supported activities that provide access to information, promote collective action, and facilitate the networking and linkages to allow transformative exchanges among the partners (SusGren 2005). It is within this context, consistent with an EA and the principles of the Convention of Biological Diversity and the St. George's Declaration for Environmental Sustainability, that the current study was initiated.

At the World Summit on Sustainable Development (2002), global attention was given to the implementation of the EA to marine resource assessment and management by 2010. The application of an inclusive inquiry using multiple sources of information to address complex socio-ecological problems is recognised as an appropriate direction in marine resource management (Bavinck et al. 2005, Hughes et al. 2005, Berkes 2007, Ostrom et al. 2007, Armitage et al. 2008, De Young and Charles 2008, Mahon et al. 2008). However, putting measures in place to give effect to EBM principles remains an on-going challenge, particularly in the Caribbean (Ogden 2010, Aswani et al. 2011, Fanning et al. 2011). A collaborative spatial approach derived from the fullest possible information base is proposed by this study to effectively understand the transboundary and multifaceted nature of the marine resources of the Grenada Bank and manage its users. A fundamental shift from a purely scientific approach, based on gathering empirical and measurable evidence, to one in which quantitative and qualitative knowledge systems are amalgamated, is an important component to realise EBM (Armitage et al. 2008, De Young and Charles 2008, Mahon et al. 2008, Agardy 2010, Tallis et al. 2010, Agardy et al. 2012). The application of this holistic multidisciplinary approach can possibly advance an EA to marine resource management in the Caribbean. The strengthening of transboundary governance, including the building of multi-scale and multi-level partnerships, is also proposed in this study to allow for the production of, integration of and access to holistic information, an informed decision-making environment, and support for adaptive social-learning to support EBM and aid sustainable development (Berkes et al. 2001, Garcia et al. 2003, Folke 2004, Chakalall et al. 2007, Armitage et al. 2008, De Young and Charles 2008, Mahon et al. 2008, Agardy 2010, Tallis et al. 2010).

The principles of interactive governance may provide a holistic theoretical approach to contend with complex social-ecological problems currently facing resource management; yet the definition of practical mechanisms to provide for its implementation are yet to be fully realised (Folke et al. 2002). Based on the literature, a PGIS can potentially be employed as a tool for EBM. The application of PGIS can serve to integrate social, economic, cultural and conventional biophysical information with the local knowledge system of marine resource stakeholders in a single framework to aid informed decision-making. Moreover, PGIS integrates the ways stakeholders can be engaged in both the research approach (process) into the development of information (product). Participatory methods can be utilised to: (a) obtain and include the comprehensive information available from all possible sources; (b) increase inter- and intra-stakeholder understanding of interdisciplinary marine resource information; and (c) promote stakeholder ownership and use of the information produced thereby strengthening interactive marine governance. Despite these claims, benefits of PGIS to date, has primarily been in terrestrial rather than marine environments. Furthermore, it is not clear whether PGIS will be feasible or appropriate within the Caribbean context.

1.3.2 Research propositions

In this study of marine space use in the transboundary Grenadines Islands, a PGIS approach was employed as a conceptual framework to integrate conventional biophysical and management information with information derived from the practical knowledge of marine resource users. This study explores the requirements for interactive governance, focusing in particular on the development of a participatory decision-making framework within a marine spatial planning context. Thus, this study applies PGIS as a conceptual framework for strengthening ecosystem-based management (EBM) with in the Caribbean context and uses an inductive reasoning approach to explore the potential benefits gained compared to the application of a conventional scientific approach. Based on the literature and prior knowledge of the living marine resource governance on the Grenada Bank this study sets out to explore two propositions. Proposition one, is that merging local knowledge on ecology of marine resources, space-use patterns related to these resources and the socio-economic situation regarding users, with conventional biophysical environmental information in the Grenadine Island setting, will provide significant improvements in planning insights over the use of the latter alone. Proposition two is that integrating information from the full range of stakeholder groups and their respective sectors through the use of GIS will provide management insights that cannot be acquired by examining the data and information from each group and sector separately. In order to do this, a participatory geospatial framework, the 'Grenadines Marine Resource and Space-use Information System' (MarSIS) was developed. The research utilises a variety of participatory research methods to acquire local knowledge that could be integrated with conventional scientific information. The process for this research involved several steps including: data scoping and preliminary appraisal; marine resource and use assessment and mapping; development of marine habitat mapping products; definition and compilation of the MarSIS geodatabase; and planning for stakeholder usability. The MarSIS geodatabase was applied to provide a comprehensive baseline of conditions in the Grenadine Islands. An evaluation of the research process and product as a basis for understanding, planning and managing the marine resources of the transboundary Grenada Bank was also conducted. This includes an assessment in regard to: key PGIS and interactive governance principles; the practical application of the geodatabase product as an appropriate tool to provide a baseline inventory of the extent and distribution of marine resources and human activity occurring on the Grenada Bank; and a practical demonstration of the ways PGIS information can be analysed as a starting point for MSPM.

1.4 CONCEPTUAL BACKGROUND

This section provides an overview of current marine governance concepts, issues and methods that underpin the work undertaken in this study. These include: status of coastal marine ecosystems, governance of complex systems, ecosystem-based management (EBM), stakeholder engagement in governance, marine spatial planning and management (MSPM), geographic information system (GIS) and the participatory geographic information system (PGIS) approach. This review aims to give the reader insight into the prevailing conceptual framework for marine governance and places the research within the context of the current literature.

1.4.1 Status of coastal marine ecosystems

Tropical coastal marine ecosystems, namely coral reefs and the nature of their interactions with seagrass beds and mangrove forests, provide a diversity of ecosystem goods and services to society including food, coastal protection and recreation, as well as aesthetic and cultural benefits (Smith 1978, Hughes 1994, Moberg and Folke 1999, Stallings 2009). Coral reefs, considered among the most productive and dynamic of all marine ecosystems (e.g. Odum and Odum 1955, Connell 1978, Hughes 1994, Wilkinson 2008, Yang 2008), support almost a third of the world's fish species (McAllister 1991). In the Wider Caribbean region, coral reefs are estimated to provide ecosystem services valued at US $3.1 billion to $4.6 billion per annum (Burke et. al 2011).

Correspondingly, increasing coastal populations and development attracted by and dependent upon healthy coastal marine ecosystems, have resulted in their degradation in many parts of the world (Hughes 1994, Moberg and Folke 1999, Jackson et al. 2001, Rogers and Beets 2001, MEA 2005, Mora 2008, Wilkinson 2008, Gibbs and Cochran 2009, Paddack et al. 2009, Ogden 2010). A recent comprehensive analysis found that 75 percent of the world's coral reefs are currently threatened by local and global pressures (Burke et. al 2011). In the Caribbean region, live coral cover has experienced an 80% reduction since the 1970s (Gardner et al. 2003). Other interconnected ecosystems, such as seagrass beds and mangrove forests, have also experienced similar declines (Moberg and Folke 1999, Jackson et al. 2001, Rogers and Beets 2001, FAO 2007, Mora 2008). Caribbean reef fisheries have begun to respond negatively to habitat degradation with significant region-wide declines in fish densities occurring since the mid-1990s (Mora 2008, Paddack et al. 2009).If current trends in coastal marine ecosystem degradation continue, economic losses for many of the Caribbean's small island developing states will be substantial (Hughes 1994, Burke and Maidens 2004, Pulwarty et al. 2010). Clearly, effective management of activities that impact negatively on coastal marine ecosystems is urgently needed.

1.4.2 Governance of complex systems

Governance is a term used to describe how political, economic, administrative and other forms of power or authority are exercised to manage a country's resources and affairs (De Young and Charles 2008). In other words, governance "encompasses the whole of public, as well as private interactions that are initiated to solve societal problems and to create societal opportunities" (Bavnick et al. 2005).

One failure of conventional governance systems applied to manage human use of marine resources has been attributed to geographic, administrative and temporal mismatches of those governance systems with the biophysical systems they are intended to govern (Crowder et al. 2006, Young et al. 2007, Chuenpagdee and Jentoft 2009). The challenges facing marine resource governance are complex and dynamic, characterised by high levels of uncertainty and interlinked processes at multiple levels and scales (jurisdictional, spatial, temporal, ecological and institutional) (Reed 2008, Bavinck et al. 2005, Berkes et al. 2001, McConney et al. 2007, Apgar et al. 2009). The recognition that social and ecological systems are intrinsically linked has added to this complexity (Berkes and Folke 1998, Berkes et al. 2001, De Young and Charles 2008, Chuenpagdee and Jentoft 2009). Finding the right balance between social and economic demands for development, and protecting the health and resilience of ecosystems is a difficult task, particularly in the marine environment (McLeod and Leslie 2009). It should therefore be no surprise that conventional top-down scientific approaches and single-issue management have failed to achieve the goals of sustainable development and are insufficient to respond to the versatile nature of social, economic, political and environmental challenges facing marine governance today (Sayer and Campbell 2004, Pomeroy et al. 2004, Wiber et al. 2004, Bavnick et al. 2005, De Young and Charles 2008, Allan et al. 2009, Mahon et al. 2011).

In light of this complex and dynamic environment, there is the need to implement management measures even before cause and effect relationships are fully known (De Young and Charles 2008). Accordingly, the 'interactive governance' (Kooiman et al. 2005) approach seeks to strengthen governance by providing for a representative and inclusive framework to organise information and make informed decisions that are transparent, accountable, comprehensive and effective. These approaches emphasise that in order to adequately respond to uncertainty; management must be interactive and adaptive, occur at multiple scales and levels and provide for a 'learning-by-doing' feedback cycle (Bavinck et al. 2005, Cash et al. 2006, Berkes 2007, Christie and White 2007, De Young and Charles 2008, Mahon et al. 2008, Apgar et al. 2009). Enabling the collaboration of a multiplicity of stakeholders within aspects of governance (including the generation of information, problem-solving and decision-making) is purported to increase access to a wide range of knowledge and information and build capacity for good governance (Mackinson and Nottestad 1998, De Young and Charles 2008). Thus, through the application of such a broad collaborative approach, adaption and resilience are supported and an EA to management can be provided for (Bavinck et al. 2005, Hughes et al. 2005, Berkes 2007, Armitage et al. 2008, Mahon et al. 2008).

1.4.3 Ecosystem-based management (EBM)

An ecosystem approach (EA), used interchangeably in this dissertation with ecosystem based management (EBM), has arisen out of a realisation that a biophysical focus and conventional top-down management approach are insufficient or inappropriate for responding to complex social, economic and environmental challenges and consequently have failed to achieve the goals of sustainable development (Sayer and Campbell 2004, Pomeroy et al. 2004, Wiber et al. 2004, Wilkinson 2008, Christie et al. 2009, McLeod and Leslie 2009, Tallis et al. 2010). A comprehensive strategy or an ecosystem approach to management which considers both natural and human elements and their interactions is needed (Crowder et al. 2006, Ehler and Douvere 2007, De Young and Charles 2008, Tallis et al. 2010). The application of EBM builds on the concept of integrated management, but also requires that management be adaptive, cross-scale and multi-level allowing for broad stakeholder participation (Christie et al. 2007, De Young and Charles 2008, Douvere and Ehler 2009).

> ‘EBM is an environmental management approach that recognizes the full array of interactions within an ecosystem, including humans, rather than considering single issues, species, or ecosystem services in isolation. The goal of ecosystem-based management is to maintain an ecosystem in a healthy, productive and resilient condition so that it can provide the services humans want and need. Ecosystem-based management differs from current approaches that usually focus on a single species, sector, activity or concern; it considers the cumulative impacts of different sectors.
>
> Specifically, ecosystem-based management:
>
> - emphasises the protection of ecosystem structure, functioning, and key processes;
> - is place-based in focusing on a specific ecosystem and the range of activities affecting it;
> - explicitly accounts for the interconnectedness within systems, recognising the importance of interactions between many target species or key services and other non-target species;
> - acknowledges interconnectedness among systems, such as between air, land and sea; and
> - integrates ecological, social, economic, and institutional perspectives, recognising their strong interdependences.’
>
> *- McLeod et al. (2005)*

Major advances towards an EA stem from the 1992 United Nations Conference on the Environment and Development (UNCED or the Rio Earth Summit) which was convened in response to a need to reconcile economic development with environmental protection. As a result, a global action plan (Agenda 21) was developed to improve environmental management and provide a comprehensive strategy for sustainable development. Chapter 17 of Agenda 21 provides guidelines for the sustainable development of the coastal and marine environment and calls for an integrated multi-sectoral policy and decision-making framework that focuses on the ecological/spatial boundaries required to maintain the structure and function of the ecosystem. Furthermore, Chapter 17 speaks directly to the importance of utilising a precautionary and holistic multi-level and multi-scaled approach to the management of marine resources which recognises the rights of stakeholders, including the utilisation of local knowledge, to participate in decision-making.

A paradigm shift which embraces an EA, composed of both natural and human elements, is taking place in marine governance (Berkes et al. 2001, Folke 2004, Chakalall et al. 2007, Armitage et al. 2008, De Young and Charles 2008, Mahon et al. 2008, Agardy 2010, Tallis et al. 2010). Likewise, a number of other international treaties and multilateral environmental agreements, such as FAO's Code of Conduct for Responsible Fisheries (1995), the Millennium Development Goals (2000), the Reykjavik Conference on Responsible Fisheries in the Marine Ecosystem (2001), the World Summit on Sustainable Development (WSSD) targets (2002), and FAO's Ecosystem Approach to Fisheries (2007) as well as regional umbrella agreements, such as The Convention for the Protection and Development of the Marine Environment in the Wider Caribbean Region (i.e.

Cartagena Convention) and the St. Georges Declaration (SGD) of Principles for Environmental Sustainability in the Organisation of Eastern Caribbean States (2006) *inter alia*, speak directly to the need for an EA to marine governance.

In 2008, the Convention on Biological Diversity's (CBD) Conference of the Parties further advanced the EA paradigm by providing operational guidance and recommendations on its application through the development of the Malawi Principles (Table 1-1). Thus EA is not an end in itself, but rather a mechanism intended to help better achieve societal objectives through broadening governance into an integrated, participatory framework (De Young and Charles 2008). According to De Young and Charles (2008), success of implementing an EA is more likely given an ability: to work within accepted policy frameworks; to develop or reinforce institutional arrangements that allow for good governance; to allow for effective nested institutions (outside and between institutions) and for appropriate organisational structures (inside institutions and/or agencies). Yet institutional failures have been pointed out as the main obstacles to effective marine resource management (Reed 2008). Institutional mechanisms that can support an EA, particularly in the face of increasing complexity and uncertainty, include increased: coordination, cooperation and communication between relevant institutions; access to holistic socio-ecological information; and multi-level,

Table 1-1 The guiding principles for implementing an ecosystem approach (e.g. Malawi Principles).

1	Management objectives are a matter of societal choice.
2	Management should be decentralized to the lowest appropriate level.
3	Ecosystem managers should consider the effects of their activities on adjacent and other ecosystems.
4	Recognizing potential gains from management there is a need to understand the ecosystem in an economic context, considering e.g. mitigating market distortions, aligning incentives to promote sustainable use, and internalizing costs and benefits.
5	A key feature of the ecosystem approach includes conservation of ecosystem structure and functioning.
6	Ecosystems must be managed within the limits to their functioning.
7	The ecosystem approach should be undertaken at the appropriate scale.
8	Recognizing the varying temporal scales and lag effects which characterize ecosystem processes, objectives for ecosystem management should be set for the long term.
9	Management must recognize that change is inevitable.
10	The ecosystem approach should seek the appropriate balance between conservation and use of biodiversity.
11	The ecosystem approach should consider all forms of relevant information, including scientific and indigenous and local knowledge, innovations and practices.
12	The ecosystem approach should involve all relevant sectors of society and scientific disciplines.

multi-scale stakeholder involvement (De Young and Charles 2008).

Putting measures in place to give effect to EBM principles remains an on-going challenge (Fanning et al. 2011). While the role of EBM is evolving, it is increasingly clear that governments and stakeholders lack the necessary tools and capacity to make them operational, particularly in the marine environment (Crowder and Norse 2008, Douvere and Ehler 2009, Ogden 2010, Tallis et al. 2010). Correspondingly, the role of EBM within the Wider Caribbean has yet to be fully determined (Rothwell and VanderZwaag 2006, Ogden 2010). A multi-stakeholder symposium, ‘Marine EBM in the Wider Caribbean’ was held in 2008 to develop a vision for EBM and identify mechanisms to achieve the needs and potential actions required to adopt and implement an EA to marine governance in the region. Seven key elements were identified. These include: inclusive participation; comprehensive, coherent and consistent decision-making; efficient multi-level networks and institutions; individual motivation for stewardship; and enhanced social capital (Fanning et al. 2011). Despite this understanding, a practical framework to realise these elements of an EA to marine governance is yet to be established in the Caribbean.

1.4.4 Stakeholder engagement in governance

To successfully implement an EA, socio-cultural considerations play a central role. If management of resources is a matter of societal choice (e.g. Malawi Principles), understanding how human interactions and (direct or indirect) uses of marine ecosystems take place in the context of socio-ecologic systems is necessary (Berkes and Folke 1998, Chuenpagdee and Jentroft 2009, McConney and Salas 2011). Inquiry using multiple sources of information has been effective in contending with complex social-ecological problems; particularly in situations where conventional scientific data are limited (Johannes 1994, Berkes et al. 2001, Folke 2004, Aswani and Vaccaro 2007, Reed 2008, De Freitas and Tagliani 2009). This paradigm shift in resource governance embraces the use of participatory mechanisms to obtain quantitative and qualitative knowledge from a diversity of stakeholders to provide a broad information base for decision-making (Johannes 1984, Mahon 1997, Johannes 1998, IIRR 1998, Berkes 1999, Berkes et al. 2001, Bunce et al. 2000, Allen et al. 2009, Apgar et al. 2009). 'Local knowledge' or the tacit knowledge possessed by the resource users, including their understanding of resource distribution, use patterns, critical areas (i.e. areas important for conservation, livelihoods or perceived threat) is an important source of information for marine resource management (Johannes 2002, Berkes et al. 2001, Friedlander et al. 2003, Folke 2004, Hall and Close 2007, Aswani and Vaccaro 2008, De Freitas and Tagliani 2009). In many cases, it may be the only source. Not only can combining local knowledge with conventional scientific information produce cost-effective, scientifically valid and locally relevant information, it is an important tool for learning and understanding the linkages between marine resources and human communities (Berkes 1999, Berkes et al. 2001, De Freitas and Tagliani 2009). This information can fill important data gaps and be used to guide more effective problem solving thereby allowing management to be adapted to local circumstances (Johannes 1981, Berkes et al. 2001, Folke 2004, Wiber et al. 2004).

Beyond the pragmatic role that participation can play in providing information for resource management, it is also thought to foster good governance (McCall 2003, Tripathi and Bhattarya 2004). Other principles that underpin good governance are seen to involve transparency, equity, accountability and ownership in governance (De Young and Charles 2008). Broad stakeholder engagement within an adaptive management framework is frequently reported to facilitate increased dialogue, understanding, and trust amongst stakeholders; thereby aiming to improve good governance (Mackinson and Nottestad 1998, McConney et al. 1998, Renard and Krishnarayan 2000, Chuenpagdee et al. 2004, Pomeroy et al. 2004, Mahon et al. 2008). Utilising a partnership approach within an interactive governance environment builds shared understanding, and may result in environmental decisions which are more likely to be perceived as holistic and fair, and provide for better compliance upon implementation (Johannes 1981, Mackinson and Nottestad 1998, Bunce et al. 2000, Christie et al. 2005, Reed 2008). Thus multi-level collaboration can aid empowerment, the capacity for learning and pluralistic problem solving which ultimately assists self-organisation for adaption and participation in governance (Wiber et al. 2004, Mahon et al. 2008).

1.4.5 Marine spatial planning and management (MSPM)

Successful ocean governance requires the capacity to deal with complex socio-ecological systems (Armitage et al. 2008, Crowder and Norse 2008, Mahon et al. 2008). Furthermore, effective EBM and the provision of sustainable development will entail measures that can conceptualise, rationalise and control the spatial and temporal development of human activities occurring in the marine environment (Crowder and Norse 2008, Douvere and Ehler 2009). Marine spatial planning and management (MSPM) can offer a constructive means to deal with the uncertainties associated with complex, diverse and dynamic systems by focusing on the distinctive features of an individual place and tailoring management to the local circumstance through an adaptive learning cycle (Young et al. 2007).

MSPM may improve decision-making as it has the potential to deliver an EA to managing human activities in the marine environment (Ehler and Douvere 2007). Analogous to land-use planning in the terrestrial environment, MSPM is a multidisciplinary planning process which lays out a spatially focused, multi-objective, integrated vision to be developed for an area in which ecological, economic and social objectives can be simultaneously accommodated (Crowder and Norse 2008, Douvere and Ehler 2009). A further tenet of MSPM is that stakeholder engagement is central to the process. Providing a transparent framework that can accommodate a wide diversity of multi-disciplinary information in an accessible format can serve to improve stakeholder understanding and involvement in decision-making and support interactive governance (Pomeroy and Douvere 2008, Carocci et al. 2009, Mackinson et al. 2011). MSPM provides a conceptual science-based planning framework that is consistent with EBM principles; namely that it can be adaptive, carried out at multiple scales, allow for inter-sectoral cooperation, and facilitate broad stakeholder participation.

To address the multiple, cumulative and potentially conflicting uses of the sea, MSPM usually includes the development of a marine space-use plan (i.e. zoning plan) as an operational output to regulate, manage and protect the environment. By allocating space-use for the various sectors, including conservation, in an equitable and harmonised manner, MSPM can reduce the potential for conflicts. Successful MSPM therefore requires not only mapping of biophysical features but also the corresponding human use patterns and legal arrangements of the area (Crowder and Norse 2008). An initial step in the MSPM process is to prepare a baseline inventory that defines and analyses the existing conditions. Consideration should be given to understanding: (a) what the ecological characteristics of the area are; (b) what economic, social and jurisdictional factors are relevant; (c) which sectors depend on certain areas; and (d) what are the main pressures/threats on the area? Therefore at least four categories of spatial information are relevant: biological and ecological distributions; extent of human activities; physical environmental features; and jurisdictional boundaries (Douvere and Ehler 2009).

Notwithstanding the central role of human agency in the concepts of EBM and MSPM, the scope of ‘human dimension’ information included is often inadequate relative to its actual importance and complexity (St. Martin and Hall-Arber 2008). Furthermore, it is recognised that marine management has not been effective in part due to a failure to use the full range of available sources of information and knowledge, particularly the local knowledge of the resource users (Johannes 1998, Anchiracheeva et al. 2003). Despite the known usefulness of these types and sources of information (Johannes 2002, Berkes et al. 2001, Friedlander et al. 2003, Folke 2004, Aswani and Lauer 2006, Aswani and Vaccaro 2008, De Freitas and Tagliani 2009), they are often not appropriately incorporated in MSPM and therefore can hinder management effectiveness (St. Martin and Hall-Arber 2008).

1.4.6 Geographic information system (GIS)

The process of collecting information for MSPM, from diverse sources and levels across scales is often laborious, time-consuming and costly (Berkes et al. 2001, Tripathi and Bhattarya 2004). Recognition of the need to integrate, analyse and spatially understand a variety of types of information relating to the marine environment and the interactions among them, has increased reliance on the use of geographic information systems (GIS). GIS permits the assimilation of information across various scales and disciplines thereby providing an effective data management framework (Balram et al. 2004). GIS not only provides the capability to conduct spatial analysis by querying, summarising and modelling marine resource data and corresponding human activities but can allow for improved understanding through the visualisation of the marine environment, its uses and the interactions amongst stakeholders (Carocci et al. 2009). By improving access to an integrated information base and allowing for the development of multiple scenarios, GIS can permit knowledge-based holistic decision-making in resource management (De Freitas and Tagliani 2009).

The use of GIS in marine resource management is relatively new. Marine GIS applications have primarily focused on spatial planning (or zoning) to promote the sustainable use of coastal and marine resources and to reduce space-use conflicts (Douvere et al. 2007). Some examples include: Australia's Great Barrier Reef Marine Park (Agardy 2010); the Florida Keys National Marine Sanctuary (http://floridakeys.noaa.gov/); the Eastern Scotian Shelf Management Initiative in

Canada (www.dfo-mpo.gc.ca); and the Provincial Resource Management Plan in the Philippines (Douvere et al. 2007). Within the Caribbean, GIS has been used to map marine habitats and determine management priorities in Barbados (Welch 2008) and has been applied to develop a draft marine zoning plan in St. Kitts and Nevis (Agostini et al. 2010). These examples have focused primarily on the utilisation of conventional scientific information with the goal of marine conservation and the reduction of space-use conflicts (Pattison et al. 2004, Douvere et al. 2007).

Constraints of GIS can be the unavailability of, or the cost of obtaining, comprehensive and reliable biophysical data (Balram et al. 2003). GIS also requires substantial finances to purchase software, computer hardware and acquire technical training; all of which may be beyond the capacity of many environmental managers (Lindenbaum 2006). Despite the inherent analytical power of GIS, its focus on spatial interpretation and modelling based primarily on a 'snapshot' of static biophysical information is often criticised. It is also recognised that many times conventional GIS discount the social and dynamic aspects of human space-use activities (St. Martin and Hall-Arber 2008). For these reasons the application of conventional GIS may not be entirely congruent with an EA.

1.4.7 Participatory geographic information system (PGIS)

An emerging development in the use of GIS technologies is the ‘participatory geographic information system’ (PGIS) approach, which has developed from the merger of geographic information technologies with participatory learning and action, and participatory rural appraisal methods (Chambers 2006, Corbett et al. 2006, Rambaldi et al. 2006). Promoting the participation of stakeholders in the development of a technical representation of spatial knowledge can allow for a comprehensive understanding of the social characteristics of natural resource use patterns (Quan et al. 2003, Aswani and Lauer 2006, Aswani and Vaccaro 2008). PGIS provides a framework for incorporating local knowledge and stakeholders’ perspectives in a GIS database alongside conventional biophysical and jurisdictional information (Calamia 1999, Corbett et al. 2006). This not only demonstrates the relevance of information provided by stakeholders, but also supports an EBM approach through the utilisation of multi-discipline and multi-knowledge information sources for management (Balram et al. 2003, Aswani and Lauer 2006, Corbett et al. 2006, Chambers 2006). A further tenet of a PGIS approach is that information can be displayed in a format which is understandable and accessible to stakeholders, facilitating equitability, transparency and collaboration in decision-making (Rambaldi et al. 2005, McCall 2006).

Strengthening the capacity of stakeholders through involvement in aspects of PGIS can increase their understanding and acceptance of management initiatives, and promote interactive governance (Aswani and Lauer 2006b, Chambers 2006, Corbett et al. 2006). Moreover, by broadening the information base for management, a PGIS approach can be of particular relevance in data-poor situations, typical of marine environments in developing nations (Johannes 1998, Berkes et al. 2001, Aswani and Vaccaro 2008, Lauer and Aswani 2008, De Freitas and Tagliani 2009), yet its implementation is still uncommon.

Ultimately a PGIS approach can contribute to interactive governance by strengthening the capacity of stakeholders within aspects of information generation, increased understanding and adaptive decision-making (Aswani and Lauer 2006b, Chambers 2006, Corbett et al. 2006, Carocci et al. 2009). Enabling easy and equitable access by stakeholders, as well as tailoring the technology and information produced to their capacity, can lead to the increased use of information and facilitate a more equitable, transparent and collaborative decision-making environment (Corbett et al. 2006). Thus, PGIS process can ameliorate the production of information, as well as support understanding amongst stakeholders and ownership of the information produced. Essentially, the concerted effort required to develop a PGIS may provide a practical approach to achieving interactive governance by providing a framework which: (a) fosters an equitable and inclusive environment; (b) strengthens capacity and legitimacy for collaboration; (c) aids the production of locally relevant information; and (d) allows access to a range of integrated multi-knowledge information. This in turn, can facilitate linkages across geographic and jurisdictional scales and among levels from the community to the governments of the counties making up the larger region involved in transboundary EBM of Caribbean marine resources.

PGIS is relatively new to marine resource management; yet applications have proven to be both functionally and socially successful. PGIS processes were used in part, to functionally assist in the design of the Seaflower Marine Park in the San Andres Archipelago of Columbia (Friedlander et al. 2003, Agardy 2010); Tortugas Ecological Reserve within the Florida Keys National Marine Sanctuary (Pomeroy and Douvere 2008); and in California under the Marine Life Protection Act to redesign the state's system of marine protected areas (Scholz et al. 2004, Agardy 2010). PGIS was used in Nicaragua to catalog reefs to support fishing right claims (Nietschmann 1995); in Bang Saphan Bay, Thailand to map fishing locations (Anchiracheeva et al. 2003); in Roviana Lagoon, Solomon Islands to map habitats and fishing patterns to design marine protected areas (Aswani and Lauer 2006b); and in the Patos Lagoon Estuary, Brazil to create a fisheries information database (De Freitas and Tagliani 2009). Within the Eastern Caribbean, the only known case of marine PGIS utilisation is within the participatory mapping project in Laborie Bay, St. Lucia within the Caribbean Natural Resources Institute's 'People and the Sea' Project. This project demonstrates the socially empowering benefits of PGIS; whereby the natural resource information base was developed through the integration of scientific and popular knowledge systems. The application of PGIS not only provided the production of comprehensive information, it strengthened the local capacity to address land-based sources of marine pollution (Smith 2003, Lindenbaum 2006, Smith A. personal communication 2006). These case studies support the multifaceted benefits of utilising PGIS; not only to allow for a better understanding of marine resources and human space-use patterns, but to support stakeholder empowerment and social capital by providing a framework for participation in governance and ecosystem-based MSPM. Notwithstanding this, these marine PGIS applications have been implemented either on a small geographical scale (i.e. bay) or have sought to collect specialised information (i.e. fisheries) and the feasibility of employing a multi-disciplinary marine PGIS across a transboundary scale is novel.

1.5 THE STUDY AREA

The study area is the Grenadine Island archipelago and the portion of the Grenada Bank upon which it lies (amid 13^{o} 04' - 12^{o} 14' N and 61^{o} 41' - 61^{o} 04' W) located between the main islands of Grenada and St. Vincent (Figure 1-1). The Grenadine Islands lie atop the Grenada Bank, an area of approximately 2,000 km^2 shared between the small island developing states of St. Vincent and the Grenadines in the north, and Grenada in the south (Figure 1-1). Seven of the inhabited Grenadine Islands (Bequia, Mustique, Canouan, Mayreau, Union, Palm and Petite St. Vincent) belong to St. Vincent and the Grenadines, and the remaining two (Carriacou and Petite Martinique) are a part of the tri-island state of Grenada. The study area includes the Grenadine Islands seascape and extends to the 60 metre depth contour of the Grenada Bank but does not include the mainland of St. Vincent or Grenada (Figure 1-1).

1.5.1 Physical environment

The Grenadine Islands provide a potential example of a complex transboundary marine management environment. The Grenadine Island seascape is recognised for its beautiful natural scenery consisting of rolling hills, spectacular beaches, clear blue waters and diverse marine habitats (ECNAMP 1980, CCA 1991a).

1.5.1.1 Geology

The island archipelago's geophysical formation resulted from tectonic plate subduction of the Caribbean and Atlantic plates and volcanic eruptions creating the island chain. Today volcanos are still active on the mainland St. Vincent and Grenada, as well as 'Kick'em Jenny', the only known active submarine volcano in the Lesser Antilles (CCA 1991a, CCA 1991b). Due to the geographical positioning of the islands on top of the Grenada Bank, they are more geologically related to Grenada than St. Vincent which is actually located approximately half a mile north of the bank and is separated from it by a deep channel (Howard 1952).

1.5.1.2 Marine habitats

Three quarters of the Grenada Bank is less than 50 m deep and supports the most extensive coral reefs and related habitats in the south-eastern Caribbean (CCA 1991a, CCA 1991b). In the Grenadine Islands all reef-related habitats are represented: seagrass and lagoon, areas of mangrove, and a variety of patch, fringing and bank barrier reefs (ECNAMP 1980, ECLAC 2004). These habitats provide many commercially important marine resources such as conch, lobster and reef fish as well as several ecosystem goods and services for the coastal communities of the Grenadine Islands.

1.5.1.3 Climate and vegetation

The Grenadine Islands lie in the path of the prevailing northeast trade winds, and experience a tropical maritime climate with a dry season from November to May and a rainy season from June to October (CIA 2011). Due to the low topography and small size of these islands, they experience very low levels of rainfall (sometimes as low as 460 mm per year), compared to 1700 mm on the St. Vincent mainland (Culzac-Wilson 2003) and 2500 mm on the Grenada mainland (Government of Grenada 2009). Howard (1952) describes the vegetation in the Grenadines as deciduous forests, mostly transforming into leafless forests during the dry season. The lack of ground water means that, the climate and vegetation control the availability of water to the local population which relies on storing rain water year round. Moreover, this has also led to a greater dependency on the sea for food and income than on the land (Jardine and Straker 2003).

1.5.2 Social environment

1.5.2.1 Historical context

The Grenadine Islands share similar cultural ancestry and histories. Amerindians were the initial settlers of the islands. The Arawak group was displaced by the Caribs (Kalinagas), who inhabited and defended the islands until the arrival of

European settlers in the early 1700s (Adams 2002). For years colonial possession of the Grenadines was fought over by France and Britain. During the 17th century the Grenadine Islands were dependencies of Grenada until Britain finally defeated the Amerindians in the 1790s (Adams 2002). During this time the chain of isles was divided into two for easier management: those islands to the north of and including Petit St. Vincent (PSV) were linked to St. Vincent, while Petite Martinique (PM) and Carriacou were attached to the Grenadian regime. The Grenadine Islands were distributed to individual European families and were privately owned until the 19th century. Today, only Mustique, Palm Island and Petit St. Vincent are privately owned resort islands (Logan 2001).

The early settlers of the Grenadines began exploiting their natural resources and building their economy based on agriculture. Small plantations were established by the Amerindians and British, and crops such as sugar, cotton, coconuts, cassava and potatoes were cultivated and exported (Adams 1996). Shepard (1831) reports thriving livestock agriculture in the Grenadines, with high quality horned cattle and sheep, but this industry and livelihood declined because of high livestock mortality during the dry season. Eventually, resource extraction shifted from the land and soil to the coast and sea (Clive 1976, Adams 1996). Farmers adopted a fishers' livelihood, they began fishing with modern fishing gear and boats, and were able to efficiently extract fishery resources offshore. Although tourism has now become the mainstay of the economy, fishing still plays a major role in generating income and providing employment for the Grenadine coastal communities (Adams 1996, FAO 2002, Baldwin et al. 2006).

1.5.2.2 Demographics

Ownership of the Grenadine Island chain is by two nations which share a similar population size and structure; based on the 2001 census St. Vincent and the Grenadines has a total estimated population of 103,869 and Grenada has a total estimated population of 108,419 (CIA 2011). Likewise, each country's Grenadine islands citizens make up less than 10% of the national populace (Table 1-2). Although the international boundary between Grenada and St. Vincent and the Grenadines runs east to west across the Grenada Bank between Petite Martinique and Petite St. Vincent, linkages among all of the Grenadine Islands are historically strong and continue to be active in the areas of fishing, informal trading, tourism and social life, with little attention to the jurisdictional boundary. Many people consider these connections among the people of the Grenadines to be stronger than connections with their respective mainland (SusGren 2005).

Table 1-2 The approximate land area and estimated resident population for each of the inhabited and resort Grenadine Islands listed by mainland country *(*Indicates resort island).*

Mainland country	Island	Area (km^2)	Population	Data source
St. Vincent	Bequia	16.1	4,420	Susgren (2005)
& the Grenadines	Mustique	5.6	1,290	
	Canouan	7.5	1,830	
	Mayreau	1.8	170	
	Union I.	8.6	1,900	
	Palm I.*	0.4	4	
	Petit St. Vincent*	0.4	40	
Grenada	Petit Martinique	2.1	800	OECS (2005)
	Carriacou	32.0	6,081	
Total		**74.5**	**17,371**	

1.5.2.3 Island profiles

A brief profile of each of the nine inhabited or resort Grenadine islands (Figure 1-1) is given in the following section. Relevant marine and coastal histories and a description of existing infrastructure aim to provide a better understanding of the local context of each Grenadine island with respect to the dependency on coastal and marine resources.

Bequia

At 16.1 km^2 Bequia, meaning ‘island of the clouds’ in Arawak, is the most northerly and second largest of the Grenadine islands (Table 1-2, Figure 1-1). There is a small airport and four main settlements (Figure 1-2). Port Elizabeth is the island’s main seaport with a long history of exportation of sugar, limes, molasses and cotton (Shepard 1831). Some of the earliest settlers were shipwrights and carpenters, thus maritime activities such as boat building and sea faring are a rich part of Bequia's heritage and continue to be active today (Adams 1996). Port Elizabeth, is located in Admiralty Bay, is the main ferry terminal and is very popular with visiting yachts due to the large sheltered anchorage, marine services, a yacht charter company and a lively yachting community (ECLAC 2004). Accordingly a number of bars, restaurants, hotels, grocery stores, day tour operators, water-taxi operators, two dive shops and a vegetable and fish market are located in Port Elizabeth.

Whaling is also an important cultural, and at one time also an important economic activity, for the island (Adams 1971). The first whaling station was built in the 1870s by William Wallace Junior in Friendship. At this time whale oil was ranked fourth nationally in value of exports. Bequia is one of the few places in the world where whaling is still allowed today by the International Whaling Commission. Natives of Bequia are allowed to catch up to four humpback whales each year using only traditional hunting methods of harpoons in small double-ender boats (FAO 2002). Whale meat is a staple food for many Bequians and whale bones are used in furniture, trophies and as part of home and building décor (Adams 1971).

Paget Farm is the most active fishing village in Bequia as well as the largest fish landing site in the entire Grenadine Island chain. There are also a number of smaller landing sites located in Port Elizabeth, Lower Bay, La Pompe and Friendship Bay. In 1994 the Japanese funded the construction of a large fishing complex in Paget Farm with facilities for storage and cleaning, an ice machine, offices and a research laboratory. There is also a built-in desalination plant which is necessary to operate such a large facility in a water scarce island. Despite the presence of this infrastructure, the complex was not utilised until recently (2005) due to the high operational cost. Presently a part of the facilities are leased to a local export company called Grenadine Seafood Distributors. To allow for the export of live lobster, there are two lobster pools built next to the fishing boat ramp in Paget Farm. Each is approximately 13 cubic metres and operated by local fishers. A Barbadian importer purchases the majority of these live lobsters.

Figure 1-2An aerial view of Bequia and its major settlements (Google Earth 2012).

Mustique

The second in the chain of Grenadine islands from north to south, is the 5.6 km^2 private island of Mustique (Table 1-2, Figure 1-1). In 1958 the island was purchased for US $67,500 by Lord Glenconner, under a development agreement with the government to encourage tourism and the building of private homes on the island (Mustique Company 2011). In 1968‘The Mustique Company Limited Act’ was passed into law which appointed The Mustique Company as custodian of the island. The Mustique Company has declared a no-fishing marine conservation zone that surrounds the entire island of Mustique and extends 1 km offshore.

Today the island is owned and managed by the Mustique Company, in which the 100 homeowners make up the island’s shareholders (Mustique Company 2011). Britannia Bay is a popular yacht anchorage with a limited number (25) of moorings for rent. The Mustique Company also operates the airport, the desalination plant, the cargo and passenger ferries, the water-sports and dive shop, and sport-fishing day trips. A fishing complex is located in Britannia Bay (Figure 1-3) and is owned and operated by The Mustique Company which buys fish from the fishers and sells to tourists and private houses on the island. Here fishers are provided with living quarters and other infrastructure such as a fish processing area, refrigerators for chilled storage, desalination equipment, SCUBA tank compressor and a boat haul-out site. The majority of fishers operating in Mustique are from Paget Farm, Bequia.

Figure 1-3 An aerial view of Mustique and its main bays (Google Earth 2012).

Canouan

Approximately 40.2 km south of St. Vincent is the 7.5 km^2 island of Canouan, the Carib word for 'turtle' (Rovati and Gerbert 1999) (Table 1-2, Figure 1-1). In the 19^{th} century, two whaling stations were established on the island after the British shipwright Benjamin George Compton was invited to teach boat building techniques. These boats were the basis for the whaling trade in the Grenadines although it was dominated by Bequia (Adams 1971).

Since the 1990s when 3.2 km^2 of the island was sold to an Italian group, the Canouan Resorts Development Limited, Canouan has been heavily dependent on tourism. Since that time, a luxury hotel and spa equipped with a casino, golf course, desalination plant and private villas have been developed in the north of the island. The 'Moorings' yacht charter base is also located in Grand Bay, Canouan, and offers a number of yachting-related amenities including waterfront gas, water and ice services. Furthermore, Canouan is the only Grenadine Island which hosts an airport large enough for jets to land.

There are two main fish landing sites in Canouan: Grand Bay and the fisheries complex and camp located in Friendship Bay (Figure 1-4). Constructed with support from the Japanese government in the 1990s, this fisheries complex is currently operated by the St. Vincent and the Grenadines Government. Similar to Mustique, this complex consists of living quarters and other infrastructure such as a SCUBA tank compressor, locker facilities, refrigerators for cold storage and desalination equipment. Likewise, almost all the fishers that utilise this complex are from Paget Farm, Bequia.

Figure 1-4An aerial view of Canouan and its major settlements (Google Earth 2012).

Mayreau

At 1.8 km^2, Mayreau is the smallest of the inhabited islands and has the smallest community (Table 1-2, Figure 1-1). The entire island of Mayreau is situated within the boundary of the Tobago Cays Marine Park (TCMP). This island consists of one concrete road and one village (Old Wall), located on the hilltop on the southwest of the island (Figure 1-5).

Mayreau's community depends primarily on fishing and tourism for sustenance. In the north of the island, Salt Whistle Bay is a calm leeward bay which is home to a small resort and is one of the most popular anchorages for yachts travelling to the Tobago Cays. There is a small hotel and a number of bars, restaurants and shops located in the village. Although there are two small fish landing sites, located in Salt Whistle Bay and Saline Bay, fishers here have few options to sell on the island and rely on selling to yachts in the TCMP and to the trading vessels (Staskiewicz and Mahon 2007). Recently, a large portion of this island was sold to private investors for tourism development and there is a plan to build a resort, desalination plant, marina and a number of private villas in the near future.

Figure 1-5An aerial of Mayreau, its village and major settlements (Google Earth 2012).

Union Island

Union Island is a dry 8.6 km^2 island located midway between mainland St. Vincent and Grenada (Table 1-2, Figure 1-1). There are two main settlements on the island (Figure 1-6). Fishing was the major economic activity around the mid twentieth century (Mohammed et al. 2003, Daudin 2005). Presently tourism is a significant contributor to the economy of Union Island. Clifton is the tourism centre of the island with several stores, fruit and vegetable markets, most of the hotels, restaurants, bars, the airport and other amenities. Many yachts frequent Clifton Harbour for provisions and the island hosts the highest population of water taxi operators in the Grenadine Islands (Cooke et al. 2005). Daily flights bring tourists to transfer to the nearby private resort islands of Palm and Petit St. Vincent. Ashton, a more rural fishing town, is located in the south of the island.

Ashton is the main fishing village in Union Island, although a smaller fish landing site is located in Clifton (Figure 1-6). In 1994 the Japanese supported the construction of a fishery complex in Clifton similar to the facility in Bequia. Although this facility is more than adequate to cope with current fish landings, the operational costs are too high for the government and the facility is not currently utilised. As a result, fishers in Union Island complain of not having enough fishing amenities available to them and rely on selling to the trading vessels (Gill et al. 2007).

Figure 1-6An aerial view of Union Island and its two main settlements (Google Earth 2012).

Palm Island

Palm Island is a small (0.4 km^2) private resort island originally known as Prune Island (Table 1-2, Figure 1-1). Despite the allure of its sandy beaches, it was uninhabited and was dominated by swampland in its low-lying interior until 1966. At this time, the island was leased by John and Mary Caldwell for 99 years from the St. Vincent Colonial Government (Day 1989). The sodden interior was reclaimed by infilling and planting of coconut palms and fittingly Prune Island became Palm Island. The couple constructed a 10 room hotel called the Palm Island Beach Club which they ran for 30 years (Day 1989). Today there are a small number of private homes and the hotel which in 1996 was redeveloped into Palm Island Resort, an exclusive 43-room resort (Figure 1-7). Palm Island Resort also operates a desalination plant, greenhouse, two passenger ferries and a number of non-motorized water sports.

Figure 1-7An aerial view of Palm Island (Google Earth 2012).

Petit St. Vincent

Petit St. Vincent (PSV) is also 0.4 km^2 in size and was uninhabited before being purchased by a small group of sailors in 1963 (Table 1-2, Figure 1-1). In 1966 one of the sailors, Haze Richardson, and his wife returned to the island and began clearing the land. They built a small 22 cottage hotel that has now become one of the leading small hotel resorts in the world (SVG Tourism 2011). Similar to Palm Island, PSV has a desalination plant, a small jetty for its passenger and staff ferries and visiting yachts, and a water sports shop (Figure 1-8).

Figure 1-8An aerial view of Petit St. Vincent (Google Earth 2012).

Petite Martinique

Roughly 0.4 km south of the political boundary between St. Vincent and the Grenadines and Grenada and three km east of Carriacou, lies Petite Martinique (PM), a small 2.3 km^2 volcanic dome island (Table 1-2, Figure 1-1). In the early 1700s Mr. Pierre, left the island of Martinique in search of new fertile lands to plant his crops. When he came to the uninhabited island of Petite Martinique, he made it his home (Logan 2001). Today the island hosts one small village, Sanchez, with a population of approximately 800. Despite its small geographic size, the island has a bank, gas and ice facilities, a number of stores and restaurants, two guest houses and a primary school. There are two school ferries and twice-daily passenger ferry service to the neighbouring islands of Carriacou and mainland Grenada.

With the migration of Scottish and Irish shipwrights to the island in the 18th century, fishing and boat-building became, and remain to this day, the basis for both cultural and economic activities on the island (Logan 2001). The majority of demersal fish species caught around PM are exported by trading vessels to French Martinique with which ties and linkages since the days of their initial settlers remain intact today (Chakallal 1994).

In the past two decades, many fishers have become involved in commercial long line or tuna fishing in Grenada (Mohammed and Rennie 2003). The catch is sold to buyers on the mainland and then exported to the United States and the European Union (Logan 2001). Unlike the other inhabited Grenadine Islands, this island has a relatively small amount of tourism development to date.

Figure 1-9An aerial view of Petite Martinique and its main settlement (Google Earth 2012).

Carriacou

At 32 km^2 Carriacou, has a population of approximately 6,000 and is the largest of the Grenadine Islands (Table 1-2, Figure 1-1). Based on the many discoveries of pottery and tool artefacts, it is believed that Arawaks settled on the island and remained until around 1000 AD when Caribs were known to be living on the island. The earliest written records go back to 1656, when the name was spelled 'Kayryouacou,' originating from the Carib language meaning 'land surrounded by reef.' In 1756 the British began cultivating cotton as well as some sugar, indigo, coffee, limes and cocoa, but now only a few farmers grow small crops for their own consumption (Petit Martinique and Carriacou Tourism Association 2010).

Carriacou is considered to be the epicenter of a boating culture that has produced numerous master boat builders. Similar to PM, the village of Windward was home to a group of European settlers from Scotland and Ireland, who began the traditional boat building culture which is still observed today. Many Carriacou built wooden boats, from small fishing sloops to large trading schooners, can still be seen today sailing the Grenadine and Wider Caribbean waters.

The five major villages of Hillsborough, L'Esterre, Harvey Vale, Belmont and Windward, also coincide with the main fishing communities on the island (Figure 1-10). Hillsborough is the largest village and functions as the capital of both

Carriacou and the neighbouring isle of Petite Martinique. Despite this, there is only one gas station and the only fisheries infrastructure is the newly constructed (2010) Hillsborough fish market equipped with an ice maker and small-scale fish processing and storage facilities. Tyrell Bay, is located in Harvey Vale, is a favourite anchorage for visiting yachts. Here are small scale marine services and yachting facilities (e.g. haul-out and boat yard) as well as a limited number of stores, bars and restaurants.

Figure 1-10An aerial view of Carriacou and its major villages (Google Earth 2012).

1.5.3 Livelihood environment

As the Grenadines are an archipelago with a strong maritime culture, marine transportation historically has been and remains today an indispensable livelihood. Ships, ferries and water-taxis are fundamental to the movement of cargo and passengers, and comprise a substantial portion of the total transportation sector (Clive 1976, Adams 1996, Cooke et al. 2007). Marine-based tourism is a key sector for employment and revenue and tourism development is proceeding apace with the number of visitors to the Grenadines increasing steadily in recent years (ECLAC 2004, CTO 2010). The marine-based tourism sector includes onshore accommodation and restaurants (resorts, hotels, guesthouses, rental villas), ferries, cruise-ships and yachts (including bareboat, charter and live-aboard cruisers), and recreation/entertainment (water-sports including SCUBA and snorkel trips, sport-fishing, day boat charters). Fishing is the other main source of employment and livelihood (CCA 1991a, CCA 1991b). Fisheries resources consist of shallow-shelf reef fishes and deep-water (slope and bank) demersal fishes, lobsters, conchs, coastal pelagics, offshore pelagics and sea turtles (Mahon 1990, Gill et al. 2006). Fisheries in the Grenadines are small-scale, with fishers typically operating independently without formal organisations, such as cooperatives or associations (Chakalall et al. 1994, Staskiewicz and Mahon

2007). SusGren has made attempts to assist fishers in organisational efforts, and the fishers from Ashton, Union Island have recently formed a small cooperative. The picturesque and biodiverse marine ecosystem, entwined with a rich maritime culture, has cultivated the belief that the entire Grenadine archipelago should be declared a World Heritage Conservation Site (Mahon et al. 2004, SusGren 2010).

1.5.3.1 Fisheries sector

The following section provides a brief overview of the Grenadine fishing sector. The relevant fishing resources, gears and vessels are provided to give insight on the Grenadine fishing livelihood.

Fishery resources

Exploited fisheries resources consist of demersals (including shallow-shelf reef fishes, deep-water slope and bank fishes, lobsters and conchs), and inshore and offshore pelagic species (including robins, jacks, dolphinfish, barracuda, tunas and sea turtles) (Adams 1970, Adams 1972, Mahon 1990). An annotated list of target species for Grenadine Island fishers is given in Box 1 and is based on information given by the Fisheries Divisions of St. Vincent and the Grenadines and Grenada.

Fishing techniques

Fishing in both the St. Vincent and the Grenada Grenadines is primarily small-scale artisanal, where multiple fishing techniques and gears target a number of fish and shellfish species (Morris 1983, FAO 2002, FAO 2007). As a result, few fishers specialise in and carry out only one type of fishing method (Gill et al. 2007). The gear consists mainly of fish traps, spear guns, SCUBA, handlines, trolling lines, gill nets, beach seines and longlines (Chakalall et al. 1994, Gill et al. 2007). The following section provides a brief description of the seven main fishing gears and techniques commonly utilised by fishers in the Grenadines.

Box 1. Main fishery resources of the Grenadine Islands.

Demersals

Major species:	Hinds, groupers, butterfish (Serranidae spp.), snappers (Lutjanidae spp.), parrotfish (Scaridae spp.)
Description/ Habitat:	Bottom dwelling; found on shallow shelf, and the deep slope
Fishing method/ Gear used:	Hand-line, bottom long-lining (sinking palang), traps, spear gun (free diving and SCUBA)
Seasonality:	All year

Offshore pelagics

Major species:	Dolphinfish *(Coryphaena hippurus)*,yellowfin tuna (*Thunnus albacares*) kingfish (*Scomberomorus cavalla)*, barracuda (*Sphynaena spp*)
Description/ Habitat:	Migratory species; found miles offshore in open water
Fishing method/ Gear used:	Towing, surface long-lining (floating palang)
Seasonality:	All year, mostly January to May/June

Inshore pelagics

Major species:	Robins *(Decapterus* sp.*)*, jacks (*Carangidae*)
Description/ Habitat:	Pelagic; found along the coastline
Fishing method/ Gear used:	Beach seine, cast net
Seasonality:	All year

Lobster

Major species: Caribbean spiny lobster (*Palinuris argus*)
Description/ Habitat: Benthic; found in reef crevices on shallow shelf areas
Fishing method/ Gear used: SCUBA and free diving using wire nooses ("jigs"), traps, gillnets
Seasonality: September-April

Conch

Major species: Queen conch (*Strombus gigas*), milk conch (*Strombus costatus*).
Description/ Habitat: Benthic; found mainly in seagrass beds and algal hard bottom areas
Fishing method/ Gear used: SCUBA and free diving
Seasonality: All year (fished mainly opportunistically)

Turtles

Major species: Hawksbill turtle (*Eretmochelys imbricata*), green turtle (*Chelonia mydas*)
Description/ Habitat: Pelagic and migratory; green turtles found on seagrass beds, hawksbills on reef
Fishing method/ Gear used: Spear, by hand when onshore while nesting
Seasonality: September – May(closed season)

Hand lining for demersals is by far the most widely practiced fishing technique in the Grenadines (Chakalall et al.1994, Gill et al. 2007). This technique involves the use of a long monofilament line, hooks, weights and bait (Chakalall et al. 1994). The major target species are parrotfishes, hinds and groupers on the shallow shelf and groupers and snappers on the deep slope (FAO 2007). Hand lining can be done solitarily or with a small crew aboard a bow and stern boat.

Fish traps or “pots” are also popular and are constructed of hexagonal wire 3.8 cm (1 ½ in) mesh on wooden frames and set on shallow reefs or on deeper slopes (Chakalall et al. 1994). Soak time can range from 3-7 days and a large variety of demersal species are caught (Gill et al. 2007). This fishery is exploited all year round and effort increases in May–August which is likely due to the closure of the lobster season (Staskiewicz and Mahon 2007). Many fishers have to replace or purchase new traps every year due to corrosion, damage, misplacement or theft. Specialised metal frame traps have recently been introduced for harvesting lobsters.

Trolling or “towing” involves the use of one or more long monofilament lines with hooks and bait (Chakalall et al. 1994). Small multi-purpose vessels are driven with the line towing behind to catch large offshore pelagic species such as tuna, wahoo and billfish (FAO 2002). This is also a common fishing technique for recreational fishers targeting these species. Small inshore pelagics, such as jacks, robins and ballyhoo, are the bait of choice for this trolling technique. This can be done solitarily or with a small crew. Some of these pelagic species are also caught incidentally by shallow shelf and deep slope fishers travelling to and from their fishing grounds (FAO 2002).

The seine fishery is important in the Grenadines and is reported as the most favoured fishery for consumption in St. Vincent and the Grenadines (Jardine and Straker 2003). This fishery targets the small inshore schooling pelagic species such as jacks and robins and is caught using wooden double ender boats. Boats surround schools in bays using a large net which has floats and a lead line so as to span the water column (Ryan 1999, McConney 2003). Divers beat the water to prevent the school from escaping the open mouth of the net which is slowly brought to a close and harvested.

Surface gill nets are small nets used to target schools of pelagic species (Chakalall et al. 1994). They are made of thin monofilament nylon which is hardly visible to the fish. Trammel nets, which are now illegal in both Grenada and St. Vincent and the Grenadines, are similar to gill nets but consist of three panels of different mesh size (McConney 2003). Gill nets have a float and lead line which span the water column and are soaked for about 18-24 hours. An alternate use of gill nets is for lobster fishing. Nets are set near the bottom of the seafloor for an extended period of time in which trapped fish die and decay to attract lobsters (McConney 2003). This type of entanglement net is very unselective, and catches many unwanted species leading to large quantities of by-catch.

Long-lining (or multi-hook fishing) varies from the homemade palang to mechanised longlining with hydraulic pulley systems. Many of the Southern Grenadine fishers are involved in the Grenada commercial subsurface pelagic longline fishery using kilometres of line and multiple hooks off a larger sloop vessel. The smaller vessels in the other islands use homemade multi-hook (300-400) palang gear. Surface or “floating” palang is set high in the water column targeting offshore pelagic species. Bottom or “sinking” palang targets demersals, and are sometimes placed vertically along shelf slopes or along the edge of banks (Chakalall et al. 1994).

Spear guns are used by divers extensively throughout the Grenadines, particularly by younger fishers (Gill et al. 2007). Free diving fishers can descend to depths of 10-20 m, whereas SCUBA diving fishers descend much deeper (e.g. 20-40 m). These fishers work in teams with an average crew size of 4-6 fishers per boat (Chakalall et al. 1994). Divers use a small wire noose to snare lobsters, a basket to collect conch, and short monofilament line to carry speared fish.

The fisheries of the Grenadines are pursued by a variety of vessel types. Fishing boats of the Grenadines are not generally fishery specific and are used in multiple fisheries (Chakalall et al. 1994) and other purposes including transportation and tourism (Cooke et al. 2007). There are four common types of Grenadine fishing boats; basic descriptions for each are given in Box 2. The most common boat type is the small wooden and fibreglass coated 'bow and stern' known locally as a cigarette speedboat (Gill et al. 2007). Less common are pirogues, double-enders, sloops, and modified speed boats.

Trading vessels regular visit bays around the Grenadines and fishers sell their catch directly to these boats for export to Martinique (Jardine and Straker 2003). Trading vessels are usually sloops with a mast approximately 12-20 m in length and are driven by a small inboard engine (Chakalall et al. 1994). These vessels usually spend most of their time in anchored in the Grenadines purchasing fish and take 3-5 days to travel and unload their cargo in Martinique. Currently, there are a total of 7 trading vessels operating in the Grenadines, most of which operate out of PM and Carriacou (Gill et al. 2007).

Box 2. Common types of fishing vessels used in the Grenadine Islands.

Bow and Stern (Cigarette/Speedboat)

Description:	Pointed bow and flat stern
Length range:	3.4-8.2 m (11-27 ft)
Width range:	0.9-2.1 m (3-7 ft)
Horsepower range:	14-115 hp
Type of fishing:	Handline, trolling, floating and sinking palang, traps, spear

Pirogue

Description:	Higher bow than the speedboat
Length range:	5.8-9.1 m (19-30 ft)
Width range:	1.2-3.0 m (4-10 ft)
Horsepower range:	40-85 hp
Type of fishing:	Trolling & demersals fishery

Double ender

Description:	Two bows, canoe-shaped
Length range:	3.0-8.8 m (10-29 ft)
Width range:	1.2-2.4 m (4-8 ft)
Horsepower range:	6-48 hp (Mainly oars)
Type of fishing:	Beach seine fishery

Sloop/Longliner

Description:	Most have mechanical equipment for hauling lines
Length range:	10.6-14.8 m (34.7-48.5 ft)
Width range:	2.9-4.8 m (9.7-15.9 ft)
Horsepower range:	90-190 hp (inboard diesel engine)
Type of fishing:	Surface longlining, trolling, and bottom longlining

Despite the relatively small number of boats, a large proportion of fish landed in the Grenadines is sold directly to trading vessels. In the period of 1996-2000, 13.1% of the annual landings (or 118.6 tons) in St Vincent and the Grenadines was reported to be sold directly to trading vessels (Jardine and Straker 2003). In PM, 98% of all the fish caught are reportedly exported to Martinique (Logan 2001) mostly by trading vessels.

Current status of Grenada Bank fisheries

As seen throughout the Caribbean, overfishing on the Grenada Bank has depleted many of the fish stocks, particularly conch, lobster and reef fish species (Finlay 1999, Ginsberg 1994, Jardine and Straker 2003, Mohammed et al. 2003). Other factors impacting fish stocks include habitat loss due to development and associated pollution (Price and Price 1998) and illegal fishing from other Caribbean and foreign vessels (Jardine and Straker 2003). As the fishing industry in the Grenadines is multispecies and lacks detailed landing and effort data, it is difficult to determine the sustainable yield of each species or species group (Chakalall et al. 1994). However, available scientific data (Mahon 1990, Mohammed *et al*. 2003, FAO 2007) as well as anecdotal reports all indicate that demersals have been harvested beyond sustainable yield for many years. Likewise, the most highly priced fish species in the Grenadines, the Caribbean spiny lobster, has been fully or over-exploited in the Grenadines (Finlay 1999, FAO 2002, McConney 2003, FAO 2007). The export of queen conch declined in the 1980s, and was subsequently linked to overfishing (Mohammed et al. 2003). The West Indian sea urchin was harvested in the Grenada Grenadines so heavily that in 1995 the fishery was closed (Finlay 1999) and remains so today. In response, both governments are trying to promote the exploitation of the deep slope demersal and offshore pelagic fisheries (Finlay 1999, Mohammed and Rennie 2003, FAO 2002).

1.5.3.2 Tourism sector

Tourism is the driving force for the economy of many Caribbean islands and has increasingly become part of the Grenadine economy (SVG Statistical Office 2001, CTO 2010). Over the past 25 years, tourism has significantly impacted the livelihoods of the Grenadine people; in particular marine-based tourism which provides a key sector for employment. In 1985 St. Vincent and the Grenadines saw a change where the majority of tourist arrivals shifted from the mainland to the Grenadines (CCA 1991a). By 2009, over 70% of visitors to each country were reported to have arrived by sea (CTO 2010) (Table 1-3). The favourable location, good conditions and picturesque scenery of the Tobago Cays in particular, attracts sailors from around the world; an estimated 84% of yachts visiting the Grenadines make a stopover there (ECLAC 2004). In the 1990s, the advent of a tourism boom attracted many people away from fishing in the Grenadines into tourism-related job opportunities such as construction and the hospitality industry (Chakalall et al.

1994). As a result, tourism now provides a large amount of foreign exchange, employment and additional revenue from tourist taxes and expenditure for both countries (ECLAC 2004, CTO 2010).

Table 1-3 Summary of visitor arrivals in St. Vincent and the Grenadines and Grenada in 2009; shown separately by country and by mode of arrival.

		By Air		By Sea			
Country	Number visitors	Visitors	Percent of total visitors	Visitors	Percent of total visitors	Yacht visitors	Cruise ship visitors
St. Vincent and the Grenadines*	270,952	80,631	30	190,321	70	40,859	149,462
Grenada, Carriacou and Petit Martinique**	459,574	112,639	25	346,935	75	4,083	342,852
Overall	730,526	193,270	26	537,256	74	44,942	492,314

*Data Source: * SVG Tourism Authority (2010) ** Grenada Tourism Authority (2010)*

1.5.4 Economic environment

According to the 2010 United Nations Human Development Index (HDI), both the tri-island state of Grenada and St. Vincent and the Grenadines are considered to be developing countries. Grenada's per capita Gross National Income (GNI) is $9,890 USD and St. Vincent and the Grenadines per capita GNI is $10,830 USD over the period of 1980 - 2011. Of the 175 listed developing countries, the country of Grenada is ranked 66th, with a HDI of 0.787, and the country of St. Vincent and the Grenadines is ranked 85th, with a HDI of 0.717 (Human Development Report 2010).

1.5.4.1 Economic value of fisheries

According to Jardine and Straker (2003), fish landings are about 1,134 tonnes annually and the contribution of fishing to the St. Vincent and the Grenadines' annual Gross Domestic Product (GDP) was 1.7%. Yet while seemingly insignificant, fishing is actually worth more than this value suggests as GDP calculations do not take into account the importance of fishing as a source of employment or its contribution to food security and to other sectors such as tourism (Kirby-Straker 2003). Fish is also a valuable trade commodity: total exports from St. Vincent and the Grenadines in 2000 amounted to 175 tonnes with a value of approximately US $1 million. Lobster and tuna are extremely important export species representing 75% of St. Vincent and the Grenadines' total export value (FAO 2002). In 2002 it was recorded that 80% of shallow-shelf demersal fish species were delivered to trading vessels for export to neighbouring islands such as Martinique (Kirby-Straker 2003). Despite this, imported fish that are usually processed and/or canned surpassed the export market for 2000 in both weight (300 tonnes) and value (US $1.1 million) (FAO 2002).

From 2002 to 2006, the contribution of fishing to the tri-island state of Grenada, Petite Martinique and Carriacou's annual GDP was 2.5% (FAO 2007). Approximately 18% of landings occur in Carriacou and Petite Martinique, with 30% of exports (mainly demersal species) going to French Martinique (FAO

2007). In 2010 Johnson St. Louis (personal communication), Senior Fisheries Officer, Grenada Fisheries Division announced the importance of the fishing sector to the national economy, reporting that in the past five years fishermen of Carriacou and Petite Martinique landed a total of 1,841 tonnes of fish with a local market value estimated at over US $10 million. Unlike St. Vincent and the Grenadines, revenue from fish exports from the Grenada Grenadines exceeds the value of fish imports. Exports in 2006 were approximately 738 tonnes (valued at US $3.7 million), while imports totalled 2,360 tonnes (valued at US $2.5 million). These facts make the fisheries sector one of the few positive performers within the Ministry of Agriculture.

1.5.4.2 Economic value of tourism

In 2009, tourism contributed 1.9% to the GDP of St. Vincent and the Grenadines, with a total visitor expenditure of US $96 million (CTO 2010). The total number of visitor arrivals in St. Vincent and the Grenadines during 2009 was 270,952, of which 70%arrived by sea (Table 1-3). Of all visitor arrivals by sea, 79% were cruise ship passengers and21% (40,859) was reported to be aboard a yacht (CTO 2010). Conversely, in 2009 tourism contributed 8.6% to the GDP of Grenada with a total visitor expenditure of US $99.1 million (CTO 2010). The total number of visitor arrivals in Grenada during 2009 was 459,574, of which 75%arrived by sea

(Table 1-2). Of all visitor arrivals by sea, 99% were cruise ship passengers and1% (4,083) was reported to be aboard a yacht (CTO 2010).

Careful consideration should be given to these national tourism statistics with regard to the distribution of tourist arrivals from yacht calls as compared to cruise ships. It is recognised within each country that the mainland receives a substantial proportion of cruise ship arrivals; whereas visiting yachts tend to spend the majority of their stay frequenting anchorages located in the Grenadine Islands. Therefore the number of yacht calls provides a better indicator of the economic importance of marine-based tourism within the Grenadine Islands. Thus there are a larger proportion of marine-based tourists entering the Grenadines through St. Vincent and the Grenadines with 10 times the number of yacht arrivals as compared to Grenada.

1.5.5 Legal environment

Although St. Vincent and the Grenadines and Grenada have different government structures, their legal systems are similar. Nationally, their executive branches of government are virtually the same, and both of the nation's legal systems are based on English Common Law. Both states are members of many of the same international and regional organisations, including the Commonwealth of Nations and the Organisation of the Eastern Caribbean States (OECS) (see Table 1-4 for summary).

Table 1-4 Membership to international and regional environmental agreements and organisations which require cooperation among member states. Shown separately for St. Vincent & the Grenadines (SVG); and Grenada (GND).

International Cooperative Organisations	**SVG**	**GND**
African, Caribbean, and Pacific Group of States (ACP Group)	X	X
Alliance of Small Island States (AOSIS)	X	X
Commonwealth of Nations	X	X
Food and Agriculture Organisation (FAO)	X	X
Group of 77 (G-77)	X	X
International Bank for Reconstruction and Development (IBRD)	X	X
International Criminal Police Organization (Interpol)	X	X
International Maritime Organization (IMO)	X	X
Nonaligned Movement (NAM)	X	X
United Nations (UN)	X	X
United Nations Development and Environment Program (UNDEP)	X	X
United Nations Educational Scientific and Cultural Organization (UNESCO)	X	X
Regional and Sub-Regional Environmental Organisations	**SVG**	**GND**
Association of Caribbean States (ACS) - Caribbean Sea Commission	X	X
Caribbean Community (CARICOM)	X	X
Caribbean Development Bank (CDB)	X	X
Caribbean Environmental Programme (CEP)	X	X
Caribbean Large Marine Ecosystem Project (CLME)	X	X
Caribbean Regional Fisheries Mechanism (CRFM)	X	X
Integrating Watershed and Coastal Area Management (IWCAM) in the Small Island Developing States of the Caribbean	X	X
Intergovernmental Oceanographic Sub-commission for the Caribbean and Adjacent Regions (IOCARIBE)	X	X
Organization of American States (OAS)	X	X
Organization of Eastern Caribbean States (OECS)	X	X
The International Commission for the Conservation of Atlantic Tunas (ICCAT)	X	X
Western Central Atlantic Fishing Area (WECAF)	X	X

X – Indicates member

Likewise, both countries are member of many of the same international and regional environmental conventions. St. Vincent and the Grenadines is a signatory to 5 and a party to 45 international agreements, whereas Grenada is a signatory to 4 and a party to 46 international agreements, directly or indirectly related to environmental issues (Gardner 2006, 2007). Key environmental agreements in regards to the coastal marine environment are listed in Table 1-5. A number of these international treaties and multilateral environmental agreements (e.g. the Convention of Biological Diversity, the Code of Conduct for Responsible Fisheries) and the World Summit on Sustainable Development targets as well as regional and sub-regional umbrella agreements (e.g. the Convention for the Protection and Development of the Marine Environment in the Wider Caribbean Region, the St. Georges Declaration of Principles for Environmental Sustainability in the OECS) speak directly to the need for an EBM approach.In accordance with their international, regional and sub-regional obligations, both countries have committed to work together to develop sub-regional legislation (e.g. the OECS Harmonized Fisheries Act, the OECS Biodiversity Conservation and Sustainable Use Act,) to allow for ecosystem-based transboundary management of natural resources.

Table 1-5 International and regional environmental agreements and organisations which require cooperation among member states. (SVG - St. Vincent& the Grenadines; GND - Grenada)

International Treaties and Multilateral Environmental Agreements	SVG	GND
Convention on Biological Diversity	X	X
Convention on Climate Change	X	X
Convention on the Law of the Sea	X	X
Convention for the Prevention of Pollution from Ships (MARPOL)	X	-
Convention on Protection of World Cultural and Natural Heritage	X	X
Convention on International Trade in Endangered Species	X	X
Convention on Transboundary Movement of Hazardous Waste and their Disposal (Basel Convention)	X	-
Convention on Civil Liability for Oil Pollution Damage	X	X
The FAO International Code of Conduct for Responsible Fisheries	X	X
The Millennium Development Goals	X	X
Regional and Sub Regional Environmental Agreements	**SVG**	**GND**
St. George's Declaration of Principles for Environmental Sustainability and National Environmental Management Strategy for the OECS	X	X
Barbados Plan of Action for the Sustainable Development of Small Island Developing States	X	X
The Cartagena Convention for the Protection and Development of the Marine Environment of the Wider Caribbean and its Specially Protected Areas and Wildlife (SPAW) Protocol	X	X
The Cartagena Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region and its Oil Spills Protocol	X	X

X – Indicates party to *- Indicates not party to*

1.5.5.1 St. Vincent and the Grenadines system of government

St. Vincent and the Grenadines gained independence from the United Kingdom on the 27th October 1979 and is an independent sovereign state within the Commonwealth. St. Vincent and the Grenadines is a constitutional monarchy and unicameral parliamentary democracy. There are three branches of Government: the Executive, Legislative and Judicial. In the Executive branch, Queen Elizabeth II is the hereditary Chief of State and is represented by the Governor General. The

Prime Minister is the Head of Government as well as the leader of the majority party and is appointed by the Governor General after legislative elections. Based on the advice of the Prime Minister, a Deputy Prime Minister and the nine members of Cabinet are appointed by the Governor General.

In the Legislative branch of government, St. Vincent and the Grenadines has a unicameral House of Assembly consisting of 21 seats. Fifteen are elected representatives from single member constituencies and six are appointed senators; four on the advice of the Prime Minister, and the remaining two by the leader of the opposition to serve five year terms.

The Judicial branch of government is divided into three districts, each with its own magistrate's court. The St. Vincent and the Grenadines Constitution was established in 1979, and makes provision for the sharing of courts. The Eastern Caribbean Supreme Court was created in 1967, is a member of the Caribbean Court of Justice, and is the superior court of record with unlimited jurisdiction in Grenada, St. Vincent and the Grenadines, as well as in other OECS Countries. The Court consists of a Court of Appeal and a High Court of Justice - Trial Division. Each country has its own High Court, and the Court of Appeal deals with appeals of decisions made by the High Court and Magistrate's Courts in each member state with regard to both civil and criminal matters. However, the jurisdiction and powers of the Eastern Caribbean Supreme Court are determined by the Constitution and any other relevant laws of the State. The court of last resort is the judicial committee of Her Majesty's Privy Council in England.

Presently, the structure of the Central Government for St. Vincent and the Grenadines comprises the Office of the Prime Minister and 12 Ministries. Table 1-6 lists the various Ministries of the St. Vincent and the Grenadines relevant to the management of the Grenada Bank marine resources. St. Vincent and the Grenadines does not have a system of elected local government; however, it does have administrative sub-divisions into six parishes, one of which is 'The Grenadines'. Although there is no local government in St. Vincent and the Grenadines, the Ministry of National Security, Air and Sea Port Development hosts the Department of Grenadine Affairs, in which there is a Northern Grenadines and a Southern Grenadines representative who report directly to the Prime Minister. Additionally, there is a Transport, Works, Urban Development and Local Government. In this Ministry there is a Local Government Division comprising of 14 local government entities: in which there are two district councils to represent the Grenadine Islands (i.e. Bequia and Union Island).

Table 1-6 Ministries relevant to the management of the Grenada Bank marine resources listed by country and name of Ministry. (SVG – St. Vincent and the Grenadines, GND – Grenada)

Country	Name of Ministry
SVG	Office of The Prime Minister
	Ministry of Agriculture, Rural Transformation Forestry and Fisheries
	Ministry of Finance and Economic Planning
	Ministry of Health, Wellness and The Environment
	Ministry of Housing, Informal Human Settlements, Physical Planning, Land and Surveys
	Ministry of National Security, Air and Sea Port Development
	Ministry of Tourism and Industry
	Ministry of Transport, Works, Urban Development and Local Government
GND	Office of The Prime Minister
	Ministry of Agriculture, Forestry and Fisheries
	Ministry of Carriacou and Petite Martinique Affairs
	Ministry of Environment, Foreign Trade and Export
	Ministry of Finance, Planning, Economy, Energy and Cooperatives
	Ministry of Health
	Ministry of Housing, Lands and Community Development
	Ministry of Tourism, Civil Aviation and Culture
	Ministry of Works, Physical Development and Public Utilities

1.5.5.2 Grenadasystem of government

Grenada gained independence from the United Kingdom on the 7th of February 1974 and is an independent sovereign state within the Commonwealth. Grenada is a constitutional monarchy and bicameral parliamentary democracy; where the formal Head of State is a monarch but is limited by the nation’s supreme law, the Constitution. Grenada has the three branches of Government: the Executive, Legislative and Judicial. The Executive branch of government is similar to that of St. Vincent and the Grenadines. Queen Elizabeth II is the hereditary Chief of State and is represented by the Governor General. The Prime Minister is the Head of Government as well as the leader of the majority party and is appointed by the Governor General after legislative elections. Based on the advice of the Prime Minister, a Deputy Prime Minister and the Cabinet are appointed by the Governor General.

In the legislative branch of the government, unlike St. Vincent and the Grenadines, Grenada has a bicameral parliament comprised of the Senate and the House of Representatives. The House of Representatives consists of 15 seats, and the members are elected by popular vote to serve five year terms. The Senate is a 13 member body, 10 are appointed by the Prime Minister, and the remaining three by the leader of the opposition.

In the Judicial branch of government, Grenada is divided into three judicial districts, each with its own magistrate's court: The Eastern Caribbean Supreme Court, Itinerant Court of Appeal, is a member of the Caribbean Court of Justice. The Grenada Constitution was established in 1973, and makes provision for the sharing of courts. However, the jurisdiction and powers of the Eastern Caribbean Supreme Court are determined by the Constitution and any other relevant laws of the State.

Presently, the structure of the Central Government of Grenada comprises the Office of the Prime Minister and 14 Ministries. Table 1-6 lists the Ministries of Grenada relevant to the management of the Grenada Bank marine resources.

Grenada does not have a system of local government; however, it does have administrative sub-divisions into six parishes, one of which is ‘Carriacou and Petite Martinique.’ There is no constitutional provision for local government in Grenada; unlike St. Vincent and the Grenadines however, Section 107 of the Constitution does state ‘that there shall be a council for Carriacou and Petite Martinique which shall be the principal organ of local government.’ As a result, there is a ‘Ministry of Carriacou and Petite Martinique Affairs’ which serves to coordinate and facilitate government-related activities in these Grenadine islands with the mainland of Grenada.

1.5.6 Coastal marine management environment

The Grenadines comprise many small, dispersed islands with very little government administrative infrastructure. Obtaining current and accurate data is therefore challenging. Most of the information collected and statistics calculated are summarised by the mainland country, with little being documented separately for each country’s respective Grenadine islands. This phenomenon is illustrated in the vastly underrepresented fisheries catch statistics for inshore and reef species in Grenada; some of the important landing sites in the Grenadine Islands were not even recorded (Mohammed and Rennie 2003). Similar data gaps exist for the Vincentian Grenadine Islands (Chakalall et al. 1994). Where possible, these limitations will be highlighted in the following sections.

Both the St. Vincent and the Grenadines and the Grenada government perceive their Grenadine Islands as having high potential for earning foreign exchange though increased tourism and associated development, yet also recognise their current value and long tradition of fishing to support coastal communities (SusGren 2005, Lee 2009, Turner 2009). They are also well aware of the high vulnerability of their Grenadine marine resources to environmental degradation, and of the dependency of sustainable development on conservation of these resources (see SusGren 2005, Lee 2009 and Turner 2009 for review). Despite this however, unplanned development and the unregulated use of the coastal and marine resources (e.g. overfishing, coastal habitat destruction, sedimentation, solid waste and sewage disposal from land-based and boat sources, as well as the recreational use of coral reefs) have already led to serious infrastructural, socio-cultural and ecosystem degradation (e.g. CCA 1991a, CCA 1991b, Price and Price 1998, FAO 2002, FAO 2007, ECLAC 2004, Mahon et al. 2004, Sustainable Grenadines Project 2005, Williams 2008, Lee 2009, Turner 2009, Price 2011).

Although there is legislation relevant to various aspects involved in the management of the coastal marine resources of Grenada and St. Vincent and the Grenadines (see Table 1-7 for review), marine and coastal zone management thus

Table 1-7 St. Vincent and the Grenadines and Grenada key legislation relevant to the management of the coastal and marine environment. ***(SVG: St. Vincent & the Grenadines; GND: Grenada)***

Country	Legislation	Area of relevance
SVG	Beach Protection Act (1991)	Beaches
	Central Water and Sewage Authority Act (1991)	Control of land-based pollution
	Fisheries Act (1986)	Fisheries
	Fishing Regulations (1991)	Fisheries
	Forestry Act (1945)	Mangroves
	Marine Parks Act (1997)	Fisheries; marine protected areas
	Maritime Areas Act (1983)	Fisheries; exclusive economic zone
	Mustique Conservation Act (1989)	Conservation areas on and around Mustique
	National Parks Act (2002)	Protected areas; integrated management
	Port Authority Act(1987)	Ports
	Public Health Act (1977)	Waste management
	Tobago Cays Marine Parks Act (1999)	Critical habitat management
	Town and Country Planning Act (1992)	Coastal zone management
	Wildlife Protection Act (1987)	Protected areas
GND	Beach Protection Act (1979)	Beaches
	Fisheries Act (1999)	Fisheries
	Fisheries Regulations (2001)	Fisheries
	Fish and Fishery Products Regulations (1999)	Fisheries
	Fisheries (Marine Protected Area) Regulations (2001)	Fisheries; marine protected areas
	Forest, Soil and Water Conservation Act(1984)	Mangroves
	National Heritage Protection Act (1990)	Transboundary protected areas
	National Parks and Protected Areas Act (1990)	Protected areas
	National Water and Sewage Authority Act (1991)	Integrated watershed management
	Physical Planning and Development Control Act (2002)	Natural and cultural sites; environmental impact assessment
	Ports Authority Act (1981)	Ships
	Protection of Natural and Cultural Resources Act	Natural and cultural resources
	Territorial Seas and Marine Boundaries Act (1991)	Fisheries; exclusive economic zone
	Town and Country Planning Act (1990)	Coastal zone management
	Yacht Act (2001)	Yachts

far is limited both within and between the two countries; each having largely administered management in a top-down sectoral fashion that has failed to adequately protect and conserve the transboundary marine resources and biodiversity of the Grenada Bank (FAO 2002, Culzac-Wilson 2003, Mahon et al. 2004, Daniel 2005, Sustainable Grenadines Project 2005, Gardner 2006, Joseph 2006, FAO 2007, Gardner 2007, Lee 2009, Turner 2009).

To date, management of the Grenada Bank marine resources has primarily been focused on the National level with fisheries sector with management entrusted to each country's respective Fisheries Division as the lead agency responsible (FAO 2002, FAO 2007). Historically fisheries resource management has mainly been applied using a conventional, top-down approach guided with the assistance of regional organisations (e.g. CRFM, OECS) to create regionally harmonised legislation (e.g. the OECS Common Fisheries Agreement) and somewhat generic national fishery management plans based on limited biophysical information (e.g. CARICOM's Fisheries Resource Assessment and Management Program based on FAO's Mahon 1987 and Mahon 1990). Current fishing management efforts (Tables 1-8 and 1-9 review the stock status, current regulations and management objectives of key fisheries for each country) have been unable to reduce the high fishing effort and destructive fishing practices contributing to the overexploitation of the majority of fishery resources of the Grenada Bank (FAO 2002, FAO 2007). Additionally, limited enforcement capacity and little formal stakeholder participation in policy and management initiatives either within or between the two countries have further hindered the successful transboundary management of marine resources (Culzac-Wilson 2003, Mahon et al. 2004, Daniel 2005, Gardner 2006, Joseph 2006, Gardner 2007, Turner 2009). Figure 1-11 is a schematic illustration of geographical and jurisdictional scales and levels on each scale relevant to the management of coastal marine resources of the Grenada Bank.

Table 1-8 Description of stock status, current regulations and objectives for the management of various fisheries in Grenada and its Grenadine Islands (FAO 2007).

Fishery	Status of stock	Current regulations	Management objectives
Demersals and shellfish	Overexploited	- Mesh size restrictions apply - All shellfish (i.e. conch, lobster, urchin) are subject to a four month closed season (1st May to 31st August)	- Expand fishing effort to deep slope fisheries
Offshore pelagics	Underexploited	- No effort restrictions, closed seasons or area closures exist	- Sustainable exploitation of stocks - Relieve overfished demersal grounds - Apply limited licensing and taxes to shape the direction of the fishery
Inshore pelagics	Not assessed	- Nets require licensing - Mesh size restrictions apply	

Table 1-9 Description of stock status, current regulations and objectives for the management of various fisheries in St. Vincent and the Grenadines (FAO 2002).

Fishery	Status of stock	Current regulations	Management objectives
Shallow shelf demersals	Overexploited	- No spear fishing in marine conservation areas	- Promote stock recovery - Divert effort to deep-slope demersals and offshore pelagics
Deep slope demersals	Underexploited	- No spear fishing in marine conservation areas	- Maximise catches with in Maximum sustainable yield - Reduce illegal fishing by foreign vessels - Protect stock from overfishing by limiting effort - Improve the collection of catch and effort data
Inshore pelagics	Moderately exploited	- Net mesh size restrictions - Use of trammel nets are illegal	- Encourage co-management - Maintain artisanal nature of the fishery
Offshore pelagics	Underexploited	- None	- Cooperate with ICAAT to assess and preserve the resource - Promote the wise development of commercial and sport fisheries by controlling effort
Lobster	Overexploited	- Size restrictions (3.5 inches) - Closed season from 1st May to 31st August - Illegal to catch or sell out of season - Illegal to remove eggs from berried lobsters	- Rebuild stocks in depleted areas - Proper management by controlling effort is needed to ensure sustainable extraction
Conch	Overexploited	- Size restrictions (7 inches) - Minister can declare any period as a closed season	- Manage sustainably and prevent further resource depletion by controlling fishing effort

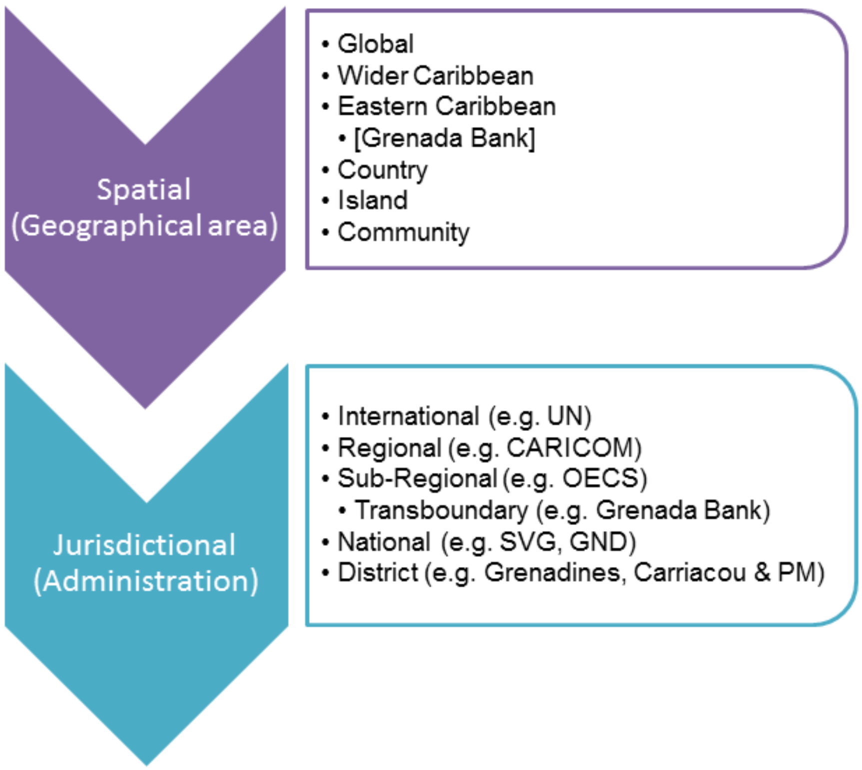


Figure 1-11 Schematic illustration of geographical and jurisdictional scales and levels and examples of relevant institutions to marine resources of the Grenada Bank.

Another form of marine management currently utilised by both countries is the designation of marine protected areas (MPAs). Presently there is one no-take marine park and one limited-take marine protected area, two marine reserves as well as nine marine conservation areas designated in the Grenadine Islands (Lee 2009, Turner 2009). In 1997 the first and only no-take marine park in St. Vincent and the Grenadines, the Tobago Cays Marine Park (TCMP) was declared and in 1998,formal regulations were adopted in 1999 and a formal management plan was approved in 2007 (Hoggarth 2007). The most recently declared and the only designated MPA in the Grenada Grenadines, the Sandy Island Oyster Bed Marine Protected Area (SIOBMPA), was launched in 2010. The mainland of Grenada hosts the only other MPA within the jurisdiction of the two countries (i.e. Moliniere / Beausejour Marine Protected Area). The remaining two marine reserves and nine marine conservation areas (MCAs) are all under the jurisdiction of St. Vincent and the Grenadines with only one located on the mainland of St. Vincent (Lee 2009). Although legally designated, the only adopted formal regulation for these marine areas is the prohibition of spear fishing. Unfortunately, as a result of a lack of on-site management for any of these marine reserves or MCAs, they are largely 'paper-parks' that are not demarcated, enforced or known of by the community at large (UNEP-CEP 2012 unpublished document).

Despite the lack of strategic and tangible marine resource planning and effective management, it is worth noting that both countries are signatory to an extensive number of relevant international (e.g. Convention on Biological Diversity) and regional multilateral environmental agreements (e.g. OECS 'St. George's Declaration of Principles for Environmental Sustainability') (Table 1-5), many of which call for an EBM approach. In addition, both of the involved nations share membership to at least 12 international and 12 regional organisations (Table 1-6) intended to formally facilitate transboundary linkages and cooperation which will be required to sustainably manage common resources. In line with these commitments, both countries have developed national environmental management strategies (NEMS) to provide an enabling framework to allow for the fulfillment of the CBD and the St. George's Declaration of Principles for Environmental Sustainability (SGD) (Homer and Shim 2004). Despite this, legislation in both countries is fragmented, often outdated, and not adequate to support the implementation of the NEMS (Culzac-Wilson 2003, Daniel 2005,Gardner 2006, Joseph 2006,Gardner 2007, Mattai and Mahon 2007, Lee 2009, Turner 2009). Moreover, neither country has made institutional provisions for an agency responsible for environmental management or an integrated management structure (Jessamy 1999,Culzac-Wilson 2003,Daniel 2005,Gardner 2006, Joseph 2006, Gardner 2007, Mattai and Mahon 2007, Lee 2009, Turner 2009). Despite these factors, the need to implement an EA to transboundary marine governance that includes stakeholder participation, inter-sectoral collaboration and access to holistic and integrated information is well acknowledged in the objectives of an array of national plans (Table 1-10). It has become increasingly clear that although both countries understand the importance of access to holistic information and cross-level collaboration to aid decision-making and EBM, they lack the necessary tools to make transboundary management operational, particularly in the marine environment.

Table 1-10 National strategies, plans, policies, committees and reviews which recommend key elements for an ecosystem approach to provide for sustainable development.

Country	National plan	Stakeholder participation	Inter-sectoral collaboration	Need for information system	Easy access to information
St. Vincent and the Grenadines	Environmental Management Strategy and Action Plan 2004-2006	X	X	X	X
	Fisheries Act - Fisheries Advisory Committee	X	X	-	-
	Fisheries Management Plan	X	X	X	X
	Marine Tourism Policy		X	X	X
	National Biodiversity Strategy and Action Plan	X	X	X	X
	National Parks and Protected Areas Systems Plan 2009-2014	X	X	X	X
	Report to the Regional Consultation on SIDS Specific Issues (2003)	X	X	X	X
	Review of Policy, Legal and Institutional Frameworks for Protected Area Management in St. Vincent and the Grenadines	X	X	X	X
Grenada	Cross Cutting Assessment of Integrated Management (2006)	X	X	X	X
	Fisheries Act - Fisheries Advisory Committee	X	X	-	-
	Grenada Protected Areas Systems Plan – 2009	X	X	X	X
	Land and Marine Management Strategy for Grenada– 2011	X	X	X	X
	National Biodiversity Strategy and Action Plan	X	X	X	X
	National Environmental Policy and Management Strategy for Grenada	X	X	X	X
	National Report on Sustainable Development	X	X	X	X
	National Strategic Development Plan	X	X	X	-
	Review of Policy, Legal and Institutional Frameworks for Protected Area Management in Grenada	X	X	X	X

2 A STRATEGIC APPROACH TO STAKEHOLDER ENGAGEMENT

2.1 INTRODUCTION

The transboundary Grenadine Island chain (Figure 2-1) provides a good locality to evaluate the application of PGIS and assess its implications for governance within a complex coastal management environment (a full description is provided in Chapter 1). As outlined in detail in Chapter 1, marine resources and their use are of vital importance as they provide food security, livelihoods and social identity for these small coastal communities (Jardine and Straker 2003, Sustainable Grenadines Project 2005). To address the complex nature of cross-scale and multi-level transboundary marine resources of the Grenada Bank, there is a clear need for an integrated EBM approach, including access to holistic information to support informed decision-making for adaptive management and the provision of sustainable development.

This chapter describes the ways in which stakeholders were engaged in the development of a PGIS for the Grenadine Islands; in terms of both the research approach (process) and the final geodatabase (product). To this end, participatory processes were utilised to: (a) obtain and include the best available information from all possible sources; (b) promote stakeholder ownership and use of the information produced; and (c) increase inter- and intra-stakeholder understanding

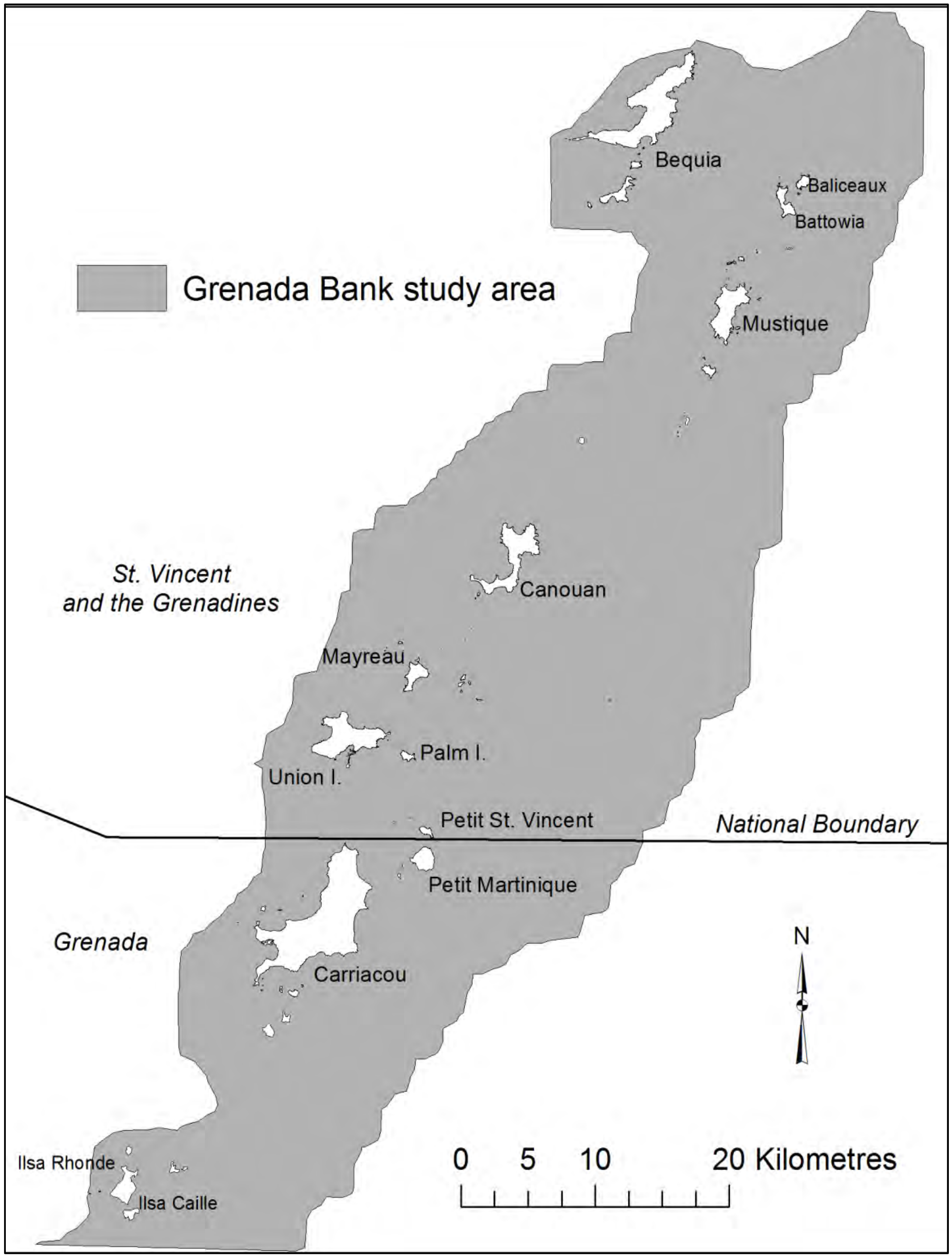


Figure 2-1 Geographical scope of the study area - the transboundary Grenada Bank out to the 60 m isobath and the Grenadine Islands. Location of the study area relative to the Caribbean is shown in Figure 1-1.

of interdisciplinary marine resource information. Additionally, the research appraises the application of this approach as a practical mechanism to aid dimensions of interactive governance such as inclusiveness, transparency, appropriateness, ownership, equitable access as well as capacity building and learning.

2.1.1 Review of stakeholder engagement methods

Based on a review of a number of PGIS methodological guides (e.g. Quan et al. 2001, McCall 2003, Rambaldi et al. 2005, Chambers 2006, Rambaldi et al. 2006), there appear to be several critical factors for successful implementation. Defining the appropriate form and function of stakeholder engagement is essential to the application of a PGIS approach. The intensity of participation chosen should be appropriate to the tasks, competencies and specific needs of the stakeholders involved in the spatial planning context (Renard and Krishnarayan 2000, Quan et al. 2001, McCall 2004). Essential questions in determining the degree of participation in planning a PGIS approach include: Why is this approach being utilised? Who is involved and sets the agenda? How will this be accomplished? (McCall 2003, Fox et al. 2005, Rambaldi et al. 2006). Although stakeholder engagement may initially be more time consuming than conventional planning approaches, taking the time to fully address these questions at the start of a PGIS endeavour is essential to appropriately tailor the system to the local context and effectively incorporate management and decision-making needs (Maine et al. 1996, McCall 2004).

To gain an understanding of the local context and capacity of stakeholders, there is a variety of participatory research tools to choose from. Regardless of the methodology applied, good interpersonal and facilitation skills are essential to adequately engage a wide range of stakeholders (Grenier 1998, IIRR 1998, Walters et al. 1998, Patton 2002, Bunce et al. 2006). Furthermore, it is crucial that all information is frequently, transparently and equitably shared amongst stakeholders to maintain a common level of understanding and build trust among levels and across scales (Berkes et al. 2001, McCall 2003, Fox et al. 2005, Quan et al. 2006, Rambaldi et al. 2006). Stakeholder validation and feedback exercises should be employed not only to aid the production of accurate information, but also to build shared understanding and support learning (McAllister and Vernooy 1999, Berkes et al. 2001, McCall 2003, Fox et al. 2005, Rambaldi et al.2006, Maine et al. 2008). Knowledge of the variety of participatory research techniques available is critical to allow for effective and widespread participation amongst a range of stakeholder groups. The following section provides a brief review of participatory research tools applied in this study.

2.1.1.1 Preliminary appraisal

A preliminary appraisal (Walters et al. 1998, Bunce et al. 2000) is an important first step to better understand the local context and stakeholders as well as help identify the existing coastal and marine resources, all of which are required to tailor a PGIS endeavour appropriately. The review of secondary (or existing) information together with a reconnaissance trip can give insight into the ecological and social conditions of the area and provide baseline information on the social, economic and political characteristics and space-use patterns occurring in a project area (Walters et al. 1998, Bunce et al. 2000, Berkes et al. 2001).

Adequate time should be spent at the outset of a PGIS project to conduct a preliminary appraisal. Information on the physical geography, population, settlement patterns, occupations, fisheries and other marine-based activities, community infrastructure, social groups, major issues and destructive practices should be included (Walters et al. 1998, Bunce et al. 2000, Berkes et al. 2001). To start, an extensive literature and data search on the status, uses and management of coastal and marine resources should be undertaken. This includes the collection of environmental and marine-related legislation, policies, management plans and GIS datasets, as well as any associated research on the marine environment and socio-economics of the fisheries, tourism, institutional, civil-society and private sector organisations. Next, a combination of informal interviews, semi-structured key informant interviews and participant observation exercises can be undertaken with each of the various stakeholder groups and sectors to gain awareness of stakeholder dynamics, environmental awareness and capacity for participation; as well as to build trust and a partnership approach (IIRR 1998, Walters et al. 1998, Bunce et al. 2000, Berkes et al. 2001). A preliminary appraisal should also include stakeholder consultation meetings to: (a) discuss the objectives of the PGIS endeavour; (b) share and assess existing information as well as get stakeholder feedback; and (c) to explain the importance of stakeholders' role with in the research (McCall 2003, Rambaldi et al. 2006). Early stakeholder consultation can ensure local priorities are included in the objectives of the PGIS as well as provide access to local knowledge, resources and assistance. Taking the time to conduct a thorough preliminary appraisal can help to establish a transparent and inclusive start to the ensuing collaborative research endeavour as well as aid understanding of the social and political context and help in the identification of assisting and resisting factors; all of which are essential to a successful PGIS (McCall 2003).

2.1.1.2 Informal interviews

Unstructured informal interviews are normally conducted as a preliminary step in the research process to gain understanding of the subject of interest (Berkes et al. 2001). Such interviews are entirely informal and are not controlled by a specific set of detailed questions. Rather the interviewer guides the discussion points by a pre-defined list of issues. These interviews amount to an informal conversation about the subject. The aim of this type of interview is to find out how people think and how they react to issues, so that the subsequent survey questionnaire can be framed appropriately for the intended respondents. In an informal interview, the respondent is encouraged to talk freely about the subject, but is kept to the point on issues of interest to the researcher.

Key informants are purposely selected stakeholders or community members who are expected to be able to provide information on a particular topic based on their knowledge, skills or experience (IIRR 1998, Patton 2002). By informally interviewing a key informant, detailed and relevant information can be quickly obtained to appraise the local context, issues at hand and capacity of stakeholders for participatory research. Key informant interviews can be of use to initially gain insight on coastal and marine resources and associated human activities of the project area (Walters et al. 1998, Bunce et al. 2000, Berkes et al. 2001). As different types of people have different types of knowledge and biases, it is important to interview a range of key informants (e.g. an elder, woman, community leader, outsider) to get a broad and balanced understanding of the issues at hand.

2.1.1.3 Participant observation

Participant observation allows for an opportunity to observe stakeholders and their livelihood strategies by actively taking part in their daily activities (IIRR 1998, Berkes et al. 2001, Patton 2002). This is an effective technique to learn 'first-hand' about livelihoods, and better understand daily routines, cultural traditions, folk taxonomies and relationships with other stakeholders. By asking questions relevant to the parameters being investigated (e.g. while observing a fishing method, asking where, when and how fish were captured), the researcher aims to seek a broader understanding of activities (Patton 2002). Spending an extended period observing and working alongside stakeholders can generate extensive descriptive information perhaps not initially apparent or easily described by stakeholders. Although time-consuming, participant observation provides a deeper understanding of the local context. By showing an interest in stakeholders' livelihoods, the researcher can gain trust and build camaraderie.

2.1.1.4 Semi-structured interviews

Semi-structured interviews are based on a set of open-ended questions or discussion points to generate qualitative information (IIRR 1998, Quan et al. 2001, Patton 2002). Through informal two-way interactions, the interviewer has the flexibility to ask descriptive questions, probe for answers or pursue new questions so that information generated evolves with new information provided by the respondent (Berkes et al. 2001). Semi-structured interviews allow for the generation of in-depth and explanatory qualitative information by encouraging informants to raise relevant issues and tailor answers to their situation, experience and knowledge.

A focus group interview is a type of semi-structured interview which involves asking questions of a selected group of key informants (usually 4 to 10) who share a common background or knowledge (Bunce et al. 2000, Patton 2002). One benefit of a focus group interview is that it can stimulate group discussion and prompt others to respond as well as help to ensure consensus in responses given.

2.1.1.5 Structured interviews

Structured interviews use questionnaires with closed-ended questions which result in quantitative data that can be analysed statistically (Bunce et al. 2000, Patton 2002). Unlike semi-structured interviews, the survey questionnaire has specific questions with discrete answers (e.g. multiple choices, true/false), and does not encourage follow-up questions or explanatory answers. If a statistically representative sample is used, surveys can generate information representative of the larger stakeholder group. Key informant and semi-structured interviews may often be conducted first to obtain a broad understanding of stakeholder groups, and then structured interview surveys are conducted to get quantitative data on specific topics (Berkes et al. 2001).

2.1.1.6 Communication and information exchange mechanisms

Equitable and transparent communication and information exchange is central to both an EA (De Young and Charles 2008) and PGIS (Rambaldi et al. 2006), and can be accomplished through the use of both one and two-way channels (Berkes et al. 2001). One-way channels can include regular newsletters, emails, flyers, media press releases, radio or television public service announcements as well as through other NGOs and civil-society group’s pre-established communication channels. Two-way channels, including meetings, Web 2.0 technologies (i.e. Twitter, Facebook, Blogger), the development of an e-group and/or a website, allows for feedback and exchanges. The use of an open-access website where technical reports/documents, maps, photos, useful links and the research calendar can be easily shared, accessed and discussed amongst all stakeholders is of key importance. These mechanisms not only increase access to information but augment transparent information exchange and communication by bringing stakeholders into a common space of understanding.

The objectives of the research, the role of stakeholder involvement, and the progress of the development of the research, including issues encountered and possible solutions, should be clearly communicated to stakeholders through both one-way and two-way channels (Bunce et al. 2000, Berkes et al. 2001, McCall 2003). Communication and information exchange mechanisms chosen should be appropriate for the audience and established at the outset of the project. Key informants can be consulted and the results of the preliminary assessment used to assist in the identification of the most applicable methods. Furthermore, throughout the duration of the research, all stakeholders should be encouraged to use the communication mechanisms applied so that they can participate in an informed way.

2.1.1.7 Socioeconomic assessment

A socioeconomic assessment is a study of the social, cultural and economic characteristics of individuals, groups, communities and organisations (Bunce et al. 2000, Quan et al. 2001). A socioeconomic assessment can allow for: (a) the integration of stakeholder interests and concerns into the management process; (b) an increased understanding of the linkages between marine resources and services to stakeholders and their value to society; and (c) the determination of the effects of management decisions on the stakeholders in order to improve policy decisions and minimise adverse impacts. The scope of a socioeconomic assessment may vary depending on the geographical size of the area and available resources. Commonly identified topics include: resource use patterns; stakeholder demographics; gender issues; stakeholder perceptions; organisation governance; traditional knowledge; community services and facilities; market attributes; non-market and non-use values (Walters et al. 1998, Bunce et al. 2000, Quan et al.2001). The majority of socioeconomic information is spatially-based and can therefore be included in the PGIS to provide for a more comprehensive information base.

Socioeconomic assessments typically use semi-structured interviews and/or structured interviews to generate quantitative information (Quan et al. 2001). Semi-structured interviews (e.g. with key informants) may be helpful at the outset of the project to: (a) gain a general knowledge of the various stakeholder groups; (b) identify appropriate survey variables; and (c) determine the survey sampling design (Bunce et al. 2000). Based on the initial assessment, a more detailed socioeconomic assessment can be used to produce quantitative data.

2.1.1.8 Participatory mapping techniques

> 'Participatory mapping is, in its broadest sense, the creation of maps by local communities – often with the involvement of supporting organisations including governments (at various levels), NGOs, universities and other actors engaged in development and planning.' *– IFAD 2009*

Using cartography, participatory mapping allows for the documentation of local spatially-based knowledge that aims to make visible the association between resources and the communities (Fox et al. 2005, IFAD 2009). Participatory maps therefore present geographical feature information but also can illustrate environmental, social, cultural and economic knowledge. Participatory mapping is one of the most common means to collect and represent local knowledge for PGIS.

IFAD (2009) cites six purposes for initiating participatory mapping initiatives which include:

- Communicating local spatial knowledge to government / external agencies
- Recording and archiving local knowledge
- Assisting land-use planning and resource management
- Increasing the local capacity and raising awareness
- Enabling communities to advocate for change
- Addressing resource-related conflict

A list and brief description of participatory mapping techniques applied in the study is provided in the following section.

Scale mapping:

Scale mapping is a participatory mapping exercise in which information gathered is drawn on existing scale (or base) maps (Walters et al. 1998, IIRR 1999, IFAD 2009). The types of information which can be collected through scale mapping exercises include names and locations of coastal and marine habitats, resources and their use. Pre-existing basemaps are usually produced by a professional mapping agency, which consist of selected features such as coastlines, roads and villages (i.e. topographic land and surveys map) and serve to orient the participant to the area of interest through the use of accurate georeferenced information.

Local spatial knowledge is provided by stakeholders during conversation around the map and the information is drawn directly upon the map. The use of a scale map provides for relatively accurate positioning of features and the representation of an area relative to natural landmarks. Scale maps can be georeferenced since the scale of area or a distance on the map is proportionally relative to known area on the ground and information drawn on the scale map can be incorporated into a PGIS by digitization.

Photo mapping:

Photo mapping is participatory mapping technique in which an aerial photo or satellite image is used as a base map (Fox et al. 2005, IFAD 2009). Aerial photos are used to determine the location of marine and coastal habitats, resources and corresponding human uses and fishing activities occurring in the area of interest. Similar to scale maps, photo maps can provide for relatively accurate positioning of features and the representation of an area relative to natural landmarks and can be easily georeferenced and information digitised for input into the PGIS.

Photo mapping provides a good format for participatory mapping since pictures (unlike scale maps) are easily understood by most stakeholders (Fox et al. 2005). Taking the time to collaboratively review the map from an aerial perspective and identify key landmarks at the outset of the exercise can aid stakeholder understanding and conversation about the local environment. Photo mapping can be a very engaging process and make excellent base maps for use in participatory mapping (IFAD 2009). In addition, if there is a time sequence of images of the same area it can stimulate community discussion and provide a means to understand environmental and other changes over time.

Internet mapping:

Internet mapping is the newest arena for participatory mapping initiatives. In the past five years, there has been a rapid increase in the number of communities using web-based applications (i.e. Google Earth, Google Maps, Open Street Map) to document and present local spatial knowledge (IFAD 2009). Internet mapping uses interactive maps that allow users to click on spatially referenced map features in order to access other multi-media information (i.e. pictures, videos, tables, websites).

Internet mapping is particularly useful because it is low cost (usually free besides the cost of a computer and internet access) and provides an efficient way to share and visualise georeferenced local knowledge to a wide audience. Internet mapping services are relatively easy to use and can allow mapping information to be easily communicated over the internet thereby quickly reaching a wide audience. Although this tool is not a fully-functional GIS, internet maps provide georeferenced information that can be easily produced by stakeholders and exported for inclusion in a PGIS. Likewise GIS data can be easily exported and shared through an internet mapping interface. The technological capacity of participating stakeholders must be evaluated prior to an internet mapping initiative as some technical training may be required.

2.1.1.9 Participatory field surveys

In participatory field surveys, stakeholders work with scientists to conduct conventional field surveys (e.g. marine habitat mapping, reef survey transects, fish counts) (Walters et al. 1998, Bunce et al. 2000, Berkes et al. 2001). Marine resource users (i.e. fishers, divers, community members) may be trained as part of the survey team to conduct field surveys alongside scientists. Training should be provided to explain the purpose and methods to be used in the field survey. Stakeholder feedback can be used to further develop the methodology applied or the location of surveys (e.g. identification of fishing grounds). Additionally, sharing the results with the stakeholders and obtaining feedback can yield unique insights based on their understanding of local conditions.

The benefits of participatory coastal and marine field surveys are two-fold. Primarily, local knowledge can be collected alongside biophysical information as part of the field data variables and incorporated with in the PGIS. Secondarily, the active participation of stakeholders in the field surveys provides an understanding of the purpose of the study and the methods applied. Ultimately, this can increase stakeholders' awareness of the marine environment, ownership of the information generated and can support two-way learning and problem solving.

2.2 METHODS

The overall process for stakeholder engagement in the research comprised several parts: data scoping and preliminary appraisal; development of communication and information exchange mechanisms; marine resource use inventory and assessment; marine habitat classification scheme and habitat map development; mapping exercises; definition and compilation of the MarSIS geodatabase structure; the planning for stakeholder usability and access; and evaluation of the PGIS process and product (Figure 2-2). Technical aspects of the research related to the development of a marine habitat classification scheme and the mapping are provided in Chapter 3. Chapter 4 summarises the development of the MarSIS geodatabase structure and provides a demonstration of PGIS applications to provide a baseline picture of the extent and distribution of marine resources, associated patterns of use and the identification of threats of use in the development of various scenarios as a starting point for collaborative ecosystem approach to MSPM.

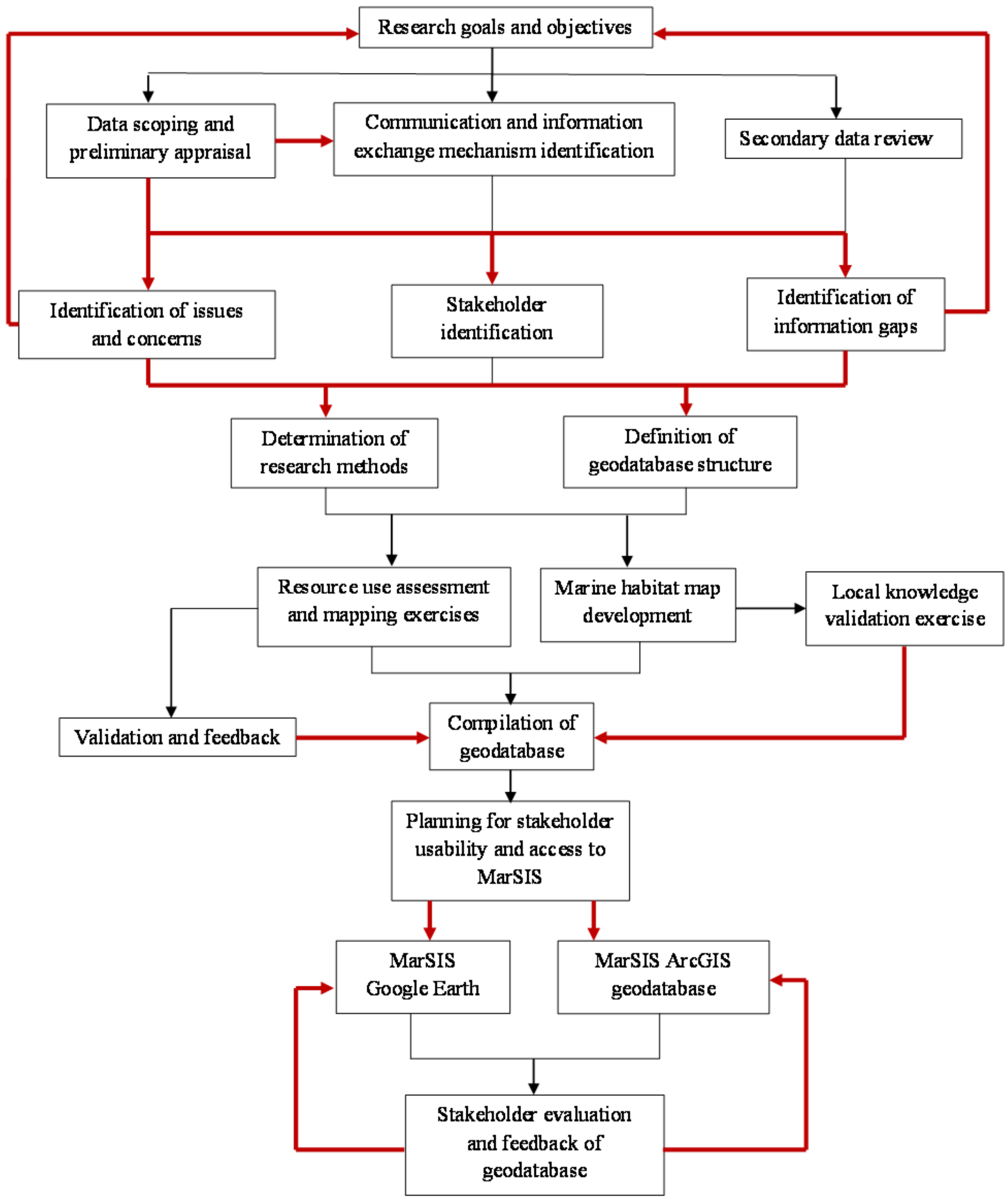


Figure 2-2 A flowchart showing the research activities that were applied to engage stakeholders. (*N.B. red arrows indicate loops in which stakeholder feedback was applied*).

2.2.1 Data scoping and preliminary appraisal

The research approach and objectives were guided by the context set out by SusGren (SusGren 2005; see Chapter 1 for review) yet remained flexible in order to be able to address both the community and government needs. Time was taken (July 2005 – June 2006) at the outset of the research to conduct a preliminary appraisal of the study area to understand the social and political environment, identify stakeholder groups and build the working relationships necessary for a collaborative approach (IIRR 1998, Berkes et al. 2001, Renard 2004).

The preliminary appraisal began with an extensive literature review conducted for information on the status, uses and management of coastal and marine resources of the Grenada Bank. This included environmental and marine-related legislation, policies, management plans and GIS datasets, as well as any associated research on the marine environment, fisheries, tourism, civil-society and private sector organisations. The preliminary appraisal was applied to gain awareness of stakeholder dynamics, environmental awareness and capacity for participation; as well as to build trust and a partnership approach. The preliminary appraisal included formal stakeholder meetings with a data scoping questionnaire (Appendix I), semi-structured key informant interviews (Appendix II) and participant observation (Appendix III) based on a blend of participatory research methodologies (IIRR 1998, Walters et al. 1998, Bunce et al. 2000, Berkes et al.

2001, Patton 2002). These exercises were undertaken in each of the nine inhabited Grenadine Islands, as well as the two main islands, over a four week period (May 2006).

Three formal multi-sectoral government meetings were held with all marine-related agency stakeholders identified by previous research (Finlay et al. 2003) to share research principles, augment objectives and foster transparent collaboration in the research. Visits were also made to each marine-related agency (i.e. Fisheries, Forestry, Planning, Tourism, Coast Guard, Port Authority, Statistics and Maritime Administration Departments). This was done to share information that had been gathered, source additional secondary information and identify information needs and gaps. Furthermore, understanding each department's mandate, institutional arrangements and marine resource management priorities, including current systems of data collection and corresponding database structures within the two countries comprising the transboundary island chain was paramount. Thirty two persons working for government agencies were interviewed to obtain this information.

The preliminary appraisal also included brief visits (approximately 3 days each) to each inhabited Grenadine Island so as to identify the types and distribution of marine stakeholders to be designated as marine resource users (MRUs). To better understand each of the MRU groups, 'dawn to dusk' participant observation exercises were undertaken with each of the various types of MRUs including each type of fishery and fishing gear (Appendix III). A baseline study of the demographics of each community, the locations of coastal activities, key marine resources and their current uses was conducted through observation, informal interviews with community members and key informant interviews (Table 2-1) (Appendix IV) (based on the methodologies of: IIRR 1998, Walters et al. 1998, Bunce et al. 2000, Berkes et al. 2001). These visits were used to gain insight into stakeholder dynamics, capacity for participatory research and level of environmental awareness in the various islands. Key informants were questioned on: (1) the perceived value of and threats to existing marine resources and livelihoods, (2) the identification of any existing conflicts among users, and (3) each community's perception of the institutional management systems of the two governing states involved. Key informants were identified based on the recommendation of either SusGren or suggested by other key informants (a snowball sample). Fifty-seven semi-structured key informant interviews, consisting of a minimum of three different types of marine resource users and one community leader within each island, were conducted. Information gathered during the preliminary appraisal was shared and validated with stakeholders and used to further develop and fine tune the research objectives through the identification of appropriate survey variables, methods and data collection tools.

Table 2-1 Socio-economic monitoring variables selected for the preliminary appraisal (variables selected from Bunce et al. 2000).

Var. No.	Community Level Demographics
C1	Study area
C2	Population
C3	Occupation
C4	Community infrastructure
C5	Coastal/marine resources and perceived conditions
Var. No.	**Stakeholders - Marine Resource Users**
S1	Coastal activities and number of users
S2	Goods/services from activities
S3	Types of use of good/service
S4	Community and stakeholder organizations
S5	Enabling legislation or management plans
S6	Use patterns – fishing
S7	Use patterns - other marine resource users
S8	Stakeholder identification - key informants
Var. No.	**Detailed Key Informant Information**
D1	Areas of importance for your resource use
D2	Existing infrastructure for your resource use
D3	Perceived coastal management problems
D4	Conflicts with other marine resource users

Stakeholders were categorised into primary or secondary stakeholders (Figure 2-3). Primary stakeholder groups included key government agencies (e.g. Fisheries Division, Physical Planning and Tourism) of each country and the direct marine resource users of each of the Grenadine Islands. Direct marine resource users (MRUs) were categorized by type of use and included: dive shop operators, day-tour operators (general, sailing and sport-fishing), water-taxi operators, fishers, ferry operators, yacht charter companies and cargo ship operators. Fishers were further grouped by landing site and analysed by fishing type. Secondary stakeholders include civil society organisations and NGOs, other relevant government agencies, and the general public of the nine inhabited Grenadine islands. These stakeholders have an interest in marine resources but do not directly rely upon them for livelihoods or have them as a primary area of jurisdiction or activity.

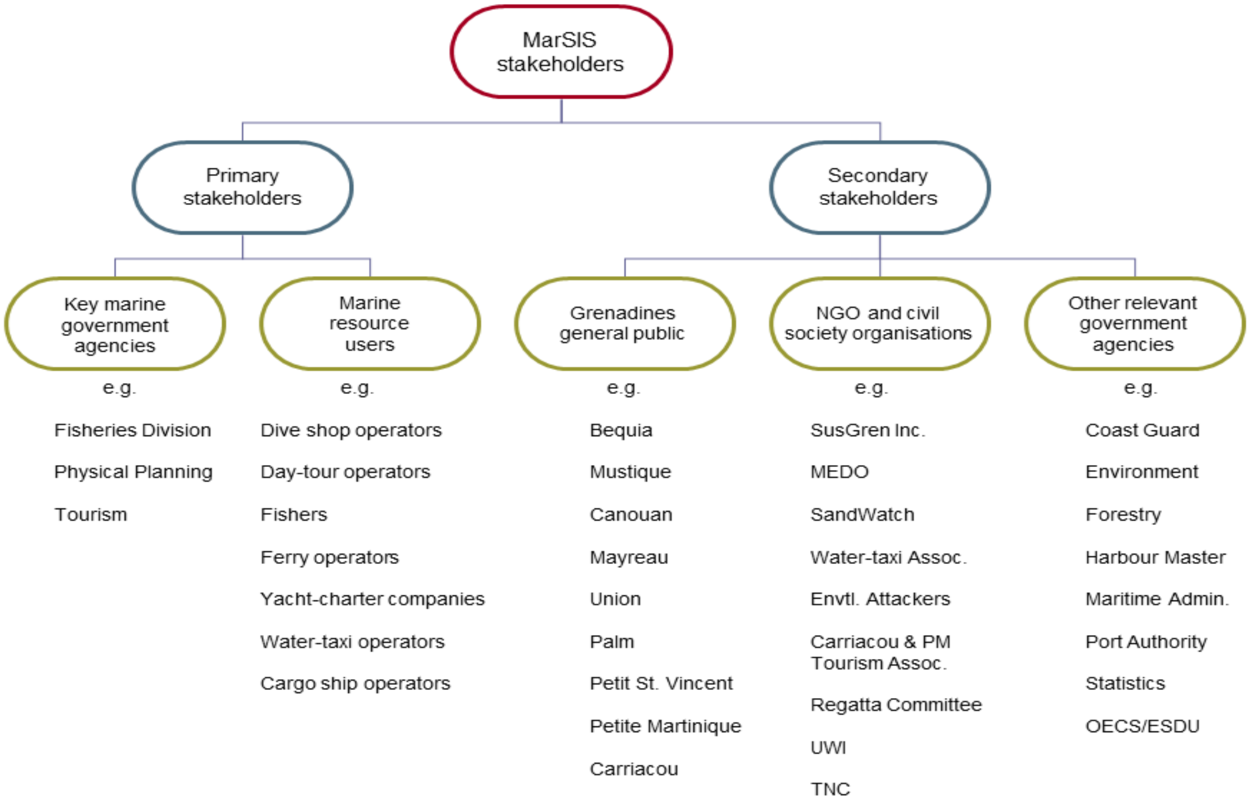


Figure 2-3 The Grenadines MarSIS primary and secondary stakeholders comprise five main sub-groups.

2.2.2 Communication and information exchange mechanisms

The findings of the preliminary appraisal and the determination of stakeholder groupings were shared with all stakeholders through a variety of one and two-way communication channels as recommended by Berkes (et al. 2001) to facilitate participation. These communication mechanisms were maintained throughout the research and used at every stage. One-way channels included the distribution of regular newsletters, press releases, flyers, technical reports and a website/blog (www.grenadinesmarsis.com). Two-way channels included governmental and community stakeholder meetings held after each stage of data collection and email through the development of an internet-based Yahoo e-group (www.GrenadinesMarSIS.yahoogroups.com). The Grenadines MarSIS e-group and website allowed for technical reports, email messages, documents, maps, photos, useful links and the research calendar to be easily accessed by all members. All stakeholders and interested parties with internet access were encouraged to join the e-group which ultimately had more than 400 members. All secondary information and data obtained were compiled into an electronic library with an annotated bibliography in collaboration with the SusGren Project NGO (Blackman et al. 2006) and recurrently shared with stakeholders via a reference DVD. Moreover, all meetings and field research activities were documented using summary reports, maps, press releases and bi-monthly newsletters shared through the e-group and website as well as distributed in hard copy by the researchers and the SusGren (www.grenadinesmarsis.com).

2.2.3 Marine resource use assessment

A socio-economic marine resource use assessment was undertaken to understand the social, cultural, economic and political conditions of individuals, groups, communities and organisations operating in the Grenadine Islands. To quantify the number and distribution of users, an inventory of each Grenadine MRU group was undertaken by five persons over a three month period. We aimed to interview all MRUs using a snowball sampling technique, where each community was intensely surveyed until no new respondents were encountered. Questionnaires sought information on socio-demographics, livelihood strategies, resource (temporal and spatial) use patterns as well as environmental practices (Appendix IV-IX) (based on the methodologies of: IIRR 1998, Walters et al. 1998, Bunce et al. 2000). Survey instruments were distributed for review using the MarSIS e-group to allow for feedback from stakeholders before being utilised.

MRU inventory and socio-economic assessment information (Baldwin et al. 2006) were presented to both primary and secondary stakeholders through a series of two government and eleven community meetings. This was done to validate information produced and obtain feedback as well as allow transparent information exchange and two-way learning (Maine et al. 1998, McAllister and

Vernooy 1999). The logistics of community meetings were planned in collaboration with key informants, so as to identify convenient times and public places, in particular where fishers were known to congregate (i.e. ‘on the block’ or street corners, ‘rum shops’ or bars, boat ramps and ‘fish camps’ typically located at a fisheries complex). Additionally, prior to each community meeting, researchers would post flyers, walk the streets and ask community members to help spread the word in order to increase stakeholder turnout. Afterwards, results from the MRU assessment were spatially translated into GIS and were accompanied by a written summary report for distribution to stakeholders. Table 2-2 lists the name and attributes for each of the seven MRU feature classes created.

Table 2-2 List of the attributes collected for each MRU feature class produced from the MRU assessment.

Dive shop operators	Day tour companies	Charter yacht companies	Ferry operators	Ship operators	Water taxi operators	Fishers
Island	Island	Island	Island	Island	Island	Island
Home dock	Home dock	Home dock	Home dock	Home dock	Home dock	Landing site
Company name	Company name	Company name	Company name	Company Name	# boats	# fishers
Phone number	Services	Phone number	Phone number	Name of boat	Owner name	Mean age
Email	Email	Email	Email	Routes	Sex owner	# hand line
Contact name	Contact name	Contact name	Contact name	Type of boat	Type of boat	# fish trap
Position	Position	Position	Position	Type of cargo	# operators	# Spear gun
# boats	Phone number	Total # boats	# boats	Boat length	Length boat	# SCUBA
# compressors	Total # boats	# monohauls	Type boat	Tonnage	Name boat	# gill net
Owner name	# monohauls	# catamarans	Type cargo	Beam	Boat material	# trolling line
Sex owner	# catamarans	# powerboats	Owner name	Draught	Phone number	# beach seine
# divemasters	# powerboats	Services at dock	Sex owner	Capacity	Number engines	# trammel nets
# skippers	Type boat	Owner name	# skippers	Engine type	Main routes	# sinking palang
sex skipper	Owner name	Sex owner	sex skipper	# engines	5 top anchorages	# floating palang
# full-time employees	Sex owner	# skippers	# full-time employees	Horsepower		
# part-time employees	# skippers	sex skipper	# part-time employees	Engine brand		
% male employees	sex skipper	# full-time employees	% male employees	Fuel type		
% guests – tourists	# full-time employees	# part-time employees	% cargo goods	Country registered		
High season	# part-time employees	% male employees	% tourist passengers			

Table 2-2 (cont.) List of the attributes collected for each feature class produced from the MRU assessment.

Dive shop operators	Day tour companies	Charter yacht companies	Ferry operators	Ship operators	Water taxi operators	Fishers
# trips/week high season	% male employees	% yachts – chartered	% local passengers			
# trips / week low season	% guests – tourists	% yachts – bareboat	high season			
5 top anchorages	high season	high season	# trips/week high season			
Own GPS	# trips/week high season	# trips/week high season	# trips / week low season			
	# trips / week low season	# trips / week low season	Main routes			
	Environmental briefing	5 top anchorages	Own GPS			
	% moorings used	Environmental briefing				
	% anchors used	Briefing topics				
	% drift used	Sewage holding tanks				
	5 top anchorages	Grey water holding tanks				
	Own GPS	Own GPS				

2.2.4 Mapping exercises

A series of three incremental iterative participatory mapping exercises was conducted with MRUs over a three-year period to obtain local knowledge of marine resources and space-use information for inclusion within the MarSIS database. A basemap of the Grenada Bank showing coastlines, bathymetry and the national boundaries of the study area was created using ArcInfo version 10 for spatial data compilation and management. All mapping exercises were conducted with the identified stakeholders primarily in the form of individual (or sometimes small group) interviews using hard copy maps. Additional persons were consulted when more specialised information or validation was needed.

To begin each mapping exercise, the purpose of the exercise and the information to be collected were explained. Each participant was orientated with a topographic land and survey map of their island. Participants identified the locations of one feature at a time, working in a counter-clockwise direction around the island. Stakeholders guided the researcher in the annotation of attribute information and the drawing of points, lines or polygons around the boundaries of each identified area of interest on the basemap. To conclude each mapping exercise, participants reviewed the final annotated map for completeness.

2.2.4.1 Local names

The first scale mapping exercise was conducted with MRU and community stakeholders to determine the locally-used toponymy (or place names) for the beaches, bays and cays of the Grenada Bank. This information was mapped using government issued 1:10,000 topographic land and survey maps, due to their availability and community members' familiarity with major landmarks. Community members from each island were asked to provide the local names of beaches, bays and cays with which they were familiar and all names were written directly on each island's scale map (Appendix X). In each island, the annotated map was carried around to each community until all coastal features were identified and consensus reached by a minimum of three stakeholders. Toponymy collected was spatially referenced to annotate the Grenada Bank base map's coastal features in order to facilitate stakeholders' geographical understanding of coastal and marine areas in the successive mapping exercises.

2.2.4.2 Space-uses

In the second scale mapping exercise, semi-structured interviews were used to map space-use patterns of the various MRU groups on the base map consisting of coastlines, bathymetry and territorial boundaries annotated with toponymy. In each island, MRUs identified key areas of use for their respective livelihood. Charter yacht companies, day tour and water taxi-operators identified anchorages of use, dive shops mapped their dive sites and the ship and ferry operators mapped their routes travelled (i.e. shipping lanes) across the Grenada Bank. MRU spatial patterns were supplemented with demographics, environmental practices and information on the frequency of space-use collected as part of the MRU socioeconomic assessment survey (Table 2-2). Table 2-3 lists the name, geometry and attributes used to create space-use profiles resulting from these mapping exercises.

2.2.4.3 Distribution of resources

The third mapping exercise was conducted to identify the distribution of key coastal and marine resources, uses and livelihoods as well as areas of concern or threat (following methods of IIRR 1998, Walters et al. 1998, Bunce et al. 2000). In each island, MRU stakeholders were asked to identify the persons or group in the community of interest that they deemed to be most knowledgeable with regard to each of the variables to be mapped. Mapping exercises were conducted with the identified stakeholders using a hard copy of a topographic map annotated with local names of beaches, bays and cays (previously collected) for easier identification of areas. Additional persons were consulted when more specialised information or validation was needed. In this third set of scale mapping exercises, information to be collected was explained using a pictorial legend of features (categorised as resources, uses and threats to coastal and marine resources) which were to be mapped (Appendix XI). A coded list of information collected is given in Table 2-4. Participants mapped the locations of one feature at a time and annotated each with a corresponding letter code. A total of 28 mapping exercises, with a minimum of three mapping exercises conducted in each island, were completed in order to cross-validate information collected.

Table 2-3 List of MRU space-use profile feature classes by name, geometry and associated attribute.

Name feature class	Geometry	Attributes
Anchorages	Polygon	MRU group, rank of importance, % MRU group use
Dive sites	Polygon	Site name, dive operators, island
Ferry routes	Line	Name of route, ferry operators, schedules
Fishing areas	Polygon	Number of fishers by island

Table 2-4 Coded list of marine resources, uses, and areas of threat identified by stakeholders.

Resources	Uses	Threats
Sea turtle nesting beach (T)	Dive site (DS)	Dumping / pollution (DS)
Seabird roosting site (B)	Nursery area (NA)	Beach erosion (BE)
Baitfish bay (BB)	Breeding ground (BG)	Dredging (D)
Sea moss (M)	Ship-wreck (SW)	Sand-mining (SM)
Whelks (W)	Cultural / historical area (HA)	Artificial structure (ASx)
Oysters (O)	Recreational area (RA)	Mangrove cutting (MC)
Iguanas (I)	Ship building site (SB)	Desalination outfall pipe (DO)
	Aquaculture (A)	Wild goats (G)
	Vending site (V)	

2.2.4.4 Data processing

Geodatabase attribute schema for each feature class emanating from the mapping exercises were created using ArcCatalog. Paper base maps were georeferenced and digitized (either as points, lines or polygons) and all of the individual islands datasets were integrated using ArcGIS. Several composite maps were produced for each island (one each of local names, critical coastal and marine resources, space-use patterns and areas of threat or issues) (Appendix XII-XV). These individual island maps were routinely shared as Adobe Acrobat *(.pdf)* documents electronically via the e-group and website, as well as distributed as printed maps in each community (including to all stakeholders who participated in mapping exercises) to validate and obtain feedback before being rendered complete.

2.2.5 Planning for usability and equitable access

PGIS, specifically in the context of the appropriateness and usability of the technology applied, requires the consideration of stakeholders' technical capacities (McCall 2003, Rambaldi et al. 2006b). This is to ensure that the technology applied is suitable for the local context and can allow for widespread use (McCall 2004, Tripathi and Bhattarya 2004, Rambaldi et al. 2006a). In light of the numerous advances in Web 2.0 technologies since the start of the study, at the beginning of the final year, two half-day meetings were held with primary stakeholders to determine the most appropriate means of public access to the MarSIS. To start, a review of the study and its importance to sustainable development and marine spatial planning was given. Stakeholders were then presented with various options for the possible data types (e.g. ArcGIS, Google Earth) and end-products (e.g. atlases/maps, reports, DVDs) as well as means of access to the MarSIS (i.e. internet, DVD, local computer use at community centres). In addition, discussions on responsibility for the MarSIS (in terms of maintenance of information) on conclusion of the study were facilitated using focus groups. Feedback on preferred data types, end-products and means of public access were obtained from stakeholders through the use of a one-page questionnaire administered at the conclusion of the workshop (Appendix XVI).

2.2.6 Stakeholder evaluation of the MarSIS

After the compilation of the MarSIS geodatabase, a wide variety of all stakeholders evaluated the research during the course of three one-day workshops. Workshops were used in part to review the research activities and communicate the functionality of the MarSIS as a decision support tool for marine space-use management and planning. The workshops also allowed for testing the practical application of the MarSIS by the stakeholders themselves through either an ArcGIS or Google Earth interface. After a 1½ hour Google Earth training session, stakeholders explored the Grenadines MarSIS guided by a series of computer exercises (Appendix XVII). All 55 participants chose to use the Google Earth interface as opposed to ArcGIS, during the computer evaluation exercise. In the next 1½ hour period they investigated three environmental management scenarios, created their own maps of interest as *(.jpeg)* files, learned how to add existing information, create new data and how to email the maps and Google Earth *(.kmz)* files they had created.

Stakeholder evaluations were accomplished through the use of oral and written techniques (following methods of ICA 1999 and McAllister and Vernooy 1999). Feedback on the practical application of MarSIS in the Google Earth interface was obtained through informal interviews and group discussion. These were used to: (a) review the overall usability and effectiveness of the MarSIS design and layout; (b) identify errors in the system; and (c) accommodate suggestions for improvement. A four-page written questionnaire was administered to all stakeholders in order to assess the overall application of a PGIS approach over the course of the study (Appendix XVIII). Questions were asked to evaluate the participatory methods utilised (process); to examine the effectiveness of the resulting Grenadines MarSIS geodatabase (product); and to understand their usefulness in supporting interactive governance principles.

2.3 RESULTS AND DISCUSSION

This study aimed to use an equitable and transparent multi-level collaborative approach to actively engage a wide range of stakeholders in the development of a holistic and practical multi-knowledge marine resource and space-use PGIS product. Participation was used to: refine objectives and research methodologies applied; obtain existing information and document local knowledge; share and validate information produced; obtain feedback; and determine the appropriate data types and avenues to access to the MarSIS. These practices not only were of use in the collection of information, but were applied to foster a collaborative learning environment as well as an appreciation for the legitimacy and importance of wide-spread stakeholder participation with in the production of relevant ecosystem-based information. A brief assessment of each engagement mechanism as well as application of core PGIS principles applied from both the researcher's perspective and from the results of stakeholder evaluation surveys is provided.

2.3.1 Data scoping and preliminary appraisal

Considering the wide variety and number of involved stakeholders together with the geographical scope of the transboundary island chain, the preliminary appraisal was extremely time-consuming. Existing information was scattered across the islands amongst numerous government agencies, libraries, NGOs and community leaders and had not been systematically compiled before. Personal office visits, key informant interviews and surveys administered to government stakeholders were found to be advantageous in identifying and locating additional sources of information. Approximately three months of full-time work were required to photocopy, scan and catalogue all secondary information, produce an annotated bibliography and convert these into an electronic library format for distribution to stakeholders via DVD. The collation and continual transparent two-way sharing of existing information amongst stakeholders was time-consuming yet aided the sourcing of existing information and ultimately continued over the course of the study. Despite the amount of time (18 months) that this iterative information and data collection process took, the process of information exchange is considered to have been instrumental in building partnerships. The secondary data collection process was truly a group effort that could not have been accomplished in a single visit, short-time frame or without the assistance of a wide range of stakeholders. Moreover this cyclic and transparent communication and information exchange process strengthened working relationships and cultivated a cooperative alliance and trust within the research environment from the outset.

Taking the time for participant observation activities with each MRU group (including each type of fishing activity) as part of the preliminary appraisal provided a unique opportunity to gain insight into each marine-based livelihood. Observation throughout the course of each MRU's work-day combined with the opportunity to ask practical questions, allowed for a better understanding of ethnographic information such as folk taxonomies, marine resource space-use patterns and livelihood practices. This involved going to sea with MRUs which provided information that could not have been acquired from observations or surveys on shore. For example, the lack of use of maps or GPS units for navigation, illiteracy of many MRUs as well as the difference in local naming conventions for coastal areas, marine habitat and classification were recognised during activities at sea. The knowledge obtained from learning activities enhanced understanding of the local context and the capacities of the MRUs. This in turn was required to determine appropriate methods for the ensuing participatory research activities. Furthermore, being seen in the water and assisting with daily activities, earned the researcher the respect of MRUs which in turn built trust and gained community support. Spending the day with each of the various MRUs also allowed time for informal discussion of marine resource problems and the research objectives. This process cultivated a deeper understanding by the MRUs of the importance and legitimacy of including their local ‘tacit’ knowledge in the research and information produced.

2.3.2 Communication and information exchange mechanisms

All stakeholders reported that information exchange was a valuable part of the research. Of all the mechanisms employed, stakeholders preferred the use of summary meetings and email (Figure 2-4). This was followed by the distribution of summary reports, which 94% found useful. It should be noted that this was also the preferred format by government stakeholders, whereas the distribution of paper maps was preferred by NGO and community stakeholders. Surprisingly only half of respondents reported that the Grenadines e-library via DVD was a valuable tool and only 36% reported personal visits to be beneficial for information exchange despite their importance to the researcher to build working relationships and obtain additional secondary information. The majority (75%) of community members found the website useful for easy access to information. The MarSIS blog was reported to be the least desirable mechanism for communication and information exchange. It can be concluded that a spectrum of communication and information exchange methods (i.e. personal visits, hard copy and electronic formats) is needed to reach and engage the full range of stakeholders in a similar project of this magnitude.

The importance of holding periodic participatory validation and feedback meetings is worthy of emphasis. Recurrent sharing of results showed stakeholders how the information was being used. This not only reinforced the legitimacy and importance of locally contributed knowledge, but increased multi-level and multi-scale understanding of the various groups and island community perspectives. There were also several contributing factors that can be attributed to the success of these meetings. First, in order to obtain a large and diverse attendance, it was necessary to hold different meetings targeting the capacity and preferences of the different stakeholder groups (i.e. government vs. community). Fax invitations and

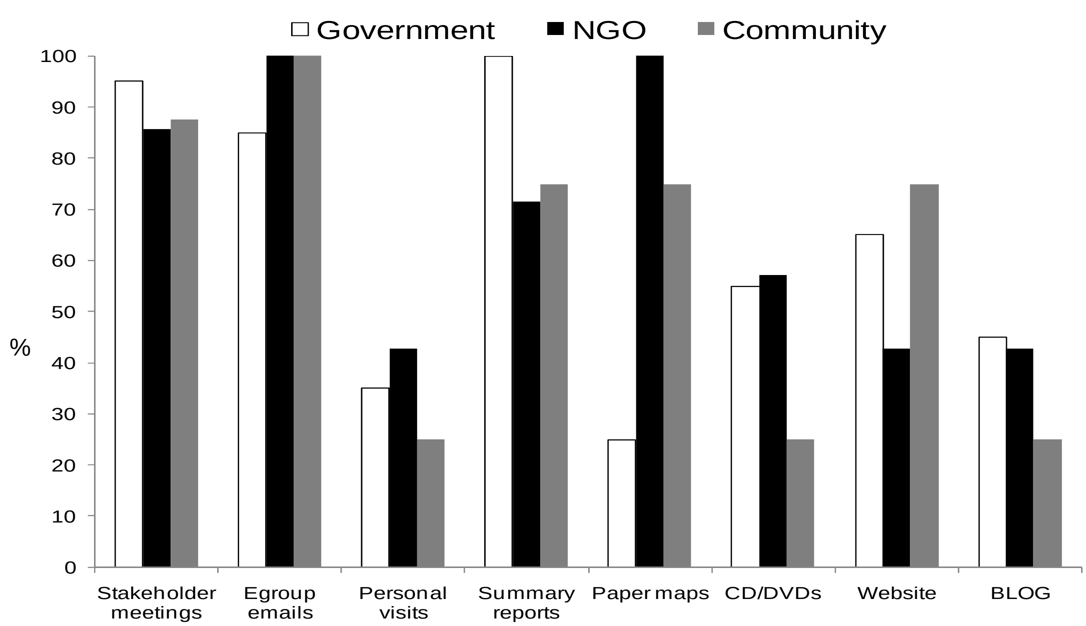


Figure 2-4 Percentage of respondents who reported that both the communication and information exchange mechanisms were either 'very useful' or 'useful', shown separately by stakeholder group.

follow-up phone calls were found to be important to ensure government agency attendance at meetings. Holding community meetings during the early evenings, in convenient locations where the MRUs felt comfortable (i.e. bars or ‘rum shops’, in the streets and fishing camps) was essential in order to obtain a good turnout of these stakeholders. Moreover consulting key informants to find an appropriate time, date and location for each meeting was critical. All stakeholder groups were pleased that careful consideration and time was taken to inform, validate and solicit feedback. Likewise, 22 of the 23 final evaluation respondents who participated in validation exercises, found them to be worthwhile. Although time-consuming, these meetings were vital to foster a collaborative learning environment, build trust and stakeholder ownership in the research and information produced. This partnership approach facilitated sustained cooperation and aided the smooth conduction of remaining participatory research activities.

2.3.3 Marine resource use assessment

The MRU socioeconomic assessment was extremely resource and time consuming due to the geographic scale of the Grenadine island chain consisting of 11 inhabited islands as well as large number (close to 1,000) and diversity of MRU types. Posting the survey instruments on the e-group allowed for questions to be rephrased with local terminology based on stakeholder feedback. Strong interpersonal skills and a genuine interest in learning about and experiencing Grenadine Island culture were essential to obtain wide-participation in MRU assessments. For example, attendance at community festivals (i.e. fishing tournaments, sailing regattas and parties) as well as numerous hours 'lingering' around town, marinas and fishing ramps to observe local activities and chat with community members were necessary to provide an opportunity to informally explain the purpose of the surveys and the need for full participation from them. Secondarily these activities increased the researcher's understanding of the local context and capacity for participation in the research.

During the MRU inventory, 444 individuals who listed their primary livelihood strategy were interviewed including: 169 water-taxi operators, 267 fishers, 9 dive shop operators, 27 day tour operators, 6 charter yacht companies, 7 ferry operators and 5 ship owners. All MRU inventory information generated was verified and accepted by a variety of Grenadine MRUs during each of the 13 community meetings held across the 9 inhabited Grenadine islands.

2.3.3.1 Demographics of users

Information given during these interviews indicated that a total of 826 persons are employed on 519 boats currently operating on the Grenada Bank (Table 2-5). The majority, 75% (or 629 individuals) are based in St. Vincent or the St. Vincent Grenadines, with the largest numbers in Bequia (203), St. Vincent (143), Carriacou (138) and Union Island (124). However with 52 MRUs, the island of Mayreau has the largest per capita number of users at 31%. Grenada and the Grenada Grenadines are home to just 25% of users (197 persons) with the majority based in the islands of Carriacou and Petit Martinique (Table 2-5). Very few Grenadine MRUs are based on mainland Grenada (7) as compared to mainland St. Vincent (134). Fishers are the largest MRU group, accounting for 33% of all Grenadine MRUs identified. It must be noted that all of the fishers were not be identified due to time and resource limitations during the study period. Water-taxi operators are the second largest group accounting for 21%, and charter yacht companies employ a further 16% (Table 2-5). Dive shops have the smallest number of individuals of any MRU group in this inventory. Marine-based tourism is the largest source of income for 56% of Grenadine MRUs' (i.e. dive shops, day tours, charter yacht companies, water-taxis), whereas fishing provides 33% and transport (i.e. ferries, ships) consists of 11% of all Grenadine MRUs' income opportunities (Table 2-5).

The importance of marine resources to livelihoods of the people of the Grenadines must not be underestimated. This inventory indicates the large number and diversity of Grenadine MRUs even though the number of MRUs given here is very likely to be an underestimate as a consequence of the limited time-frame in which the surveys were conducted. It should be recognised that employment activity in the Grenadines is highly seasonal, and that these surveys were carried out during the lobster 'closed' season and the 'low' season for tourism, when many MRUs are likely to have left the islands seeking employment elsewhere, or to have switched to land-based employment during this period. A further constraint in obtaining accurate numbers was an unwillingness of some MRUs, particularly ship owners whom may be involved in an illicit trade industry, to

Table 2-5 Summary of individual marine resource users in the Grenadines identified in the study (2006), shown by group and by island and country of home base, as a percentage of all users and per island capita (based on Table 1-2). (MRU – marine resource use, PSV – Petit St. Vincent, PM – Petite Martinique, NA – data not available)

		St. Vincent & the Grenadines (SVG)									Grenada Grenadines (GND)				Overall	
MRU	MRU Group	St Vincent	Bequia	Mustique	Canouan	Mayreau	Union	Palm	PSV	SVG total	PM	Carriacou	Grenada	GND total	No.	Percent (%)
Marine-Based tourism	Day tours	21	16	4	12	6	32	8	3	102	2	7	0	9	111	13
	Dive shops	9	11	4	3	0	4	0	0	31	0	8	0	8	39	5
	Charter yachts	82	21	1	19	0	0	0	0	123	0	0	7	7	130	16
	Water-taxis	0	20	0	2	24	56	0	0	102	18	49	0	67	169	20
Transport	Ferries	14	18	8	5	0	0	4	2	51	2	12	0	14	65	8
	Ships	8	27	2	3	0	0	0	0	40	0	5	0	5	45	5
Fishing	Fishers	0	90	20	16	22	32	0	0	180	30	57	0	87	267	32
	Total number	134	203	39	60	52	124	12	5	629	52	138	7	197	826	100
	Percent (%)	16	25	5	7	6	15	1	1	76	6	17	1	24	100	
	Per capita	NA	5	3	3	31	7	NA	NA	49	7	2	NA	9		

fully participate. As a result, only 5 of an estimated 16 ship owners were interviewed and none participated in the validation exercises. Therefore, the findings from this group may not be truly representative.

Overall, the results indicate that two-thirds of Grenadine MRUs are Vincentian, suggesting that St Vincent has a heavier reliance on Grenadine marine resource use than does Grenada. This is further demonstrated by a larger number and diversity of Grenadines MRUs operating from mainland St Vincent, rather than from Grenada. Mayreau (belonging to St Vincent) has a particularly high reliance on marine resource use, having the largest per capita number of Grenadine MRUs, despite having the smallest population. Bequia (belonging to St Vincent) also has a particularly high reliance on marine resource use, having the largest number and diversity of Grenadine MRUs.

The vast majority (91%) of Grenadine MRUs are male. There were no females in the shipping or water-taxi MRU groups, only one female working as a fisher and one female working in the sport-fishing industry. Females were found in marine-based tourism activities; with 22 women working for charter yacht companies, 11 women working for day-tour operators and 7 women working in the dive industry (Figure 2-5). Although marine-based tourism MRU groups comprised the largest proportions of female MRUs, it must be noted that the majority of these females were reported to work as either office administrators, cleaning maintenance or onboard as kitchen staff, thus not directly interacting with the marine environment in the same way as the males.

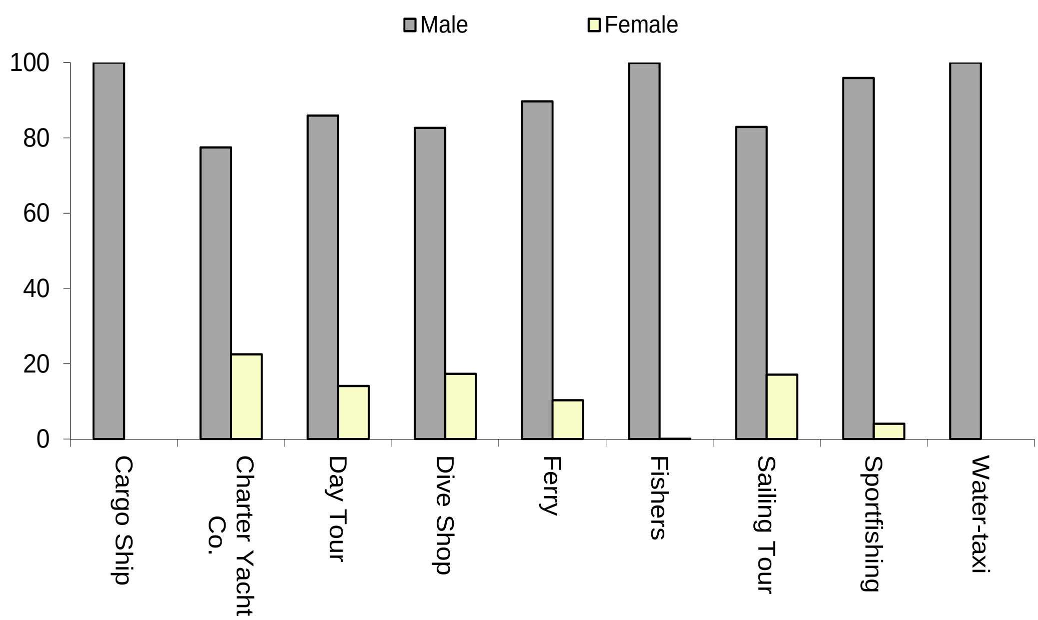


Figure 2-5 Proportion of males and females in each Grenadine marine resource user group identified in this study (2006). Sample sizes are given in Table 2-5. Data for SVG and GND Grenadines are combined.

A total of 519 boats were identified as being owned and/or operated by Grenadine MRUs. Fishing boats (162), charter yachts (152) and water-taxis (122) were the most numerous of the Grenadine MRU boats identified (Figure 2-6). It must be noted that despite the high number of water-taxi vessels reported, many water-taxi operators are also fishers and therefore the majority of water-taxi boats may also be counted as fishing vessels and be double-counted in some cases (Gill et al. 2007). Sixty-four percent of all Grenadine boats included in this inventory are reported to be involved in marine-based tourism activities (i.e. charter yachts, dive shops, day tours, sailing tours, sport fishing, water-taxis) whereas 32% are fishing vessels and only 4% are involved in the transport industry (i.e. ferries and ships).

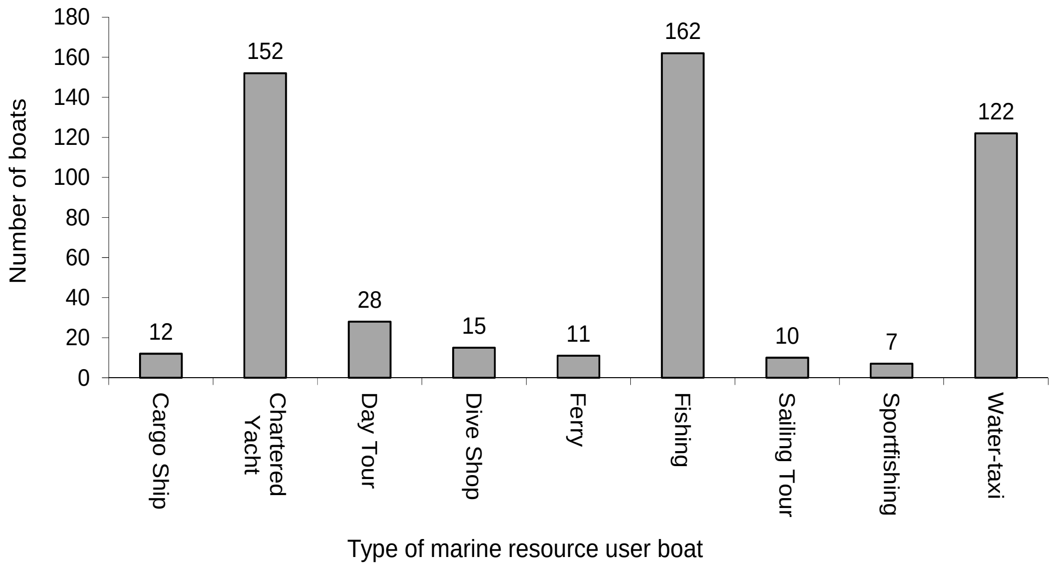


Figure 2-6 Number of boats for each type of Grenadine marine resource user identified in this study operating in the Grenadine Islands (2006). Data for SVG and GND Grenadines are combined.

2.3.3.2 User perceptions of marine environmental issues

When MRUs were asked to state the largest problem/threat currently facing the marine environment of the Grenadines, the vast majority (84%) did identify a problem/threat. Fishing-related activities (whether illegal practices or overfishing) was the problem most frequently identified (by 46% of respondents) as currently affecting the marine environment of the Grenadines. Other identified problems included garbage/pollution (23% of respondents) and harassment/theft (13%) (Table 2-6). Approximately half (49%) of all MRUs believe that a lack of marine management/enforcement in the Grenadines is the main cause of these identified problems (Table 2-7). Ignorance/lack of education about the importance of the marine environment (25% of respondents) and greed (14%) were cited as other causes of Grenadine marine environmental problems. An overwhelming number (65%) of all Grenadine MRUs recommend management initiatives as solutions to the problems facing the Grenadines marine environment (Table 2-8). MRU management-based recommendations included: increased enforcement/ penalties (52% of respondents), increased marine management (11%) and increased use of fishing closed-seasons/gear restrictions (2%). An additional 27% of MRU respondents believe that increased education on the importance of the marine environment would help solve the identified problems.

Table 2-6 Summary of perceived problems/threats currently facing the Grenadine marine environment as identified by Grenadine marine resource users. N = 59.

Identified problems	Frequency	Percent
Garbage / pollution	11	23
Harassment / theft	6	13
Illegal fishing practices	18	38
Overfishing	4	8
Anchoring on reefs	5	10
Ignorance of marine environment	1	2
Docking facilities at ports	2	4
Lack of moorings & poor quality of existing moorings	1	2
	48	100

Table 2-7 Summary of perceived causes for marine environmental problems/threats as given by Grenadine marine resource users. N =59.

Perceived causes of problems	Frequency	Percent
Ignorance / lack of education	9	25
Greed	5	14
No enforcement or management	18	50
Poverty	2	6
Too many fishers	1	3
Government politics	1	3
	36	100

Table 2-8 Summary of recommended solutions marine environmental problems/threats as given by Grenadine marine resource users. N = 59.

Recommended solutions	Frequency	Percent
Education	12	27
Enforcement / penalties	23	52
Alternative livelihoods	2	5
Increased marine management	5	11
Ban spears / longer closed fishing seasons	1	2
Leave area alone	1	2
	44	100

Due to limited time and financial resources, this study reports only on the Grenadine MRUs resident in the territories of St. Vincent and Grenada. However, during the study, it was learned through observation and key informant interviews, that there are a large number of MRUs in the Grenadines that do not reside there. In particular, residents of Martinique are seen as significant users, with Martinique charter yachts comprising more than half of all charter yachts currently operating in the Grenadines (ECLAC 2004), and Martinique trading vessels purchasing the majority of shallow inshore reef fish caught by Grenadine fishers (Chakalall 1994, Jardine and Straker 2003, Gill 2006, FAO 2007). Other significant users are a number of cruise ships and large numbers of tourists (Table 1-2; CCA 1991a, CCA 1991b).

2.3.4 Mapping exercises

As no comprehensive space-use mapping had previously been conducted in the Grenadines, mapping exercises were found to be practical in the systematic collection of each community's spatial knowledge of resource areas and human use patterns. Combining information collected from the MRU assessment survey with participatory mapping datasets allowed for MRU space-use patterns to be integrated with the associated demographic, economic, temporal and environmental attribute information with in the geodatabase. A total of 28 GIS feature classes were created in this way: 1 for the local names of coastal features, 12 for space-use patterns, 7 for marine resources and 8 for issues or threats. From these features, 32 composite island maps were created as a result comprising: 8 island coastline maps annotated with local names; 8 of marine resources; 8 of marine space-uses and 8 of areas of issues or threat (accessible at www.grenadinesmarsis.com/files).

The recurring process of personal visits to distribute hard-copy maps and summary reports after each of the 3 series of mapping exercises, together with customary stakeholder validation and feedback meetings had several benefits. First of all, it allowed for the production of accurate information based on local knowledge, but bounded as stated on the previous page (e.g. unknown number of non-Grenadine users). Additionally, the process of holding continual validation meetings fostered a collaborative working and learning atmosphere, demonstrated to stakeholders the legitimacy of their knowledge and promoted ownership in the information produced thereby creating a common space of understanding amongst stakeholders. It is recognised that conducting the mapping exercises in an incremental fashion (starting with the toponymy, then identifying livelihood space-use patterns and lastly moving on to resources, uses, and areas of threat) allowed the time needed to build capacity in the MRUs as well as the trust required for them to share controversial information (such as illegal activities).

2.3.5 Planning for usability, equitable access and maintenance

The two half-day collaborative planning workshops (held March 11-12, 2009) were valuable in the identification of practical and appropriate avenues for public access to the MarSIS geodatabase as well as to determine other desirable information end-products. Stakeholder feedback was also collected as guidance on avenues for sustainability of the MarSIS after the conclusion of the research. Of the 55 workshop participants, 30 completed questionnaires. All respondents anticipate that the MarSIS will be useful to their work; particularly to access integrated coastal and marine resource information, as a planning and decision-making tool and for educational purposes (Table 2-9). There were 25 planned or on-going research (e.g. marine-based livelihood project proposals) and coastal development projects (e.g. environmental impact assessments) identified in which the MarSIS could be useful to support decision-making (Table 2-9). Ninety percent of stakeholders envisioned the use of the MarSIS for marine spatial planning and 47% believed that it could support the process for designation of a transboundary World Heritage Site (Table 2-9). Nevertheless, in terms of technological capacity, only three departments (i.e. Fisheries, Forestry and Planning) in each country own ArcGIS software. Among these agencies, only the Planning Departments routinely use ArcGIS and only 9 people across both countries were identified as being competent in its use (Table 2-9). In contrast, 80% of respondents were familiar with the Google Earth software application and the majority (67%) suggested that this interface would be the most appropriate application for widespread stakeholder access. Despite this, 57% still desired access to ArcGIS files and 53% recommended hard copy atlases of information.

Overwhelmingly, the internet was identified (by 83%) as the most appropriate avenue for access as compared to a database DVD (17%) or dedicated public-access GIS computer (7%). Stakeholder feedback was instrumental in ascertaining the technological capacity of stakeholders and also served to determine the type of information technology and end products that would allow wide public access to the MarSIS. It can be concluded that to adequately suit the capacities and needs of

Table 2-9 Stakeholder feedback for usability, access and maintenance of the MarSIS (broken down by country and overall) shown as a number and a percentage. Sample size (N) in parentheses. (SVG - St. Vincent and the Grenadines, GND - Grenada, No. – number, % - percent, NA - not applicable).

	Country		Total (30)	
	SVG (16)	GND (14)	No.	(%)
Will the MarSIS be useful for your work?				
Yes	16	14	30	100
No	0	0	0	0
Number of upcoming marine/coastal projects that MarSIS could be of use?	13	12	25	NA
How do you envision MarSIS being used in the future?	*(Open-ended)*			
Information integration and access	9	9	18	60
Planning and decision-making tool	12	7	19	63
Educational purposes	4	4	8	27
What activities would you like to see MarSIS used for?	*(Tick all that apply)*			
Marine space use planning	13	14	27	90
World Heritage site designation	10	4	14	47
Marine Map	11	9	20	67
Software / technological capacity	*(Open-ended)*			
Number of departments with ArcGIS?	3	3	6	NA
Number of people who regularly use GIS?	5	4	9	NA
Have you used Google Earth?	14	10	24	80
What data type will best suite your purposes?	*(Tick all that apply)*			
ArcGIS files	7	10	17	57
Google Earth files	11	9	20	67
Printed maps	8	8	16	53
What will be the most useful access to the MarSIS?	*(Tick one)*			
Internet	13	10	25	83
DVD	2	3	5	17
Dedicated computer	1	1	2	7
Who should be responsible to maintain the MarSIS?	*(Tick all that apply)*			
Government	13	8	21	70
University	9	9	18	60
NGO	6	2	8	27
What is your biggest concern in regards to MarSIS?	*(Open-ended)*			
Maintenance of information	11	7	18	60
Access to information	2	2	4	13
Misuse of information	0	2	2	7
Political will to implement	0	2	2	7
No response	3	1	4	13

a wide range of stakeholders’ in a collaborative endeavour such as this, an array of data products may be required.

Emerging from the evaluation surveys, stakeholders recommend a collaborative institutional network approach as the appropriate mechanism by which to maintain the MarSIS. Approximately 70% of stakeholders are of the opinion that it should be government led, 60% suggested that it should be led by the University of the West Indies and 27% were of the opinion that an NGO (such as the SusGren) should oversee this responsibility (Table 2-9). Group discussion further underscored the importance of establishing a continuing wide-ranging collaborative effort to maintain the information system. Ultimately, maintaining the currency of information was identified as the largest (70%) impediment to the sustainability of the MarSIS after the conclusion of the study. Stakeholders also identified the need for increased political will to promote the national and regional frameworks for formal inter-sectoral cooperation that would be required to implement appropriate use of the MarSIS as well as facilitate the maintenance of and access to its’ information.

2.3.6 Stakeholder evaluation of the MarSIS

All stakeholders who participated in the MarSIS geodatabase validation and evaluation exercise chose to use the Google Earth user interface rather than ArcGIS. All participants gave overwhelmingly positive feedback regarding the practical application of MarSIS and in particular its accessibility within the Google Earth interface. Likewise, the written evaluation survey showed that 86% of stakeholders viewed the Google Earth interface as appropriate technology for public accessibility (Table 2-10). Group discussion revealed that many stakeholders were surprised at how easily the Google Earth application was mastered; especially after such a short training period. Even those who indicated that they 'do not to really use computers much' found that they could use it. Participants stated that they were impressed by the low level of technical expertise required to successfully access the full breadth of MarSIS information as well as the ability to easily create, save and email maps.

The final evaluation was also used to assess the research activity in its entirety in terms of core PGIS principles; namely partnership, inclusiveness, transparency, appropriateness and ownership. The quality of the perceived opportunity of PGIS as a framework to enable interactive marine governance and strengthen capacity building and learning was also assessed (Table 2-10). Of the 55 participants, 43 respondents completed the final evaluation questionnaire; comprising 11 community members, 23 government representatives and 9 persons from NGOs.

Participants were unanimous in their view that MarSIS is a good educational resource which highlights the importance of the sea to the people of the Grenadines and increases understanding of the marine environment. Ninety-three

Table 2-10 Stakeholder evaluation results (broken down by group and overall) shown as percentage (%) of agreement with statement. ***(N - sample size; Comm. - community; Govt. - government)***

Use of communication and information exchange mechanisms	**N**	**Comm.**	**Govt.**	**NGO**	**Mean**
Communication and Information exchange was an important part of this research.	42	100	100	100	100
Usability, appropriateness, comprehensibility for local context		**Comm.**	**Govt.**	**NGO**	**Mean**
The MarSIS is what I expected it to be after hearing about it.	43	100	100	100	100
Do you feel the MarSIS be useful to your agency or group?	43	100	100	100	100
The 'layers' of information within MarSIS are easy to understand.	43	100	100	100	100
Types of information in MarSIS are meaningful to me.	43	100	100	100	100
Stakeholder feedback was incorporated into the research methods.	43	82	91	78	87
MarSIS objectives have been developed according to local needs.	42	90	95	100	95
MarSIS (*in terms of information*) has been developed appropriately for local capacity.	43	73	87	100	90
Use of technology - MarSIS geodatabase		**Comm.**	**Govt.**	**NGO**	**Mean**
The MarSIS (in Google Earth) is too technical for most people to use.	43	27	4	22	14
MarSIS (*in terms of technology*) has been developed appropriately for local capacity.	42	80	83	100	86
Multi-knowledge information integration		**Comm.**	**Govt.**	**NGO**	**Mean**
Local knowledge datasets are a useful part of the MarSIS.	43	100	100	100	100
MarSIS provides information that is unique (i.e. not provided by any other source).	40	90	91	100	93
MarSIS can assist in prioritising marine management needs.	43	100	100	100	100
MarSIS can be used for more informed marine decision-making.	43	100	100	100	100
MarSIS can assist in the planning of more sustainable development.	43	100	100	100	100

Table 2-10 (continued) Stakeholder evaluation results.

PGIS principles and governance	N	Comm.	Govt.	NGO	Mean
The research was carried out in a clear and open manner.	43	100	100	100	100
Effort was made to include a wide range of stakeholders in the research.	43	100	91	100	95
Care was taken to properly validate information / datasets.	43	90	91	100	93
The compilation of the MarSIS was a collaborative or group effort.	42	100	100	100	100
I feel a sense of ownership in the final product.	40	89	74	63	75
Learning, increased understanding and capacity building		**Comm.**	**Govt.**	**NGO**	**Mean**
MarSIS is a good educational resource.	43	100	100	100	100
MarSIS can be used to better understand the marine environment.	43	100	100	100	100
MarSIS highlights the importance of the sea to the people of the Grenadines.	43	100	100	100	100
Participation in this research was a learning experience for me, in terms of:					
1. Participatory approaches used	39	100	95	100	97
2. New technology / skills	42	100	100	100	100
3. Increased my knowledge	41	100	100	100	100
The effort of participating in this research was worth my time.	41	100	95	100	98

percent of participants are of the opinion that datasets derived from local knowledge were useful in providing unique information. All participants reported that the MarSIS product was what they had anticipated at the outset of the project and that the information was meaningful, easy to understand and useful for their respective groups. Likewise all respondents were of the view that the MarSIS can provide a good basis for the prioritisation of marine management needs, informed decision-making and planning for sustainable development.

Respondents unanimously agreed that the research was conducted in a clear and open manner and the process of the compilation of the MarSIS was a collaborative effort. More than 90% of respondents are of the opinion that effort was made to include a wide range of stakeholders and that care was taken to properly validate the datasets. Eighty-seven percent reported that stakeholder feedback was adequately incorporated into the research methods employed. Only two respondents indicated that the objectives of the research had not been developed appropriately for local needs. Overall 75% of respondents and 89% of community stakeholders felt a sense of ownership in the final MarSIS product. All but one respondent agreed that the process of collaborating in this research taught them new approaches to participation. There was undisputed agreement that the process of participating in the research increased knowledge of the marine environment and allowed for the acquisition of new technological skills. Similarly nearly all (98%) of stakeholders reported that the effort of participation in this research was worthwhile.

2.4 CONCLUSION

In this study, the application of PGIS provided a framework to strengthen multi-scale and multi-level linkages and promoted a collaborative and transparent working environment in which equitable and easy access to a wide range of information was available to all stakeholders (e.g. government, NGO, civil-society and the communities). Stakeholders were engaged from the onset of the research (i.e. data scoping and preliminary appraisal, marine resource user assessment, mapping exercises, planning for usability and access) using a number of participatory techniques. Furthermore their feedback (obtained through a number of two-way communication channels, validation exercises and evaluation techniques) were applied to tailor the research methods and produce locally relevant ecosystem-based information. Participation, in terms of informed and equitable multi-level stakeholder involvement, was supported through the establishment of a variety of communication and information exchange channels. These facilitated on-going discussion forums which continue today. This research has demonstrated the usefulness of PGIS as a framework to substantiate the capacity and willingness of stakeholders to participate in interactive marine governance.

This research shows various potential benefits of utilising a PGIS approach in the development of marine resource space-use information system such as the Grenadines MarSIS. The collaborative development of such a system can lay the foundation for ecosystem-based transboundary marine resource management. The advantages of the approach are seen as being two-fold: it not only supports informed decision-making for the transboundary management of marine resources, it also creates engagement of the stakeholders. This engagement takes several forms: legitimacy to participate in research and governance, ownership of information produced, increased inter- and intra-stakeholder understanding and access to information as well as a platform for transparent multi-level and multi-scale communication, information exchange and problem-solving.

Beyond the benefits identified above, a participatory approach may also facilitate improved governance by building adaptive capacity and resilience in management. Engagement of stakeholders is a central element of a PGIS (Tripathi and Bhattarya 2004). It facilitates stakeholder networking through increased dialogue and partnerships. By promoting a collaborative working environment, including the equitable access to information, from the outset supported cooperation amongst a wide range of stakeholders. This in turn, demonstrated a willingness to participate by all levels of stakeholders (e.g. community, NGO and government) across the geographic scale of nine islands and two countries. To this end, the process of a PGIS can provide a practical mechanism for EBM as well as support interactive governance (McCall 2003, Tripathi and Bhattarya 2004).

2.4.1 Lessons learnt: power of GIS

Several lessons have been learned from the utilisation of PGIS approach in the development of the Grenadines MarSIS. First, the power of GIS as a functional tool to allow for the equitable integration and analyses of a diverse range of information to assist decision-making is inherent in the technology. The application of a PGIS platform further allowed the integration of a wide variety of multi-level qualitative and quantitative socio-ecological information. Stakeholder engagement and participatory research practices made it possible to document stakeholders' practical knowledge with in a GIS framework. Local knowledge accounted for 63% (54 feature classes) of the final MarSIS geodatabase. The majority of this consisted of distinctive and comprehensive spatially-based socio-ecological datasets. This provided a means for citizens to contribute to the information base for management and make input to informed decision-making. Furthermore the PGIS approach allowed this to be done across scales and among levels. Hence a PGIS approach was found valuable to obtain and amalgamate a wide range of knowledge from an array of stakeholders and sources, as well as to guide the production of locally-relevant ecosystem-based information. Thus a more complete socio-ecological understanding of the human uses of coastal and marine resources in regards to conservation, biodiversity and to the livelihoods of the Grenadine people was realised which could not have been created in any other manner.

2.4.2 Implications of geographical and jurisdictional scale

The implications of both geographical and jurisdictional scale for the appropriateness of using participatory research in the development of a transboundary PGIS must be carefully considered. The success of utilising PGIS across such a relatively large scale (i.e. two countries), including multiple levels (i.e. nine inhabited islands, thirteen communities and close to a thousand direct marine resource users) is yet to be fully realised. One aspect of working at this geographical and jurisdictional scale is that the research has taken substantially longer than anticipated. Considering the geographical and socio-political complexity of the study area, the importance of transparency, inclusiveness and communication cannot be underestimated. It takes time to understand the local context of the various stakeholders, islands and countries and the implications of the differences among them. Time is also required to allow the range of stakeholders, many of them not accustomed to thinking in terms of data and information, to understand the research objectives and what knowledge they can contribute.

Likewise, the importance of sharing information, seeking continual stakeholder validation and holding evaluation meetings must be emphasised. Holding a range of government and communities meetings after each stage of the research (including the distribution of periodic summary/technical reports and maps) combined with the utilisation of the MarSIS e-group and website for information exchange and open communication has provided for increased understanding and learning, both between and among the various stakeholders. Consulting with stakeholders before each stage of the research and seeking feedback, allowed for adaptability in research methodologies and was well received. Furthermore these mechanisms provided for ownership and legitimacy of the information produced. Therefore the benefits derived from the process of using participation must be highlighted, and may be as important as the production of an appropriate geodatabase itself, particularly in such a multi-level multi-scaled participatory project.

2.4.3 Implications for improving interactive governance

Throughout the development of the PGIS, this research demonstrated the capacity and willingness of a wide-range of stakeholders to collaborate in a process that aimed to improve governance. The PGIS philosophy shares many of the same procedural principles that are prominent in interactive governance. These include: partnership, transparency, inclusiveness, appropriateness, equitable access and adaptability. PGIS was ultimately found to legitimise local knowledge as an informational input to marine spatial management in the study area. The variety of transparent information exchange mechanisms provided for transparent and continual dialogue amongst stakeholders thereby providing for a common space of understanding. This process is considered to have strengthened the capacity for collaboration and participatory research and to have increased ownership in the research and information produced. The use of stakeholder feedback mechanisms to adapt the methods applied and produced products exemplified how stakeholders can contribute to the development of relevant information and governance overall. The findings of this study with regard to the high degree of engagement of stakeholders in the PGIS process, suggest that it has the potential to strengthen the capacity for interactive governance and thus increase resilience.

3 PARTICIPATORY MAPPING OF MARINE HABITATS IN THE GRENADINE ISLANDS

3.1 INTRODUCTION

As discussed in Chapter 1, marine spatial management can offer a constructive means to deal with the uncertainties associated with complex, diverse and dynamic systems by focusing on the distinctive features of an individual place and tailoring management to the local circumstance through an adaptive learning cycle (Young et al. 2007). Marine spatial management recognises the heterogeneous distribution of marine organisms, habitats and human activities in the sea and thus the place-based nature of resources and resource use. Furthermore, an understanding and quantification of the spatial distribution of resources and human impacts are needed to evaluate the trade-offs or compatibilities between the protection of the ecosystem and the services it provides (MEA 2005). Accordingly with the recent shift towards an EA to 'place-based' sea use management, marine habitat maps have become critical in the allocation of marine space (e.g. creation of protected areas and zoning of various human activities) and in designing networks of marine protected areas (Douvere et al. 2007). Marine habitat maps are a fundamental requirement for marine conservation and management, especially when taking an EBM approach (Young et al. 2007, Norse 2010, Olson et al. 2010). Habitat maps allow visualization of the spatial distribution of habitats and can assist in the identification of biodiversity hotspots (Roberts et al. 2003, Balram et al. 2004, De Freitas and Tagliani 2009, Ban et al. 2010). This information can facilitate the evaluation of habitat fragmentation and ecosystem connectivity (Aswani and Lauer 2006a) as well as habitat changes over time (Yang 2009). Although habitat maps are essential in the identification of the location of environmentally critical areas; they can also be of use to ascertain socially and economically critical areas (Aswani and Lauer 2006b, De Freitas and Tagliani 2009, Ban et al. 2010).

Conventional scientific methods for the creation of marine habitat maps, such as field surveys and *in situ* measurements, are still important but can be financially and logistically burdensome (Mishra 2009, Yang 2009). Remote sensing, together with geospatial technologies such as geographical information systems (GIS) have gained wide acceptance in recent years as a cost-effective alternative for producing technically sound habitat maps (Yang 2009). Geospatial technologies not only provide a synoptic view of an area, but can also facilitate information integration across various disciplines and scales. They can provide rapid access to spatial analyses to produce information for decision-making and management (Balram et al. 2004, Douvere et al. 2007, Aswani and Vaccaro 2008, Castello et al. 2009, De Freitas and Tagliani 2009). However, the mapping products, like those of conventional mapping methods often lack relevance to local resource users (Mackinson and Nottestad 1998).

Marine resources are of vital importance to the people of the Grenadines, but increasing pressures from tourism development and the non-sustainable use of these resources are making the planning and management of marine resource use on the Grenada Bank increasingly complex (Chapter 1). No comprehensive marine habitat map for the entire Grenada Bank (Figure 2-1) has been created at a scale useful for national or transboundary management. Moreover there is little or no integration amongst disciplines, between nations or among knowledge systems (i.e. conventional scientific and local 'explicit' knowledge). This segregated approach has contributed to the prevention of environmental degradation within the Grenadine Island chain (CCA 1991a, CCA 1991b, Culzac-Wilson 2003, ECLAC 2004, Joseph 2006, Mattai and Mahon 2007), and demonstrates a clear need to apply an integrated, transboundary, EA to management of the Grenadines' marine resources.

In order to develop a marine space use information system that is understood by all stakeholders it is essential to have base maps of marine habitats that reflect their knowledge and that they accept as relevant to their day to day use of the ecosystem (St. Martin and Hall-Arber 2008). Given these facts, the development of a practical transboundary, coastal marine habitat map of the entire Grenada Bank was considered a necessary foundation for the creation of the geospatial Grenadines MarSIS framework. Wide stakeholder participation in the mapping steps was seen as key to producing a 'locally-relevant' map that could incorporate available scientific and local knowledge of habitats and their use, ultimately contributing to EBM of the Grenadines' marine resources (Chapter 2).

This chapter describes how habitat maps were developed by accessing the knowledge of stakeholders and combining this with the conventional technical habitat definitions and extant maps for the Grenada Bank.

3.2 METHODS

In order to develop a useful, transboundary, coastal marine habitat map of the Grenada Bank the research took a multi-level, multi-scaled collaborative approach. The utilisation of stakeholder engagement (as described in Chapter 2) guided the development of a locally appropriate habitat classification scheme. A PGIS approach was also applied to improve upon conventional mapping techniques and incorporate fishery uses and values within the map products. Each of the steps and the participatory approaches adopted are described in more detail in the following sections.

3.2.1 Developing a locally relevant habitat classification scheme

The first step in selecting a locally relevant habitat classification scheme involved a comprehensive review of marine habitat classification schemes, used both regionally and globally, for reef ecosystem mapping and marine resource management (e.g. Mumby and Harborne 1999, Kendall et al. 2001, Andrefouet et al. 2003, Madden and Grossman 2004, Ball et al. 2006). A second step was an extensive literature and data search of all available secondary information on the distribution of coastal and marine habitats of the Grenada Bank as described in Chapter 2. This included marine-related GIS datasets, satellite imagery, aerial photos and other collateral marine habitat information sources (e.g. CCA's country environmental profiles, FAO's preliminary data atlases, EIA maps and reports). It involved summarising existing habitat information and assessing the data quality in terms of geographic extent, appropriateness, detail (i.e. scale/resolution) and variation in applied habitat classification schemes.

Once all of the collected information had been summarised it was shared at the start of one-on-one interviews with marine resource managers (i.e. the chief fisheries officers, national environmental coordinators, marine biologists and NGO leaders) in both countries. This included a presentation and informal discussion of the many and varied habitat classification schemes that have been used previously. Semi-structured one-on-one interviews (Appendix XIX) were then conducted with these stakeholders to solicit their advice in order to ascertain a locally-relevant habitat classification scheme that would be most useful for marine and coastal decision-making and management initiatives.

An important outcome of sharing and discussing the various habitat classification schemes with marine resource managers, as well as the results of participant observation exercises with the marine resources users (Chapter 2), was the recognition of a need to use a habitat classification scheme that is detailed enough to serve the needs of marine resource managers, whilst at the same time relevant (comprehensive and meaningful) to the marine resource users (MRUs). In an attempt to address this need, a 'marine habitat flashcard' exercise was conducted with a broad range of persons grouped as either 'scientists' (e.g. marine resource managers from government agencies, NGOs and academia) or local in-water resource users (e.g. commercial and recreational diver-fishers) labelled here simply as 'MRUs' to examine both the number of habitat classes that both groups would 'naturally' use, and the names they would apply to these classes. The 'scientist group' comprised a government fisheries marine biologist from each of the two countries; marine scientists from a regional intergovernmental organisation (Caribbean Regional Fisheries Mechanism) and a quasi-governmental organisation (Tobago Cays Marine Park); and two academic (University of the West Indies) marine biologists. The 'MRU group' consisted of four full-time diving fishers (one from Bequia, one from Mayreau, one from Union Island and one from Carriacou), four dive shop operators (one from Bequia, two from Mustique and one from Carriacou) and one yacht captain from Grenada. Diving fishers were used because they would be in direct contact with marine benthic habitats whereas other types of fishers using gear from boats may not be as familiar with them.

This flashcard exercise involved the use of 30 individually numbered underwater photographs (flashcards), representing the range of common shallow water marine habitats found across the Grenada Bank (e.g. coral reef, seagrass, sand *inter alia*) (Appendix XX). All photographs were taken as underwater landscape shots using a common perspective (i.e. the camera held at the same angle and distance from the substrate) and covered the typical variety and densities of key species found across common sub-littoral habitats. This meant that fewer photos (2-3) were used for the less variable habitats such as sand, whilst more photos (4-9) were used for diverse habitats such as coral reefs and reef-associated hard bottom habitats. Participants were given the full set of habitat flashcards to review and asked to group them into piles of similar 'bottom-types' (habitat classes). Thereafter they were asked to provide a name for each habitat class identified. Results were recorded for each participant, by stakeholder group and by island of residence, as a set of flashcard numbers assigned to each named habitat class.

3.2.2 Development of an appropriately scaled marine habitat map

To accommodate the full extent of the transboundary Grenada Bank marine ecosystem whilst still maintaining a locally-relevant (appropriate) scale to the Grenadine communities, the geographical scope of the marine habitat map was delimited by the island coastlines and the 60 m isobath, such that it spanned the entire ‘shallow’ bank between the island of Bequia in the north and Ilse de Caile in the south, covering approximately 2000 km^2 (Figure 2-1).

The Grenada Bank marine habitat mapping exercise consisted of two main parts. One was to develop a shallow water habitat map using both a ‘mixed-method’ of conventional remote sensing and ground-truthing in the field to model the shallow water portion of the bank (Figure 3-1a) in detail. The other was to develop a deep water habitat map by taking direct field measurements using a standardised sampling grid and remote video to interpolate marine habitat for the deep water portion of the bank (Figure 3-1b). Although two marine habitat maps were created initially; ultimately these two maps were merged into a single Grenada Bank marine habitat map product using standard ArcGIS geoprocessing tools.

To ensure that the map products incorporated the habitat classification schemes of both the resource managers (i.e. scientists) and the marine resource users, and to build common understanding among them; representatives of both key stakeholder groups were involved in the entire field data collection exercise. The Grenada Bank marine habitat map was further enhanced by the simultaneous collection and recording of additional information during the field survey cruise, taking advantage of the presence of local fishers on the research team and of sonar equipment on-board the survey vessel. This included the collection of supplementary bathymetric data and a judgement of the suitability of the habitat observed at each survey site for fishing, by gear type and by target species.

The creation of the shallow water habitat map section, the deep water map section and the data collection for the enhanced layers are each described separately as follows.

3.2.2.1 Shallow water habitat map

Developing the shallow water habitat map involved the following steps: compilation of remote sensing information and visual interpretation of marine habitats; local knowledge validation; and an accuracy assessment based on ground truthing exercises. Each of the steps and the participatory approaches adopted are described below in detail.

Remote sensing information:

The primary method used for creating a shallow water basemap was passive remote sensing. This involved the visual interpretation of high resolution georeferenced image data (e.g. aerial photos, satellite imagery) using secondary information and personal knowledge.

High resolution imagery was not available for the entire study area. The mapping exercise therefore relied on the merging (i.e. mosaicing) of a number of different

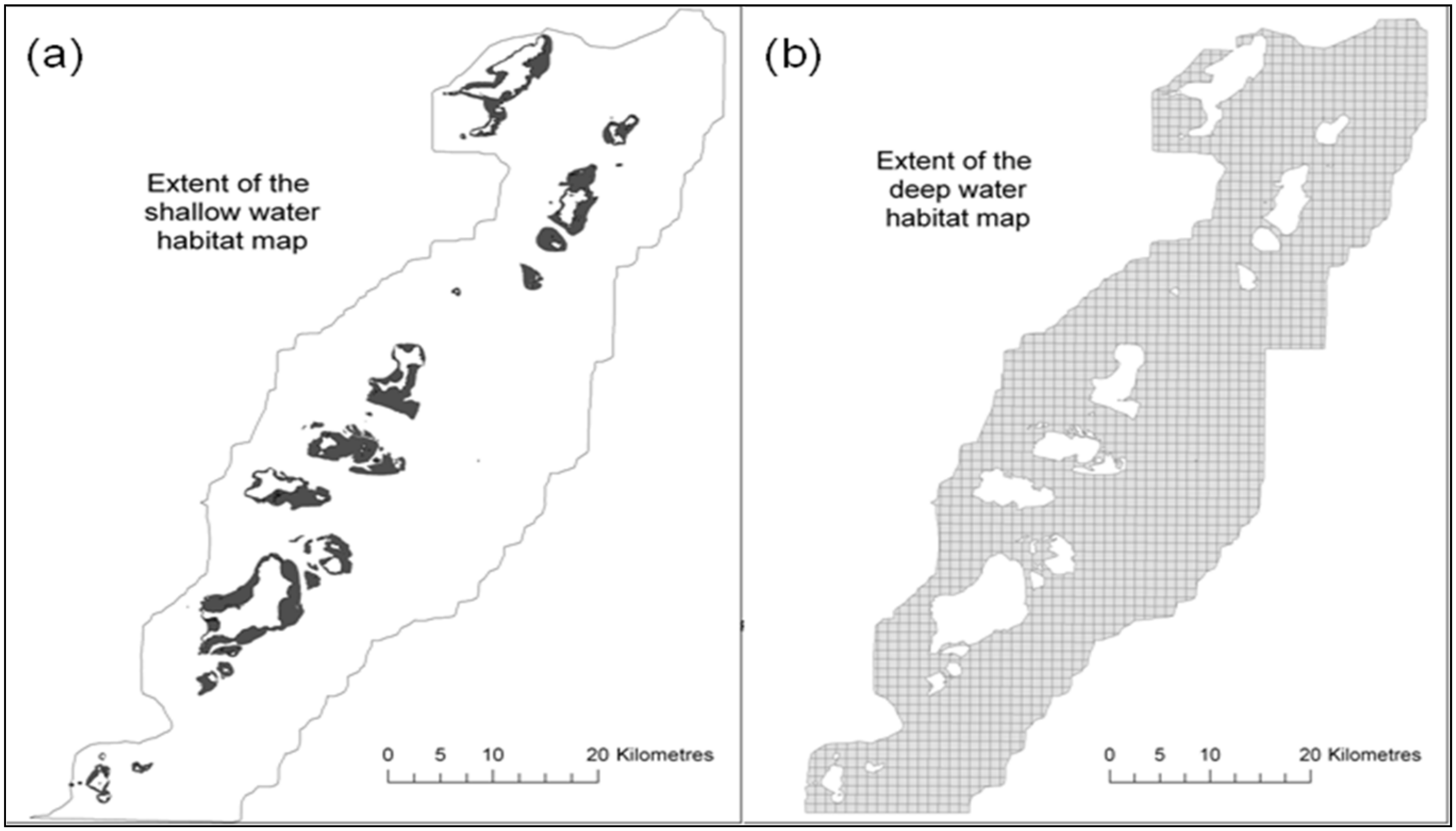


Figure 3-1 Maps showing (a) the extent of the areas covered by the shallow water habitat mapping exercise (shown by black shading), and (b) the extent of the area surveyed for the deep water habitat map (shown by grey shading).

imagery datasets (Table 3-1) to allow complete coverage of the shallow water portion of the Grenada Bank. Additional secondary mapping information, such as GIS data, nautical charts, topographic maps and aerial photos were also scanned, imported and geo-referenced to a common coordinate reference system (i.e. WGS 84 UTM Zone 20N) using ArcGIS (Table 3-2 and 3-3).

Shallow water habitats in the vicinity of the islands were mapped digitally (digitized) from available aerial / satellite imagery (Table 3-1) using passive remote sensing techniques following Kendall et al. (2001). The spatial extent of this shallow habitat digitizing exercise was constrained by light penetration through the water column, and therefore precluded the interpretation of habitats in water depths greater than approximately 20 m (Figure 3-1a). The digitizing exercises involved visual interpretation of habitats from the imagery (Table 3-1) and subsequent production of a digital map with the aid of the Habitat Digitizer ArcGIS software extension. This extension allowed for the delineation of identified habitats by a map producer on the electronic images using a point and click menu system to assign each delineated polygon to a habitat type according to the chosen classification scheme. To ensure uniform data creation, the minimum mapping unit restriction was set to 0.4 hectare (one acre) and the digitising scale was set to 1:6,000 as the best compromise between detail and mapping time (Kendall et al. 2001) except in cases when habitat boundaries were

Table 3-1 List of imagery and other secondary mapping datasets used to digitize shallow water habitat, listed here by country, area of coverage, source, scale and year.

Country	Area of Coverage	Image Source	Scale / Resolution	Year
Grenada	Northern Carriacou	Digital Globe Satellite Imagery	< 1m	2005
	Petit Martinique and Fota	Digital Globe Satellite Imagery	< 1m	2005
	Southern Carriacou, White and Saline Islands*	Digital Globe Satellite Imagery	< 1m	2005
	Isle de Rhonde, Isle de Caile, Diamond Rock*	Digital Globe Satellite Imagery	< 1m	2004
	Island of Grenada	IKONOS Satellite Imagery	4 m	2000
	Island of Carriacou, White, Saline and Frigate Islands	IKONOS Satellite Imagery	1 m	2000
	Grenada (northern half)	Land & Surveys Topographic Map	1:25,000	1979
	Grenada Grenadine Islands	Land & Surveys Topographic Map	1:25,000	1978
St. Vincent and the Grenadines	Grenada Bank (except Union)	Digital Globe Satellite Imagery	4-1m	2006
	Petit Mustique, Savan Island and Savan rocks*	Digital Globe Satellite Imagery	< 1m	2004
	Big L'Islet, Small L'Islet*	Digital Globe Satellite Imagery	< 1m	2004
	Channel Rock, Break Rock and Mayreau Baleine*	Digital Globe Satellite Imagery	< 1m	2004
	Bequia to PSV (SVG Grenadines)	IKONOS Satellite Imagery	4 m	2000
	Island of St Vincent	IKONOS Satellite Imagery	4 m	2000
	Northern part of Bequia	IKONOS Satellite Imagery	1: 33,000	Unknown
	Mustique, to Mayreau	Landsat ETM Satellite Imagery	30 m	1999
	Union, Palm, PSV, PM and Northern Carriacou	Landsat ETM Satellite Imagery	30 m	1999
	St. Vincent Grenadine Islands	Land & Surveys Topographic Maps	1:25,000	1970-1978
	St. Vincent Grenadine Islands	Black & White Aerial Photographs	Unknown	1999
Grenada Bank (Both Countries)	St Vincent, Grenada Bank and Northern Grenada	Landsat ETM Satellite Imagery	30 m	2000
	Bequia to Carriacou	Imary Nautical Chart	1:86,000	2002
	Central Grenadine Islands	Imary Nautical Chart	1:32,500	2002
	All Grenadine Islands	Imary Nautical Chart	1:192,000	2002
	St Vincent, Grenada Bank and Grenada	US Navy Nautical Chart	1:125,000	1969

** Indicates imagery which was purchased to fill data gaps.*

Table 3-2 Additional secondary information (containing marine habitat maps or descriptive references) used to aid shallow water habitat image interpretation, listed here by country, name of report, author, year of publication and area of coverage.*(SVG – St. Vincent and the Grenadines, GND – Grenada)*

Country	Name	Author	Year	Area of coverage
GND	Assessment of mangrove ecosystem of Tyrrel Bay, Carriacou	Moore	2004	Carriacou
	Carriacou coastal areas assessment report for GEF	Moore and Still	2005	Carriacou
	Country environmental profile: Grenada	CCA	1991	Grenada Grenadines
	Environmental assessment report: High North national park, Carriacou	Moore et al.	2000	Carriacou
	Grenada Grenadines: Preliminary data atlas	CCA/ECNAMP	1980	Grenada Grenadines
	Master plan for the tourism sector	Govt. of Grenada and OAS	2002	Grenada Grenadines
	Nautical tourism strategy of Grenada, Petit Martinique and Carriacou	Jackson, Gittens, Finlay, Jessamy	2003	Grenada Grenadines
	Nearshore marine resources of Carriacou, Petit Martinique and outlying Islands: Status, concerns and recommendations	Price and Govindarajulu	1998	Grenada Grenadines
	Preliminary observation of Anse La Roche beach	Patriquin and Hunte	1996	Carriacou
	Resource use survey, mapping and preliminary zoning of Sandy Island marine protected area	Issac	2006	Carriacou
	The regional training workshop in methodologies for coastal inventories information management: Grenada's coastal inventory	Taylor and Thompson	Unknown	Grenada Grenadines

Table 3-2 (continued) Additional secondary information.

Country	Name	Author	Year	Area of coverage
SVG	2004 update on environmental management in Mustique	Overing and Cambers	2004	Mustique
	A natural history monograph of Union Island	Daudin	2003	Union
	A preliminary survey of Frigate Island and Frigate Bay, Union Island, St. Vincent	Smith and Oxenford	1986	Union
	A survey of the nearshore marine environment of Union Island	Price and Price	1994	Union
	An environmental impact assessment of the airport runway extension of Union Island	Price and Price	1994	Union
	Artisanal fisheries in St Vincent and the Grenadines	Morris	1983	St. Vincent & the Grenadines
	Country environmental profile: St. Vincent and the Grenadines	CCA	1991	St. Vincent & the Grenadines
	Environmental issues related to proposals for the lagoon, Lagoon Bay, Mustique	Cambers	1992	Mustique
	L'Ansecoy bay shoreline assessment	Moffatt & Nichol	2004	Mustique
	Marine tour guide workshop: Manual for tour guiding in Mayreau	MEDO	2003	Mayreau & Tobago Cays
	Monograph of Union Island	Daudin	Unknown	Union
	Mustique coral reef assessment	Lapointe	1991	Mustique
	Mustique environmental inventory: Volume 1	Overing and Cambers	1995	Mustique
	Paradise Lost: A postmortem of the Ashton marina project	Price and Price	1998	Ashton Lagoon, Union Is.
	Preliminary description of coral reefs of the Tobago Cays	Lewis	1975	Tobago Cays
	Sea turtle recovery action plan for St Vincent and the Grenadines	Scott and Horrocks	1993	St. Vincent & the Grenadines

Table 3-2 (continued) Additional secondary information.

Country	Name	Author	Year	Area of coverage
SVG				
	SOS Union Island: Some ecological aspects	Daudin	Unknown	Union
	St Vincent and the Grenadines: Preliminary data atlas	CCA/ECNAMP	1980	St. Vincent and the Grenadines
	St. Vincent and the Grenadines beaches: Short text & photo summary	Jackson	1986	St. Vincent and the Grenadines
	St. Vincent and the Grenadines	Mills	2001	St. Vincent and the Grenadines
	St. Vincent and the Grenadines national biodiversity strategy and action plan	Simmons and Associates	2000	St. Vincent and the Grenadines
	Tobago Cays marine biodiversity conservation project summary report	Comley et al.	2002	Tobago Tobago Cays
	Water quality in Ashton Harbour, Union Island: Environmental impacts of the marina and recommendations for restoration	Goreau and Sammons	2003	Union Is.
Both countries	Sailors guide to the Windward islands	Doyle	2006	Grenadine Islands
	Vegetation of the Grenadines, Windward islands	Howard	Unknown	Grenadine Islands

Table 3-3 GIS marine habitat datasets considered for use; listed by country, habitat type, description and data source. (*SVG – St. Vincent and the Grenadines, GND – Grenada, TNC – The Nature Conservancy)*

Country	Feature class name	Description	Data source
Grenada	Beaches TNC GND	White sand beaches of Grenada	The Nature Conservancy
	Black Sand Beaches GND	Black sand beaches of Grenada	The Nature Conservancy
	Mangroves GND	Mangroves of Grenada	The Nature Conservancy
	Reef Class TNC GND	Geomorphology of Grenada	Millennium Coral Reef Mapping Project
	Rocky Shore Beaches GND	Rocky shorelines of Grenada	The Nature Conservancy
St. Vincent	Beaches TNC SVG	White sand beaches of St. Vincent and the Grenadines	The Nature Conservancy
and the	Benthic Habitat	Marine habitats of St Vincent and the Grenadines	Coastal Resources Information System
Grenadines	Black Sand Beaches SVG	Black sand beaches of St. Vincent and the Grenadines	The Nature Conservancy
	Reef Class TNC SVG	Geomorphology of St. Vincent and the Grenadines	Millennium Coral Reef Mapping Project
	Rocky Shore Beaches SVG	Rocky shorelines of St. Vincent and the Grenadines	The Nature Conservancy
	Wetlands TNC SVG	Wetland areas for St. Vincent and the Grenadines	The Nature Conservancy

not easily discernible at this scale. In these cases, a broader scale (1:10,000) was used to help in defining habitat boundaries. At these scales, small features visible in the imagery, such as very small, isolated patches of reef or single large coral heads, were not digitized and were not considered significant in this mapping project. Habitat boundaries were delineated around the configuration of a feature (i.e. spectral signature) in the satellite imagery and the corresponding habitat classification was assigned. Secondary information was used to aid image interpretation where available. This included habitat maps, nautical charts, and other descriptive references (Table 3-2) dealing with benthic and coastal habitats of the Grenadine Island chain as well as personal knowledge of the local marine environment. The area mapped in this way covered the coastal and near-shore marine environments surrounding each island extending offshore to approximately 20 m in depth, and will subsequently be referred to as the 'shallow water habitat map' in this study.

Participant validation:

After the creation of the shallow water habitat map as described above, a participatory local knowledge validation step was undertaken. The Grenada Bank map was split into 14 subset maps, to allow for a local knowledge validation exercise with stakeholders in order to improve the accuracy of the shallow water map before undertaking the ground-truthing assessment. This involved printing each subset map as a large colour poster (24" x 36") showing the satellite imagery overlaid with the derived habitat polygon boundaries (Appendix XXI). These maps were then individually reviewed with at least two types of resource users (i.e. recreational dive-fishers and commercial fishers) in each island. All changes to the habitat polygons proposed by the marine resource users were written directly on the hard copy maps and subsequently updated in the geodatabase. A subsample of these changes was subsequently checked during the ground truthing field survey (described in the following section) in order to assess accuracy and determine the usefulness of the extra participatory step in the creation of the shallow water habitat map.

Ground truthing:

Following the map creation via remote sensing and participant validation, a stratified random sampling design was used to determine the accuracy of the shallow water habitat map through field surveys (ground-truthing). This involved overlaying the shallow water map area with 1 km^2 grid squares (individually numbered) using Hawth's Analysis Tools 'Sampling Toolbar' software (http://www.spatialecology.com/htools/tooldesc.php) rendering a total grid area of 407 km^2. Fifty percent of these numbered grid cells (or 204 ground-truthing survey sites) stratified by percent of remote sensed habitat type, were selected for ground-truthing using Hawth's Analysis Tools random number generator. Accordingly, the shallow water ground-truthing sites comprised the following proportions of presumed habitat types: 37% coral reef, 22% seagrass, 20% sand and 21% mixed-live bottom habitats (Table 3-4; Figure 3-2).

Table 3-4 The proportion of shallow-water marine habitats encountered in the survey and the number of corresponding survey sites.

Habitat type	Number of survey sites	Percent (%) of sample
Coral reef	75	37
Seagrass	45	22
Mixed-live bottom	43	21
Sand	41	20
Total	204	100

Shallow-water habitats were ground-truthed from August 5th – 8th 2008 and from August 7th – September 2nd 2009 using snorkel or SCUBA gear, depending on the water depth, by a two-person research team (i.e. marine biologist and MRU) aboard a small artisanal fishing boat assisted by a fisher from the island being surveyed. All ground-truthing of the shallow water map for the entire Grenada Bank was conducted by the same two person research team for consistency across the entire area; although different fishing vessels and fisher assistants were used in each island. Information collected during ground-truthing: location using a handheld Garmin Etrex GPS; water depth to the nearest metre using a Depthmate portable depth-sounder; a photograph representative of the habitat using an Olympus Stylus SW770 underwater camera (operated by the scientist); as well as habitat type assessed independently by both research team members (scientist and

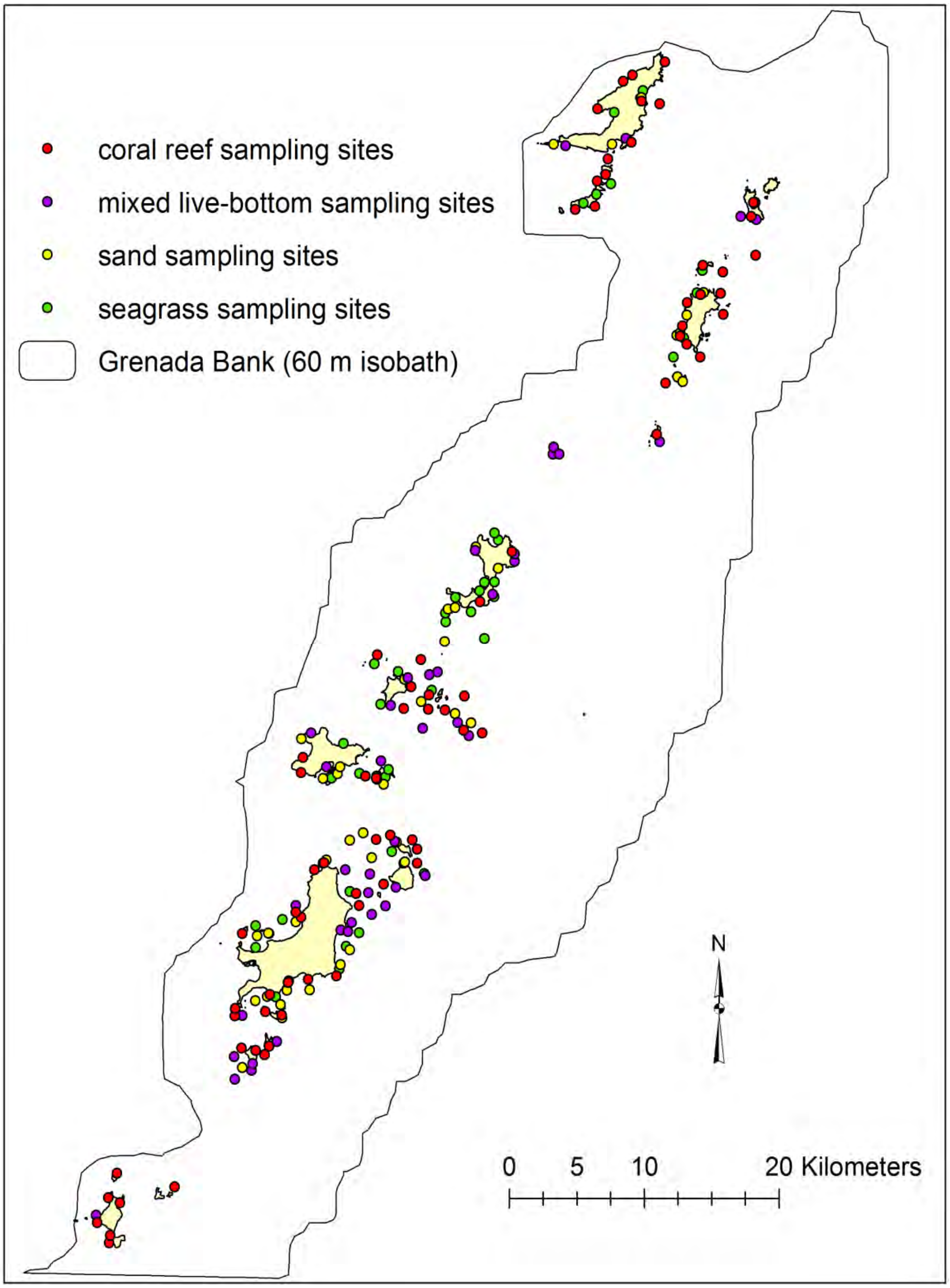


Figure 3-2 Map showing the shallow-water ground-truthing survey sites.

MRU); an estimate of benthic cover or density of habitat (low, medium, high); and habitat rugosity (low, medium, high). Each site was also judged by the MRU for its suitability as a fishing ground, based on water depth and the visual examination of the habitat (ignoring any previous knowledge of the given site). The MRU's judgement included an assessment of the likely fishery species that would be available (conch, lobster, reef fish); the fishing gear that would likely be used there (line, net, fish pot, SCUBA tank, spear gun); the apparent quality of the fishing ground (poor, okay, good, very good); and whether he would choose to fish at the site (yes, no).

The validity of the initial habitat classification based on remotely sensed data and local knowledge (i.e. the accuracy of the shallow water mapping exercise) was determined by an accuracy assessment which compared the mapped interpretation with the results of the ground-truthing exercise. Overall accuracy was taken as the percentage of points on the map which were classified correctly according to the field check. Producer accuracy was measured by how well the map producer classified the different habitat types (i.e. what percent of each habitat type was correctly classified). User accuracy was measured as the reliability of the map generated from the classification scheme. The latter provides the map user with a measure of the probability that the polygons on the classified map have been correctly assigned during the classification process. In this study, error matrices were used to calculate the overall and mean accuracy of the final shallow water habitat map from both the user accuracy and producer accuracy points of view. Following the assessment, the shallow water map was updated using ArcGIS by editing all ground-truthing sites that were found to have been wrongly interpreted in the remote sensing exercise, thereby increasing the accuracy of the final shallow water habitat map.

3.2.2.2 Deep water habitat map

The remainder of the Grenada Bank study area, ranging in depth from 20 – 60 m was too deep for visual interpretation of habitats from aerial photos/satellite imagery (i.e. remote sensing) and required a different approach to habitat mapping than was applied to the shallow areas. For this deep water area of the Grenada Bank for which there was little or no existing information, a benthic habitat field survey and modelling approach was applied and is described as follows.

A standardised sampling grid was used to collect direct field measurements. To this end a systematic equidistant sampling design (comprising a 1 km^2 grid) was applied to the deep areas of the Grenada Bank and 33% of the grid cells (217 sites, representing every 3rd grid cell) were physically sampled (Figure 3-3).

Deep water sites were surveyed from August 5th – 8th 2008 and from August 7th – September 2nd 2009 by a research team comprising a marine biologist, a local commercial fisher, a local yacht skipper (recreational fisher) assisted by two deckhands aboard a 14.3 m catamaran. All sites were examined by the same persons to allow for consistency in the data collection across the entire area. Benthic habitat was observed and assessed at each site using a remotely operated submersible live-action SeaViewer video camera, illuminated with LED lights, and operated via a 75 m cable. The camera equipment was rigged within a weighted PVC cradle (Figure 3-4a) to protect it, and set mostly perpendicular to the seafloor, yet tilted at a slight (20^o) angle in order to provide a 'landscape-view' across the substrate. Deployment of the video camera apparatus always occurred off the stern of the vessel (Figure 3-4a) and was handled by a two person team, in order to prevent entanglement. The deployment procedure at each deep water survey site required that the catamaran was held relatively stationary at the GPS waypoint whilst the camera was lowered, and then allowed to drift slowly with the current while the video footage was recorded and viewed real-time on deck using a portable DVR screen (Figure 3-4b). Real-time viewing allowed the operator to hold the camera approximately 1 m off the seafloor to obtain consistent images (approximately similar landscape perspective at each site). A minimum of 3 minutes filming time was recorded at each site including the decent

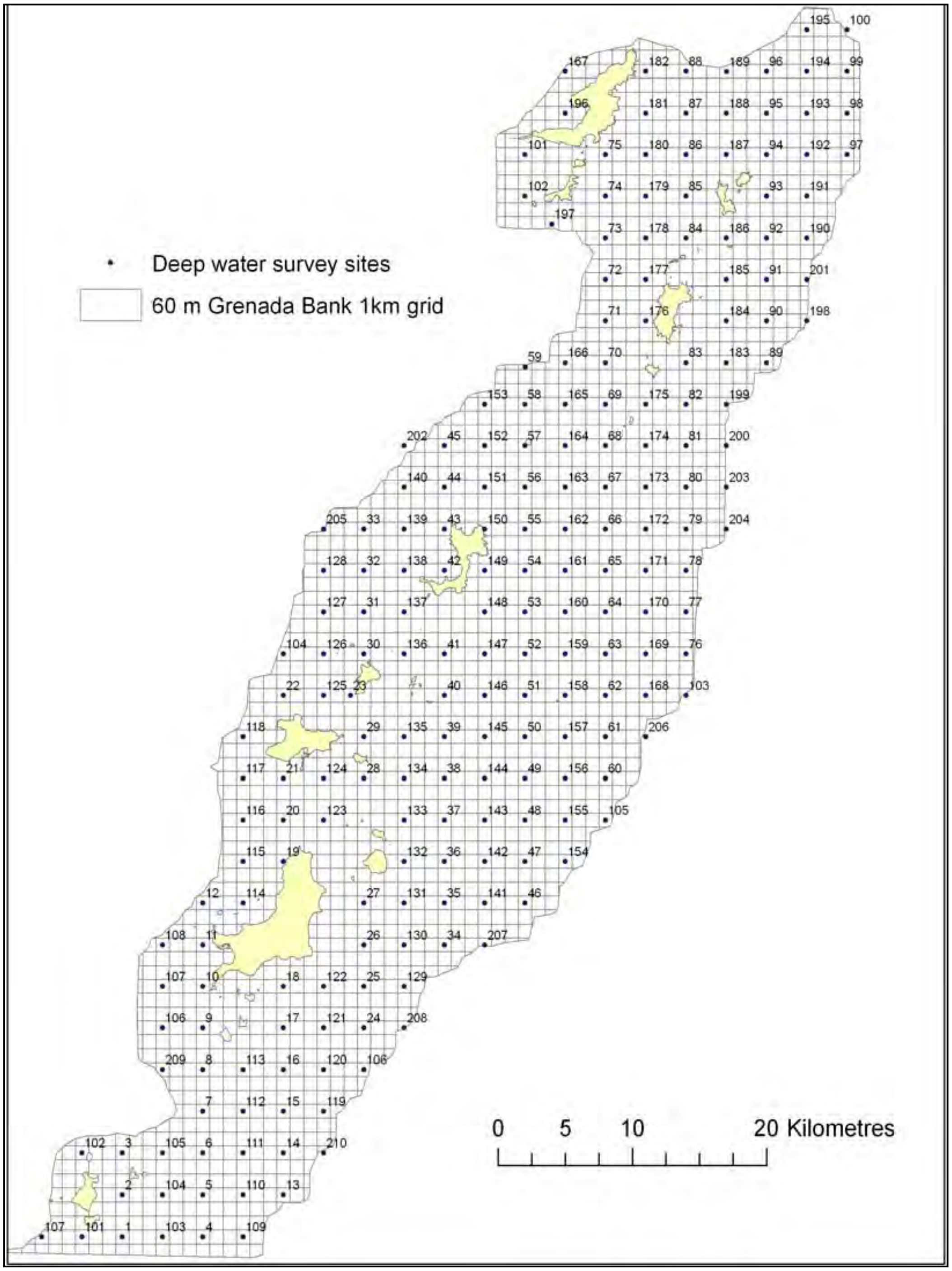


Figure 3-3 Map of the Grenada Bank study area showing the 1 km^2 sampling grid and selected deep water survey sites numbered.

and ascent of the video camera in order to accurately assess the most prominent habitat type. All recorded video footage was overlaid with the date, time, GPS location and vessel speed using a Sea-Track GPS Video Overlay. The video footage was subsequently reviewed independently by the fisher and scientist and variables recorded while in transit to the next survey site (Figure 3-4b). Information recorded for each deep water field survey site was similar to the ground-truthing variables and included: location and water depth to the nearest metre using a Garmin 540s depth sounder with a standard dual frequency (50 and 200 kHz) transducer; a video representation of the habitat; habitat type assessed independently by two observers (scientist and MRU); benthic coverage or density of habitat (low, medium, high); and habitat rugosity (low, medium, high). Each site was also judged by the MRU for its suitability as a fishing ground, based on water depth and the visual examination of the habitat (ignoring any previous knowledge of the given site). The MRU's judgement included an assessment of the likely fishery species that would be available (conch, lobster, reef fish); the fishing gear which could be used (line, net, fishpot, SCUBA tank, speargun); the apparent quality of the fishing ground (poor, OK, good, very good) and whether he would choose to fish at the site (yes, no).

The deep water field survey resulted in two sets of discrete nominal habitat data (i.e. scientist and MRU). As a result, two distinct marine habitat maps were created for the deep water portion of the map (Table 3-5). Both sets of habitat survey point data were processed in a similar fashion; using the 'Union' geoprocessing tool, each point dataset was joined with the Grenada Bank deep water portion of the grid. Then the ArcGIS Spatial Analyst extension 'Expand' geoprocessing tool was used to expand each survey point's assigned habitat class in a 1.5 km square radius (thereby creating a modelled surface with 3 km^2 habitat cells) in order to coalesce with adjoining data points and create a continuous modelled surface for each of the two deep water habitat maps.

Comparative analyses of in-situ habitat classification were then pursued using the Spatial Analyst 'Equal To' geoprocessing tool to identify overall areas of difference between the two deep water habitat maps. In this way the corresponding fisher classification was compared to the scientist's classification for each survey site, to better understand the differences in perception of habitats between these stakeholders.

Figure 3-4 Photographs of deep water survey cruise showing (a) Deployment of submersible live-action SeaViewer underwater video camera rigged with weighted PVC cradle and (b) DVR video review of deep water survey variables while in transit to next site.

Table 3-5 List of raster mapping surfaces modelled from the marine field survey variables, listed here by group, attribute, type of map product and extent of coverage.

Group	Surface	Attributes	Type of map product	Extent of coverage
Marine habitat	Deep water – scientist	Coral reef, seagrass, mixed live bottom, hard bottom, sand	Deep water habitat	Deep water map
	Deep water – fisher	Reef, grass, sand, hard bottom, gravel	Deep water habitat	Deep water map
Bathymetry	Bathymetry DEM	50 m resolution	Seafloor bathymetry	Entire Grenada Bank
	10 m contours	10 m isobaths	Seafloor bathymetry	Entire Grenada Bank
Fishery	Conch	Yes, No	Fishing suitability	Entire Grenada Bank
	Lobster	Yes, No	Fishing suitability	Entire Grenada Bank
	Fish	Yes, No	Fishing suitability	Entire Grenada Bank
	Fishing quality	Very good, good, ok, poor	Fishing suitability	Entire Grenada Bank
	Fishing preference	Yes, No	Fishing suitability	Entire Grenada Bank
	Weighted overlay – fishery	Density of fishing (scale of 1 to 3)	Fishing suitability	Entire Grenada Bank
Fishing gear	Tank (SCUBA)	Yes, No	Fishing suitability	Entire Grenada Bank
	Spear gun	Yes, No	Fishing suitability	Entire Grenada Bank
	Fish trap	Yes, No	Fishing suitability	Entire Grenada Bank
	Net	Yes, No	Fishing suitability	Entire Grenada Bank
	Line	Yes, No	Fishing suitability	Entire Grenada Bank
	Weighted overlay – gear	Density of gear use (scale of 1 to 5)	Fishing suitability	Entire Grenada Bank

3.2.3 Additional mapping products

Twelve additional fishing-related mapping surfaces (Table 3-5) were created from the MRU evaluation of fishing suitability information collected as part of the shallow water habitat ground-truthing survey and the deep water habitat assessment survey. These data comprised ordinal point data, such that Inverse Distance Weighted (IDW) interpolation was an appropriate modelling technique to create additional map surfaces. The ArcGIS ‘Union’ geoprocessing tool was used to integrate the shallow water ground-truthing and deep water survey data points into one comprehensive feature class. Then, using the ArcGIS 3D Analyst extension ‘IDW Interpolate to Raster’ tool, the interpolation mask was set to the Grenada Bank grid, at a power of three and cell size of 50 m to create each fishing suitability surface. This exercise produced one map for each target fishery species (conch, lobster, reef fish); one map for each type of fishing gear likely to be used (line, net, fish pot, SCUBA tank, spear gun); as well as one map each indicating the apparent quality of the fishing ground (poor, OK, good, very good) and another indicating whether the MRU would choose to fish at the site (yes, no). Finally, the ArcGIS Spatial Analyst ‘Weighted Overlay’ geoprocessing tool was used to identify areas of spatial overlap (one map for fishery type and one map for fishing gear) thereby creating two fishing density surfaces (Table 3-5).

In order to supplement existing bathymetric data with a finer-scale resolution of the Grenada Bank, depths were recorded continuously at 30 second intervals along the deep-water survey tracks (Figure 3-5) using a Garmin 540s depth sounder with a standard dual frequency (50 and 200 kHz) transducer. Each day sonar data were downloaded on a removable multimedia flash card and saved (as a *.gpx* file) using Garmin's 'Map Source' software version 7. The Minnesota Department of Natural Resources 'DNR GPS' software application version 5.4.0 was used to convert the (*.gpx*) data directly into a point (x, y, z) ArcGIS feature class. The sonar data were merged (using the 'Union' geoprocessing tool) into one comprehensive point feature class and masked to the extent of the Grenada Bank study area. This feature class was then merged (using the 'Union' geoprocessing tool) with the most detailed bathymetry dataset available ('Bathymetry of the Lesser Antilles area' developed by FAO in 2005 available at: http://geonetwork3.fao.org/geonetwork/srv/en/main.home) and clipped to the extent of the Grenada Bank study area.

In order to create the most realistic visualisation of the marine environment with the various marine habitats and fishing information, the merged bathymetric data were used to create a three dimensional (3D) seafloor model. The ArcGIS 3D Analyst extension 'IDW Interpolate to Raster' tool was used to create a three-dimensional 'Triangular Irregular Network' (TIN) model of the Grenada Bank

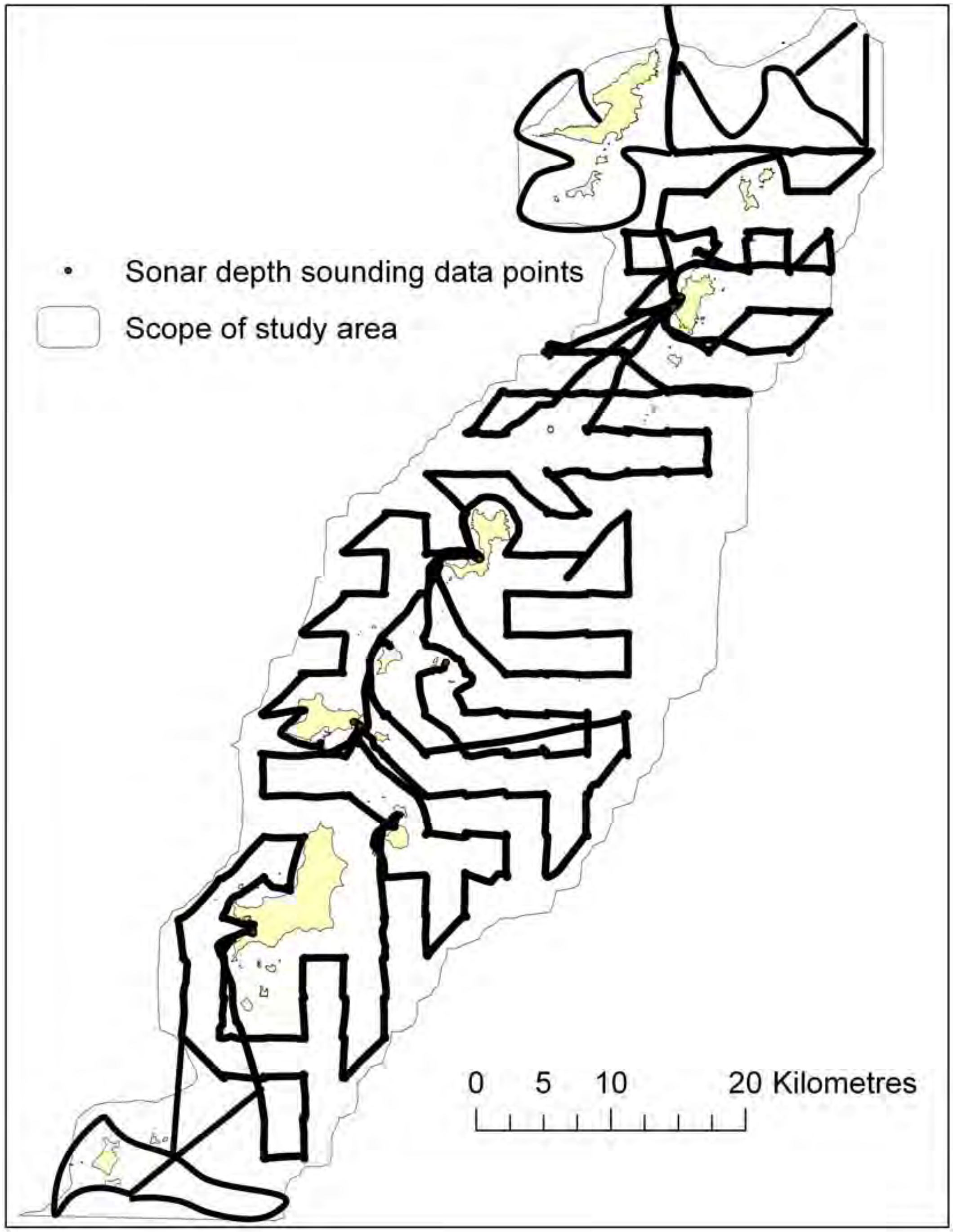


Figure 3-5 Survey cruise track showing continuous sonar depth sounding data collected to supplement existing bathymetric data for the Grenada Bank study area.

seafloor from the enhanced bathymetry dataset. Then the ArcGIS Spatial Analyst extension was used to create a bathymetric digital elevation model (DEM) (using the ‘TIN to Raster’ tool) and a 10 m contour interval feature class (using the ‘Contour’ tool) from the Grenada Bank TIN (Table 3-5). Finally, the use of ArcScene software (with a 3x vertical exaggeration) allowed for the 3D visualisation of the TIN seafloor model of the Grenada Bank on top of which the various mapping surfaces could be draped.

3.3 RESULTS

3.3.1 Data review and selection of habitat classification scheme

The preliminary appraisal and secondary data review was an extremely time consuming process as existing information was scattered amongst numerous government agencies, libraries, NGOs and community leaders across the Caribbean region, and had never been compiled (Chapter 2). The available imagery and habitat mapping datasets (Tables 3-1 and 3-2) had been developed using a multitude of different methods and spatial scales, and most lacked metadata. The review of existing GIS data (Table 3-3) was also a challenge due to an absence of metadata in almost all cases. Much time was therefore spent communicating with the data creators, wherever possible, in an attempt to determine the accuracy, scale and methods applied to each available GIS dataset.

However, despite these efforts, none of the existing GIS datasets were found to be of any use for this mapping exercise. This was primarily due to the fact that (a) the methods of data creation and the classification schemes applied were undocumented and could not be adequately established, or (b) GIS data were modelled but not validated through ground-truthing, thereby resulting in unknown accuracy. Although highly fragmented, the majority of useful secondary marine habitat information was found in environmental impact assessment reports or small project documents; comprising information from individual islands, coastlines or bays collected at different times and spatial scales for different purposes (Table 3-2). Available imagery and secondary mapping data were similarly fragmented in time and space (Table 3-1). The only comprehensive marine mapping resources spanning the entire transboundary study area (i.e. nautical charts, CCA environmental profile atlases, millennium coral reef mapping project) (Tables 3-1, 3-2 and 3-3) were at a scale too broad (e.g. too coarse a resolution) to depict marine habitats accurately enough for effective local, national or even transboundary management. Furthermore, there were several uninhabited cays for which no satellite or aerial imagery was available locally. Several satellite images were purchased to fill these data gaps (Table 3-1).

The collaborative review by 10 marine resource managers revealed that much of the existing information and most of the classification schemes were perceived by marine and coastal decision-makers to be either: at too broad a scale (therefore lacking detail); or too complex (consisting of a bewildering number of habitat classes) with little relevance to a local or regional marine management context. This interactive communication process revealed the need for local and regional managers to have marine habitat maps at a scale and level of detail which could serve transboundary ecosystem-based planning and management whilst still providing a comprehensive and accurate baseline of habitats at the level of each island and its surrounding coastal area. Interviewees were unanimous in concluding that an appropriate classification scheme should be relevant and clear to all marine resource managers as well as resource users. Thus a relatively simple classification scheme comprising just seven habitat classes was selected for habitat mapping based on: the collaborative review of existing classification schemes; relevance to a wide range of marine resource users and managers; the habitat flashcard exercise (Figure 3-6); and approval by the marine resource managers as well as by the wider group of stakeholders via the research e-group. The selected classes were: mangrove, salt pond/swamp, seagrass, coral reef, mixed live bottom, hard bottom, sand (see Appendix XXII for a detailed description of coastal and marine habitat classes).

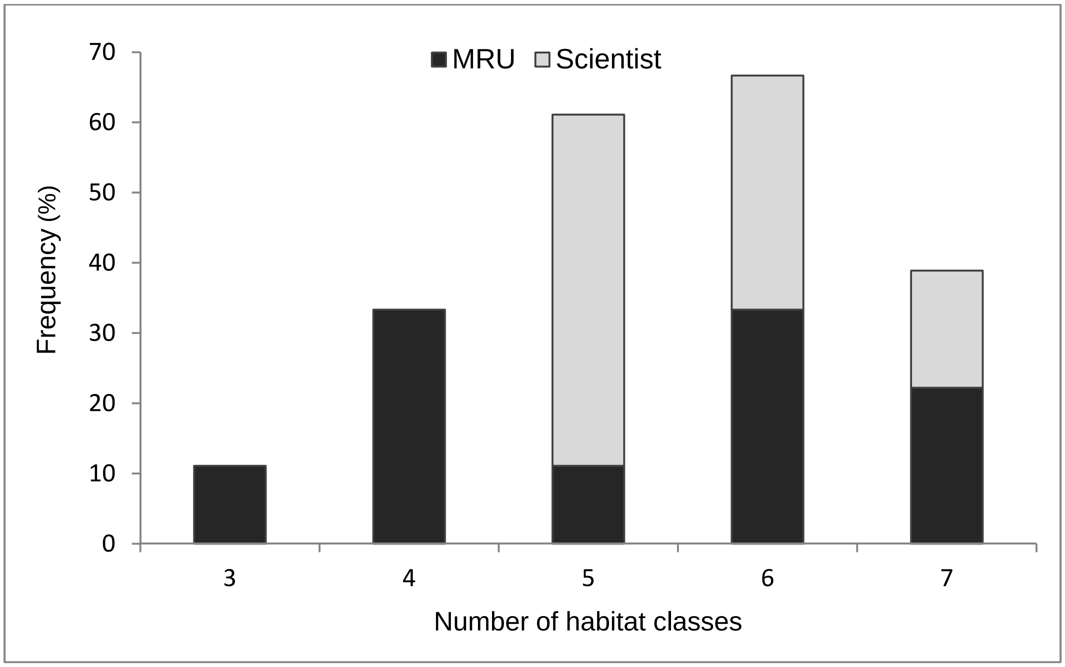


Figure 3-6 Stacked bar chart comparing the number of habitat classes created by Grenadine MRUs (n = 9) and scientists (n =6) during the habitat flashcard exercise, shown as percent of total number of participants in each stakeholder group.

3.3.2 Investigating stakeholder classification of sublittoral marine habitats

A total of 15 persons (9 MRUs and 6 scientists) from 8 islands completed the habitat flashcard exercise. This *ex-situ* habitat flashcard experiment was used to investigate commonalities in stakeholder classification of habitats typically found on the Grenada Bank. Stakeholders grouped habitat flashcards into between three and seven habitat classes, with the modal number of habitat classes being six (Figure 3-7). There were clearly some differences between the scientists and the MRUs, the latter group having a broader distribution with the modes at four and six habitat classes. However, there were also significant similarities among MRU and scientist stakeholders. Results from the habitat flashcard exercise were assessed by comparing both the grouping and naming convention applied to each flashcard as compared to the author's habitat class designation. For example, all nine 'reef' class pictures (as classified by the author) were allocated into the same habitat class by 100% of participants, despite subtle differences in the naming convention applied to the class (Figure 3-7). Similarly pictures representing the seagrass class had the next highest overall agreement. Percent agreement was lower across all habitat classes amongst scientists (Figure 3-7a) (mean agreement: 80%) than amongst MRUs (Figure 3-7b) (mean agreement: 83%). For example, MRUs had greater than 75% agreement in five of their six classes and the lowest agreement was the 'gravel' class at 67% (Figure 3-7b). Scientists had greater than 75% agreement for four of their five groups and a very low level of agreement for their 'hard bottom' class at just 33% (Figure 3-7a). This exercise confirmed the researcher's presumption of the existence of differing perceptions of marine habitat classifications amongst stakeholders, thus warranting the involvement of both MRUs and scientists in the classification of habitats for the *in-situ* marine field survey.

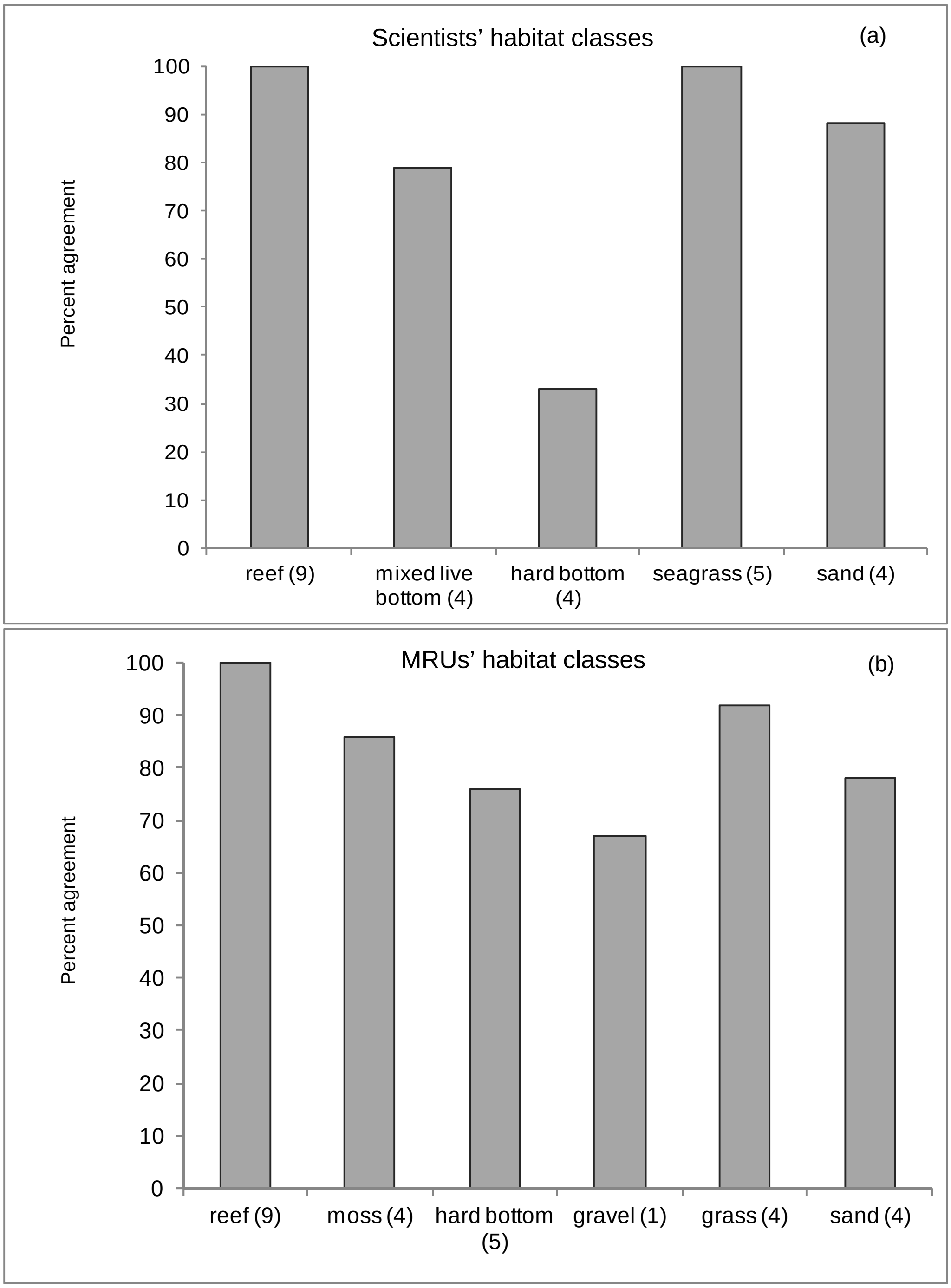


Figure 3-7 Percent ex-situ agreement: (a) amongst scientists (n=6) in grouping habitat flashcards against scientific classification scheme; and (b) amongst MRUs (n=9) in grouping habitat flashcards against MRU scheme. ***The total number of flashcard pictures selected to represent each habitat is given in parentheses.***

The various names given by MRUs and scientists for their groups of habitat class flashcards is illustrated in Table 3-6. Irrespective of user group, despite the large number of names provided for the reef and hard bottom classes, names provided were generally comparable. In an examination of naming conventions applied for the 'moss' class, flashcards in this group represent an algal-dominated class, as compared to flashcards grouped in the seagrass habitat class. Despite this apparent difference in flashcard groupings, the naming conventions applied to these two groups are analogous with the exception of 'munch' and 'shoval' names within the 'moss' class.

Table 3-6 Other names provided by scientists and MRUs as compared to each of the respective (scientist and MRU) habitat classification schemes. (*n/a – not applicable*)

Scientist scheme	reef	mixed live bottom	hard bottom	n/a	seagrass	sand
	hard coral	algae	algae		n/a	Rock
Other	high reef	macroalgae	rubble			
Names	low reef	seagrass	sand			
	soft coral					
	sponge					
MRU scheme	**reef**	**moss**	**hard bottom**	**gravel**	**seagrass**	**sand**
	Coral	grass	dead reef	dead reef	grass	Gravel
Other	Fans	munch	gravel	Rock	moss	
Names	soft coral	seaweed	reef	rubble	seaweed	
	sponge	shoval	rock			
	Trees		rubble			
			sandstone			

3.3.3 Coastal and shallow water habitat mapping

The shallow water marine habitat map was derived using conventional passive remote sensing techniques supplemented with the local knowledge of marine resource users. The ground-truthing exercise was used to improve the accuracy of the map, but also to assess the usefulness of the participant validation exercise as a method to improve the accuracy of the sub-littoral shallow water map.

The initial shallow water habitat map derived from remote sensing comprised a total of 745 habitat polygons. The local knowledge validation exercise identified a total of 89 misclassified polygons. These apparent misclassifications occurred across all habitat types although the highest proportion was in the reef class (Table 3-7). The local knowledge validation exercise therefore potentially improved the accuracy of the remotely sensed map by 12%.

Table 3-7 The number of misclassified polygons for each habitat class identified by local knowledge, also shown as percent of the total number of polygons for that class.

Habitat type	Number of misclassifications	Percent (%) total
Reef	38	17
Mixed-live bottom	18	14
Sand	24	12
Seagrass	9	7
Total	89	12

Approximately one third (29) of the polygons that were identified as misclassified were subsequently ground-truthed in the survey of shallow water sites. This exercise revealed that all (100%) reclassifications based on local knowledge were correct. As a result, all 89 changes suggested by local MRUs during validation exercise were applied to the final shallow water habitat map, and the usefulness of the validation exercise in substantially improving the map was confirmed.

A total of 205 sites were ground-truthed to determine the accuracy of the shallow water habitat map created by passive remote sensing techniques and local knowledge validation. An error matrix (e.g. confusion matrix, contingency table) was produced to determine the degree of misclassification among the habitat classes of the shallow water map. The overall accuracy, producer accuracy and user accuracy were calculated as a result. Overall accuracy was 72% (148 of 205 ground truthed sites having been correctly assigned); mean accuracy was 57% (or 72% if the hard bottom class is excluded); with a producer accuracy (level of correctness based on ground truthing) ranged between 0-88%; and user accuracy (level of correctness based on the remote sensed map) ranged between 13-99% (Table 3-8).

Table 3-8 Results of an accuracy assessment of the classification of shallow water marine habitats of the Grenada Bank based on 205 ground-truthing points. ***N.B. Diagonal sum represents the total number of sites correctly assigned. User accuracy represents the proportion of remotely sensed habitat classes that were correctly assigned. Producer accuracy represents the proportion of ground trothed sites that were correctly assigned. Both the user and producer accuracy are shown separately by habitat class.***

		Ground truthed habitat						
		Reef	Seagrass	Mixed live bottom	Sand	Hard bottom	Total sites	User accuracy (%)
Remotely sensed habitat	Reef	78	1	0	0	0	79	99
	Seagrass	5	27	5	3	6	46	59
	Mixed live bottom	24	5	5	2	3	39	13
	Sand	2	0	1	38	0	41	93
	Hard bottom	0	0	0	0	0	0	NA
	Column total	109	33	11	43	9	205	
	Producer accuracy (%)	72	82	45	88	0		148 Diagonal sum

3.3.4 Deep water habitat map

A total of 194 deep water sites were surveyed to model the deep water habitats and fishing quality of the Grenada Bank. Two separate habitat maps were created by interpolating the two sets of survey data collected by a scientist and a MRU, each using their own habitat classification scheme (Figure 3-8a and 3-8b). The total area (in hectares) for each modelled habitat type by each of the two classification schemes is shown in Table 3-9.

Based on the scientist classification, the amount of coastal and marine habitat found in the Grenada Bank study area (listed by shallow water habitat, deep water habitat and as an overall total) was calculated (Table 3-9). Reef and reef-related habitat (mixed live bottom) were the most prominent habitat classes comprising approximately 43% and 38% respectively of all marine habitats (Figure 3-9). Since the deep water map comprised waters deeper than 20 m, there were no seagrass, mangrove or salt ponds in this portion of the map.

Based on the MRU classification, (listed only by deep water habitat) the amount marine habitat found in the Grenada Bank study area was calculated as an area (Table 3-9). It is interesting to note that MRUs classified almost 90% of the Grenada Bank as either reef or hard bottom. Reef was the most prominent habitat comprising approximately 57% of all deep water marine habitats and 29% was classified as hard bottom (Figure 3-9).

Table 3-9 Estimate of area covered by each habitat class (in hectares) across the shallow water and deep water portions of the Grenada Bank. ***(NA = not applicable) N.B. Shallow water habitats assessed by a scientist only. Deep water habitats assessed by both a scientist and a fisher on the same survey cruise.***

Classification scheme	Scientist			Fisher
Habitat	Shallow water (ha)	Deep water (ha)	Overall (ha)	Deep water (ha)
Coral reef	7,284	80,572	87,857	105,927
Mixed live bottom	1,878	69,582	71,460	NA
Seagrass	3,040	-	3,040	562
Hard bottom	1,196	12,702	13,898	54,507
Sand	1,631	22,002	23,633	14,851
Gravel	NA	NA	NA	9,012
Mangrove	161	-	161	-
Salt pond / swamp	50	-	50	-
Total	15,241	184,858	200,099	184,858

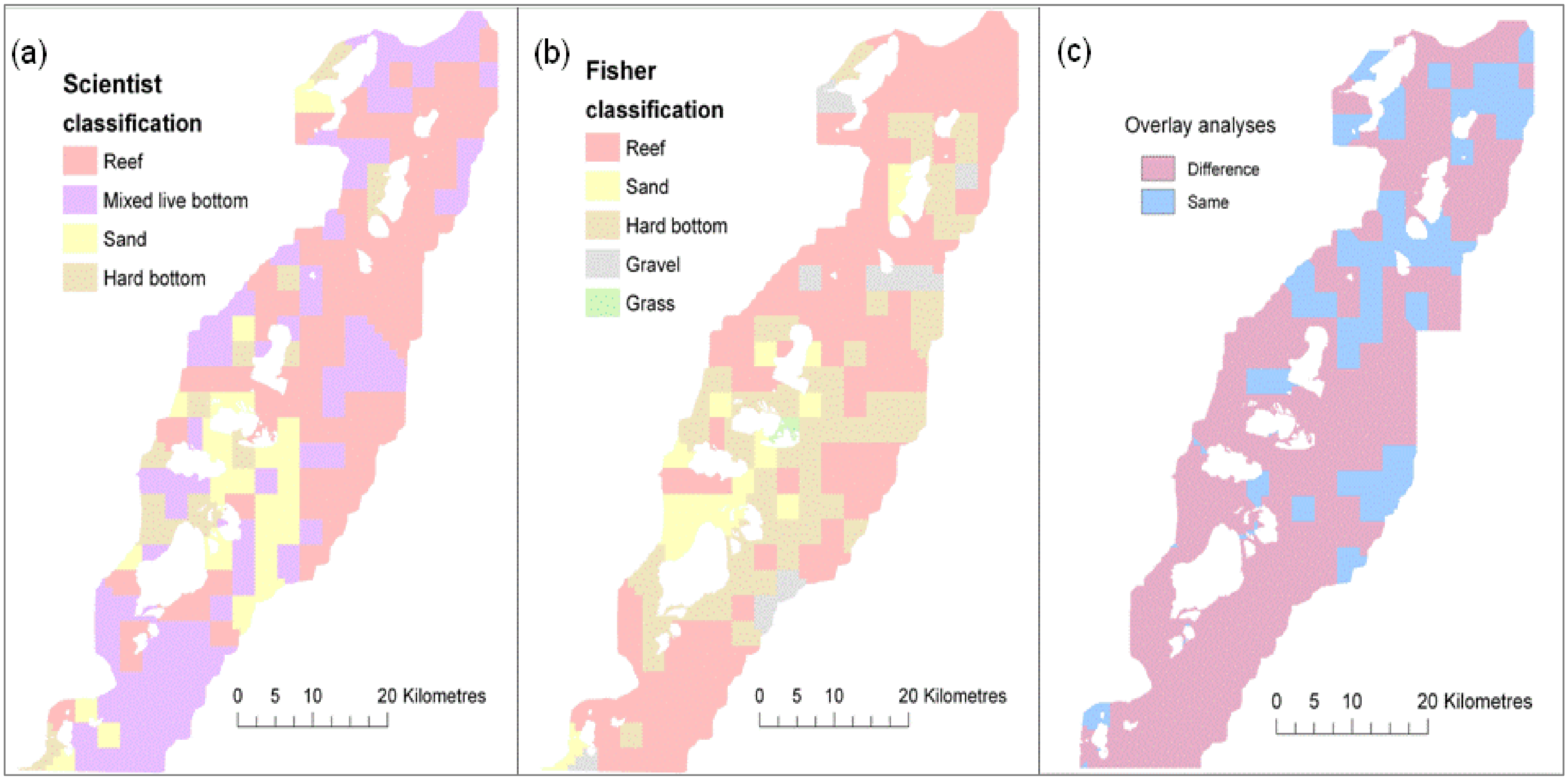


Figure 3-8 (a) Deep water habitat map created from scientific classification scheme; (b) deep water habitat map created from fisher classification scheme; and (c) GIS overlay analysis between the two deep water habitat maps. *N.B. Modelled habitat cells are 3 km^2 in size*

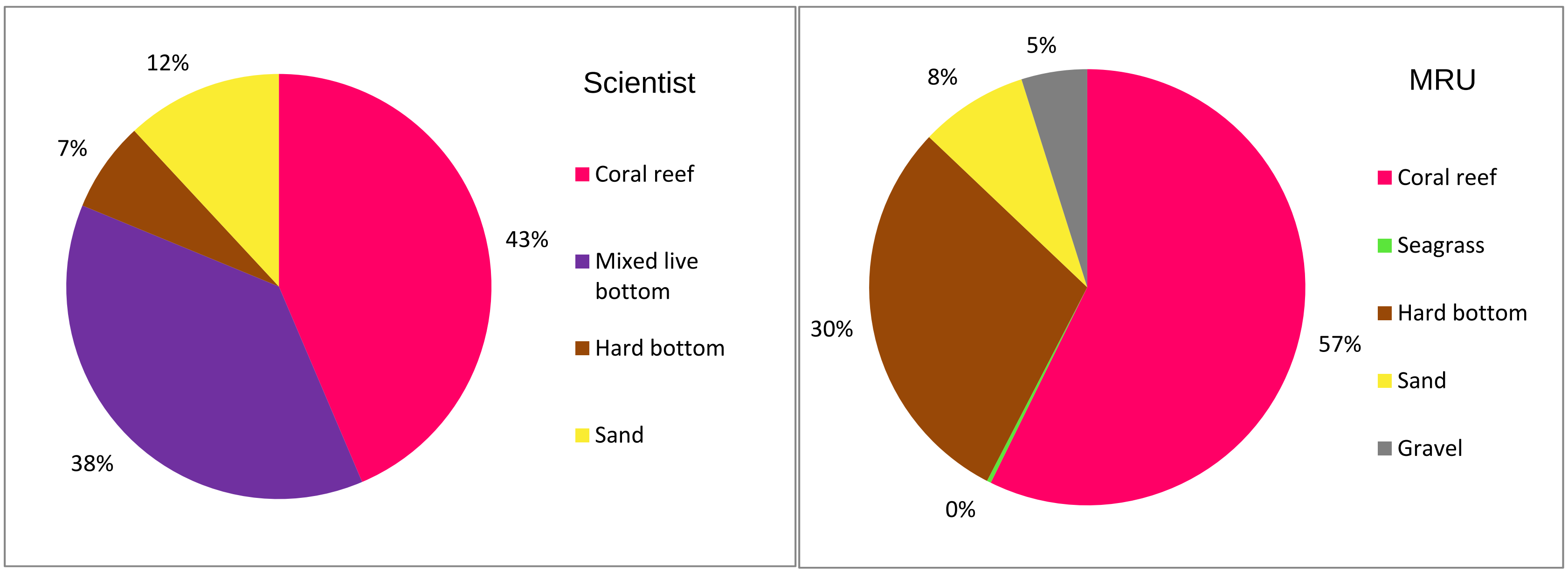
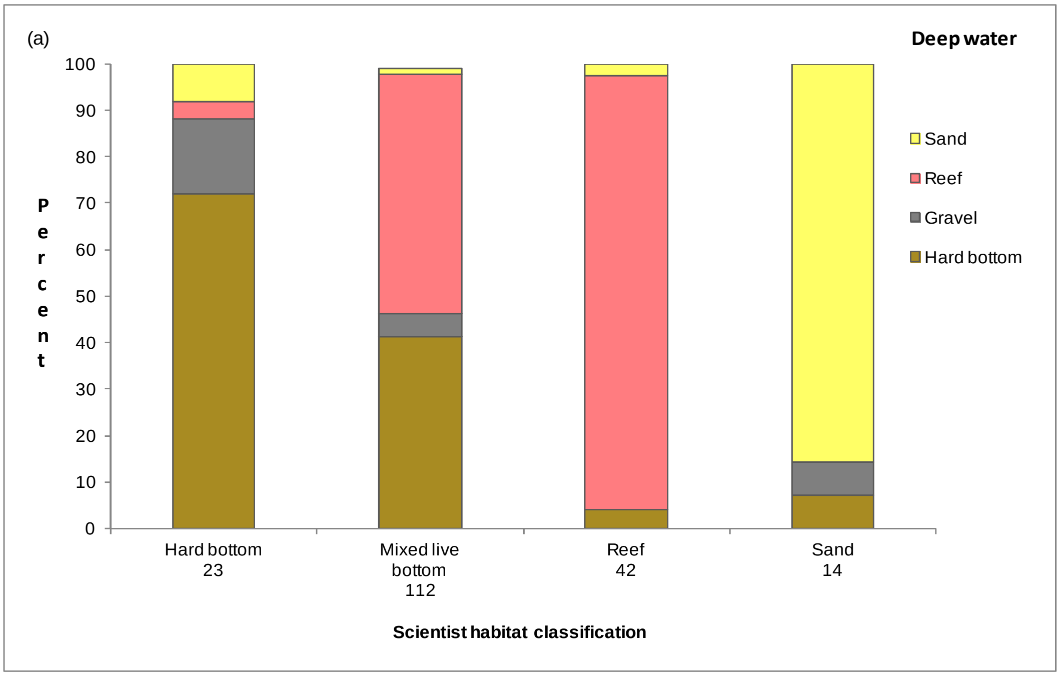


Figure 3-9 Comparison (by percent) of the assessment of deep water habitats by a scientist and a MRU.

3.3.5 Comparative analyses of in-situ habitat classification

Although there were similarities in the estimated areas covered by habitat classes between the scientist and the fisher (Table 3-9, Figure 3-9), an overlay analysis of the differences between the two deep water habitat maps indicated that there was only 31% agreement between the two stakeholders in the spatial arrangement of habitat classes (Figure 3-8c). To better identify where these discrepancies occur, the MRU classification of habitats was compared with the scientist classification at every survey site (Figure 3-10). Of the deep water survey sites (Figure 3-10a), reef and sand had the most agreement (at least 85% spatial overlap) between the two observers. Hard bottom had 72% agreement and another 16% of hard bottom was classified as gravel by fishers. The mixed live bottom class, not identified as its own class by MRUs, was composed of reef (51%), hard bottom (41%) and gravel (5%). For shallow water sites (Figure 3-10b), agreement was high (above 80%) for the classes of hard bottom, reef, sand and seagrass between the two observers. Mixed live bottom was classified by MRUs as primarily hard bottom (67%), gravel (17%) or seagrass (17%).



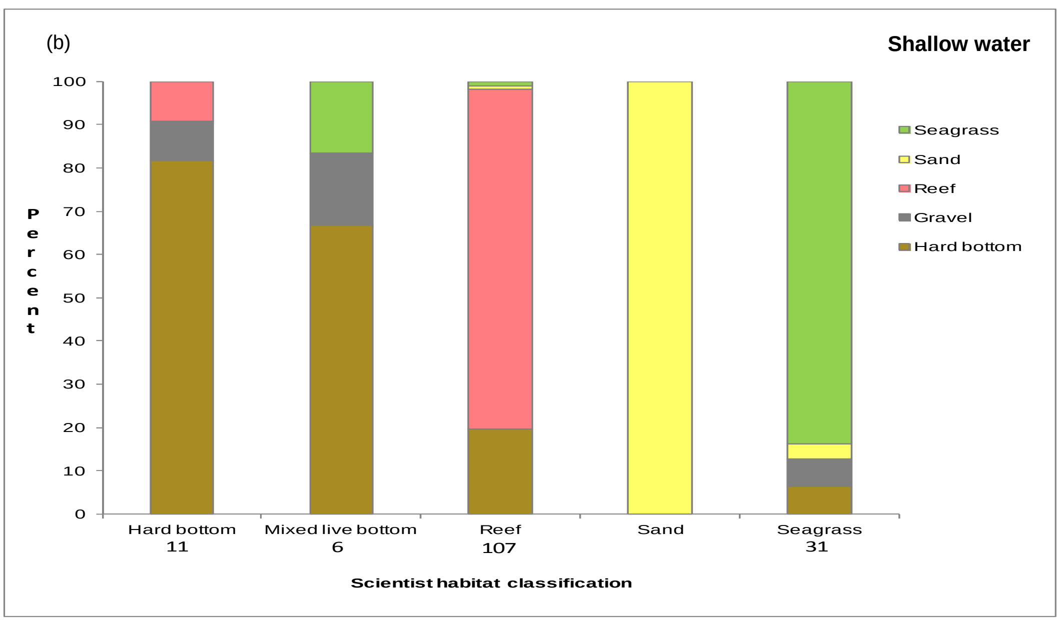


Figure 3-10 Comparison as percentage of agreement between MRU and scientist habitat classification across all (a) deep water and (b) shallow water survey sites.
N.B. Stacked bars show the range of habitats assigned by the fisher for each habitat assigned by the scientist. Sample sizes (number of sites) are given for each habitat type as assigned by the scientist.

All 387 (193 shallow water and 194 deep water) sample points classified by both MRUs and scientists were used to further examine the differences in the naming of marine habitats. Overall agreement between the MRUs and scientists across all survey sites was found to be 60% (231 of 387 sites). Across habitat classes, scientists agree with MRUs 30-89% of the time, whilst MRUs agreed with scientists between 4-96% of the time (Table 3-10). Considering only habitat classes common to both schemes, MRUs' agreement with scientists' was very high (75-96%) (Table 3-10). The 'other' class (consisting of gravel and mixed live bottom classes) as found to have the lowest agreement as a result of these other classes not being used by the scientists (Table 3-10). This discrepancy also lowers the overall accuracy. Notwithstanding this, sand had the highest percent of agreement, whereas hard bottom and reef respectively, had the least overall agreement.

Table 3-10 Comparison matrix between scientist and fisher classification schemes for the shallow and deep water survey sites combined. ***N.B. The 'other' class comprises both mixed live bottom and gravel habitats in order to allow for direct comparison between the two classification schemes.***

		Fisher Classification						
		Reef	Seagrass	Other	Sand	Hard bottom	Row total	Percent agreement with scientist
Scientist Classification	Reef	121	1	0	3	24	149	81
	Seagrass	0	24	2	1	2	29	83
	Other	72	2	5	1	37	117	4
	Sand	0	0	1	54	1	56	96
	Hard bottom	2	0	5	2	27	36	75
	Column total	195	27	13	61	91	387	231 Diagonal sum
	Percent agreement with fisher	62	89	38	89	30		

3.3.6 Additional mapping products

A total of 59,109 sonar data points were used to improve the resolution of the seafloor topography (i.e. DEM) of the Grenada Bank less than 60 metres in depth. These were combined with existing bathymetric data to create a three-dimensional (3D) DEM map of the entire Grenada Bank (Figure 3-11).

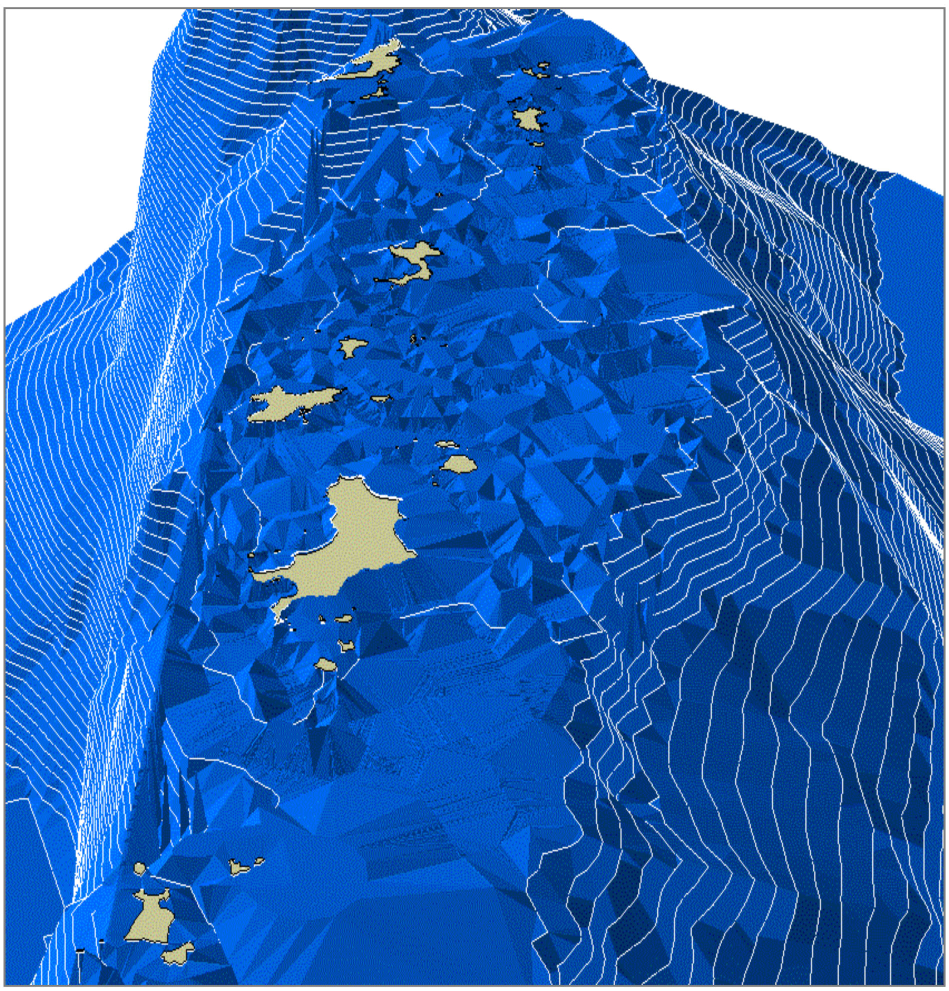


Figure 3-11 Three-dimensional map of the Grenada Bank viewed in ArcScene using available bathymetric data (FAO 2005) supplemented with bathymetric data collected during this study.

3.3.6.1 Fishing suitability maps

Twelve fishing suitability maps were modelled using MRU judgement data recorded at all 394 marine habitat survey sites. Figures 3-12 and 3-13 are the fishing suitability map products interpolated from these data. These fishing suitability maps, as well as the marine habitat maps, can be overlain atop the 3D seafloor model and used for visualisation and spatial analyses. The use of 3D maps greatly increased stakeholder understanding of the relationships between depth, marine habitat, distribution of fishery species, fishing gear use and fishing ground preferences. An example of this is provided in Figure 3-14 where the suitability of fishing areas is the variable 'draped' on the bathymetry.

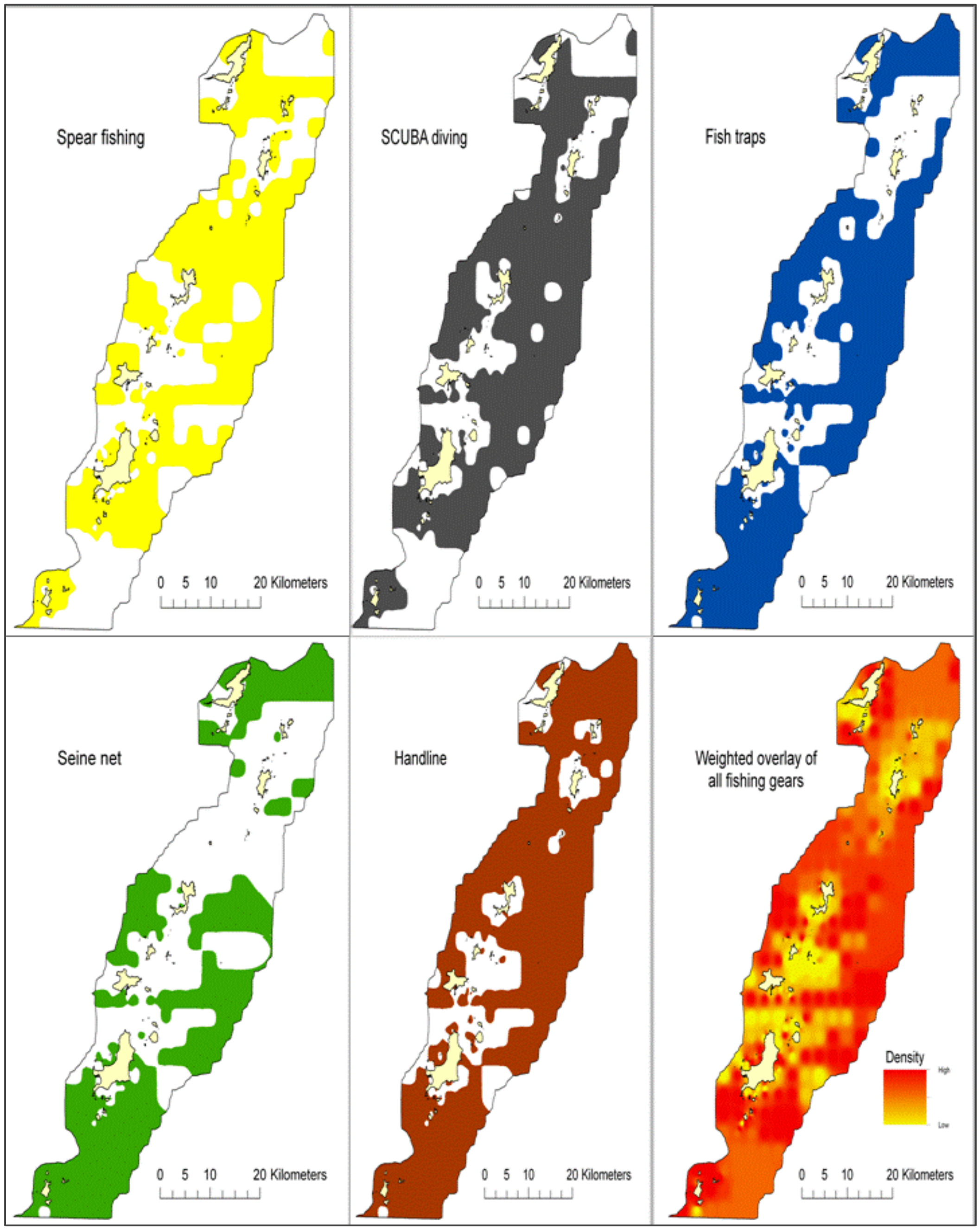


Figure 3-12Modelled surface maps of fishing gear suitability and a weighted overlay of all gear types, showing the areas of the Grenada Bank considered suitable for use of each gear type. Evaluations were made by local MRUs across deep and shallow water sample sites.

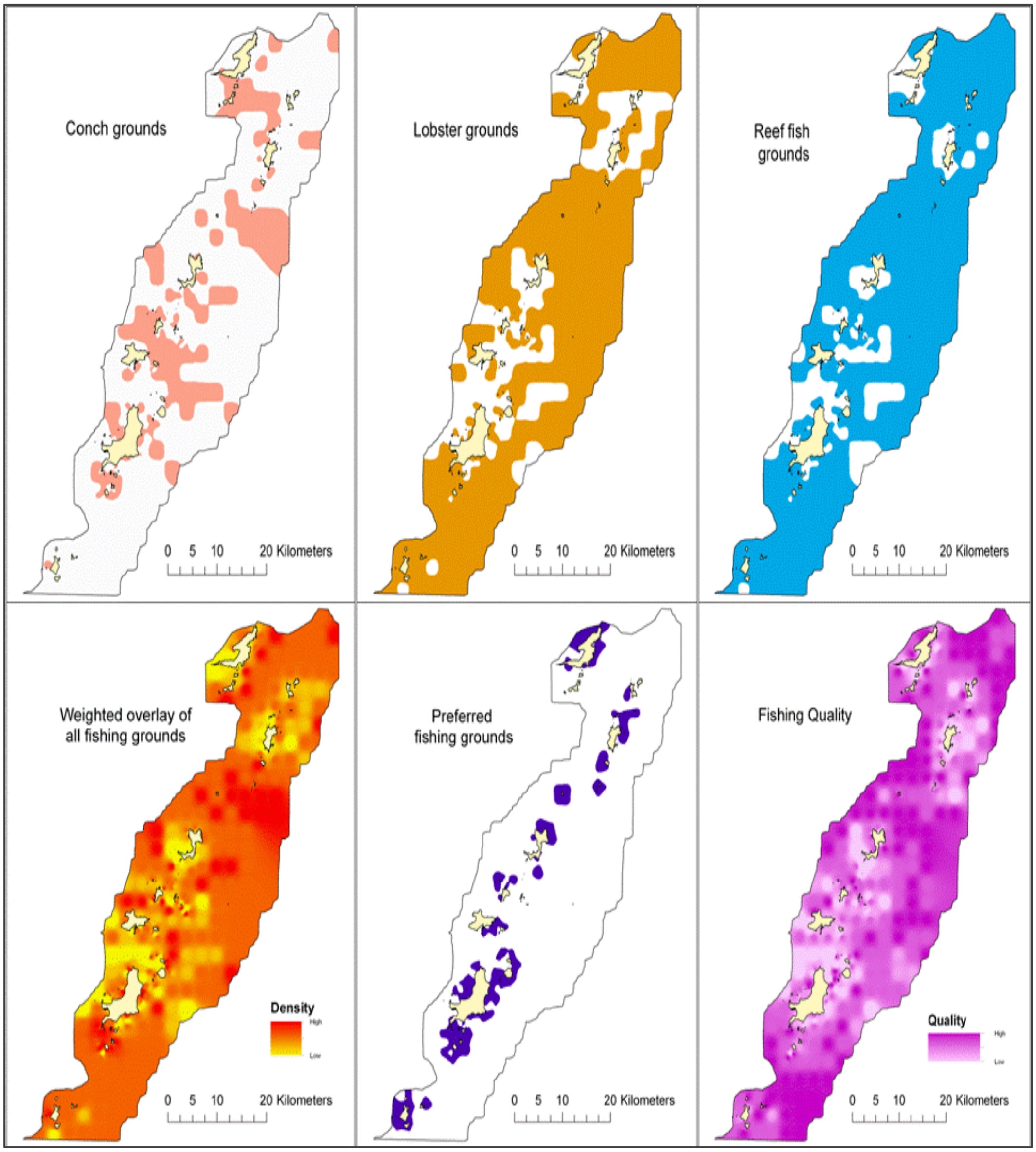


Figure 3-13 Modelled surfaces created for fishery species, a weighted overlay of all fishery species, preferred fishing grounds and presumed fishing quality, showing the areas of the Grenada Bank considered suitable for catching named fishery species; conch, lobster and reef fish. Judgements were made by local MRUs across deep and shallow water sample sites.

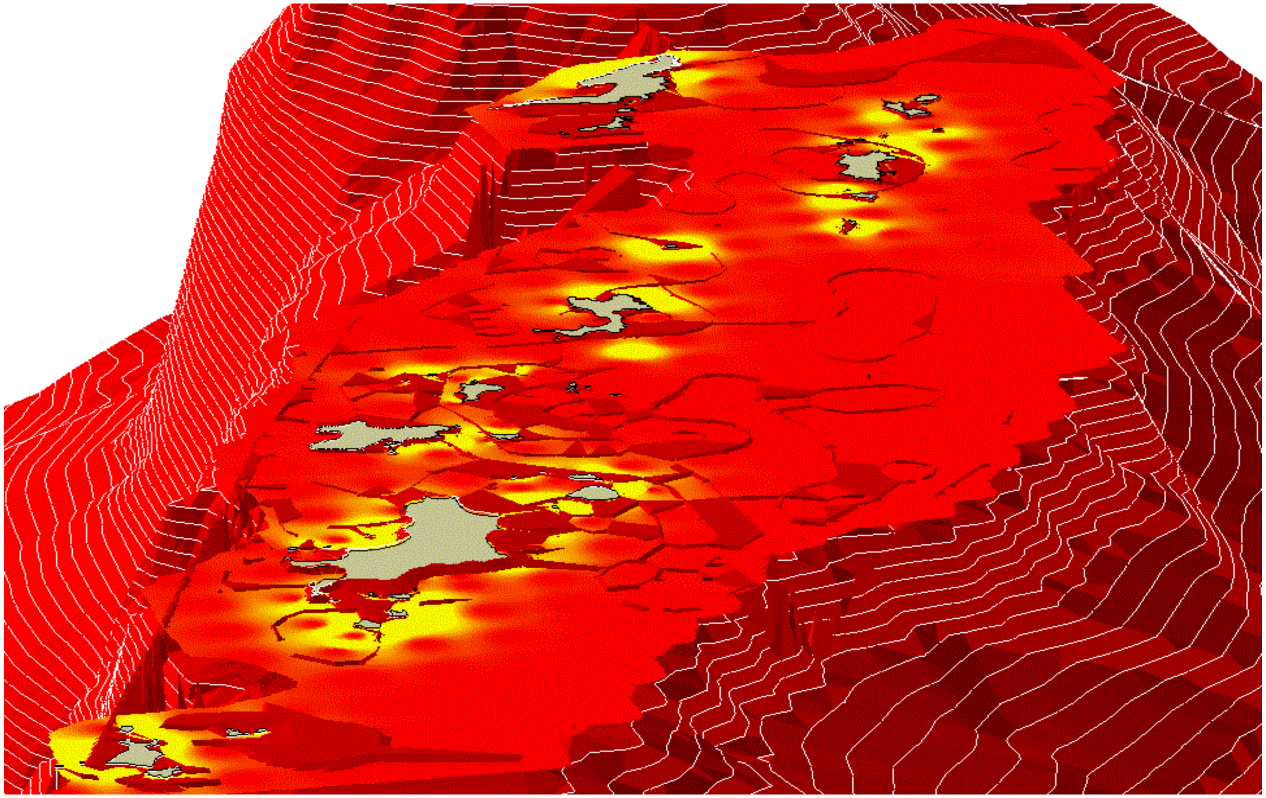


Figure 3-14 Areas identified by MRUs as preferred (in yellow) for fishing, overlain on the 3D bathymetric Grenada Bank seafloor model viewed using ArcScene.

3.4 DISCUSSION

A central premise of EBM is the need to integrate human agency within the study of the environment and the development of appropriate management initiatives. Despite the fact that many technical experts and marine resource users possess a large amount of useful knowledge, many times they are not directly involved in decision-making, planning or management (Johannes 1984, Mahon 1997, Johannes 1998, IIRR 1998, Berkes 1999, Berkes et al. 2001, Allen et al. 2009, Apgar et al. 2009). Their involvement requires a participatory framework not only to allow for effective knowledge exchange and use, but to build capacity for working together on the management of resources (Mackinson and Nottestad 1998, De Young and Charles 2008). PGIS not only provides a functional platform to draw on a wide range of available useful information, but it also serves to encourage stakeholder collaboration, increased understanding and capacity building. In this study a PGIS approach was used to enhance the development of mapping products that are relevant and comprehensible to key stakeholders and lay the foundation for the adoption of an ecosystem approach to the management of the transboundary marine resources of the Grenada Bank.

3.4.1 Developing locally relevant habitat classification scheme

Marine conservation and management depend on a number of factors, but management success has often been attributed to access to a wide range of multidisciplinary information including local knowledge sources (Mackinson and Nottestad 1998, De Young and Charles 2008, Berkes 2011). A common problem is the lack of available comprehensive data at appropriate geographical scales (Tripathi and Bhattarya 2004). This was particularly true in this study, as much time, effort and collaboration was required to collect, collate and appraise existing data and information (Chapter 2). Lack of coverage of marine areas by aerial imagery was due in part to the following factors: (a) historical use of imagery for has been for terrestrial mapping initiatives so that marine areas are only captured as a by-product of these initiatives; (b) due to the expensive nature of imagery, only specific project areas of interest were already available; and (c) the absorption of light by the water column which precludes the interpretation of habitats in water depths greater than approximately 20 m (Gibbs and Cochran 2009). As a consequence, it was acknowledged that there was not an adequate marine habitat base map or comprehensive high resolution imagery available for the entire study area from which to work. Data integration from diverse sources and scales necessitates a spatial data integration framework; consequently GIS technology was found to be essential. It allowed the variety of existing data to be integrated easily and seamlessly so it could be made available in one interface. Furthermore, GIS allowed for the clear identification of spatial information gaps which needed to be addressed in order to produce a comprehensive shallow water habitat map. GIS mosaicing was found to be beneficial in assembling the existing aerial information (i.e. maps, aerial photos and satellite imagery) in a piecemeal fashion to attain adequate coverage of the Grenada Bank from which to derive a habitat map.

In addition to access to comprehensive marine habitat information, effective marine resource management requires further information that is at a scale and format that can be understood by stakeholders. As described in Chapter 2, GIS was valuable to the preliminary appraisal in that it provided a good basis for the collaborative review of secondary data. Through the ability to easily access and spatially examine the various types and scales of existing information, it became apparent that existing marine habitat information was severely limited for effective use and transboundary marine management initiatives. Furthermore, the information that was available was of limited relevance to many of the stakeholders. As a result of this initial review, marine resource managers concluded that effective transboundary marine management would require the production of a comprehensive and consistent baseline habitat map of the entire Grenada Bank, using a simple and easy to understand classification scheme at a scale suitable for local management.

The habitat flashcard exercise revealed that MRUs are comfortable differentiating the typical variety of sub-littoral habitats of the Grenada Bank into a small number of habitat classes (between 3 and 7). Furthermore it is evident that they already do so in their day-to-day use of the marine environment (Chapter 2). This corroborates the sentiment of local marine resource managers that a simple and understandable habitat classification scheme is needed.

The habitat flashcard exercise highlighted several differences between these two stakeholder types (i.e. scientists and MRUs). Overall, MRUs agree amongst themselves more than scientists, in terms of habitat flashcard grouping, regardless of the naming convention applied. Reef and seagrass habitat classes provided the most *ex-situ* agreement within both stakeholder groups. Agreement amongst MRUs in assessing the habitat flashcards was lowest for hard bottom, gravel and sand. This may be explained in part by the subtle differences which exist amongst these three habitat classes, which is also seen in the similarity in the naming conventions applied between and within these classes (Table 3-6). Another consideration may be that these habitat classes are not desirable fishing grounds and therefore do not matter that much to MRUs. Overall, scientists showed less of a tendency to agree with each other, particularly within the mixed live bottom and hard bottom flashcards. This could be attributed to the fact that the 'mixed live bottom' (macro-algal dominated habitat) typically occurs on top of a hard substrate and thereby has a similar geomorphology to 'hard bottom' whereby the difference between these groups is ecologically-based.

Another factor which may have contributed to the lack of agreement is the content of the habitat flashcards themselves. All of the photos were taken from a vertical viewpoint, relatively close (1-2 m away) to the substrate to facilitate identification of benthic species. In retrospect, perhaps if the photos were taken from a landscape perspective further away from the substrate, the flashcards may have represented a more realistic view of the seascape and allowed for greater understanding and agreement among stakeholders.

Despite several attempts (via interviews, participant observation and habitat flashcards) to find a scheme which could serve all stakeholders, discrepancies between these two groups in classifying habitat flashcards could not be reconciled and the research advanced with the application of two habitat classification schemes (i.e. scientist and MRU).

3.4.2 Coastal and shallow water habitat mapping

The incorporation of local knowledge into marine resource management has been shown to be an effective and low-cost strategy for increased understanding and promoting effective management (Johannes 1998, Johannes 2002, Aswani and Vaccaro 2008). Despite this recognition, little has been done to date to incorporate local knowledge into remote sensing and habitat mapping techniques (Aswani and Lauer 2008, Lauer and Aswani 2008). In this study, local knowledge validation easily improved the accuracy of the remotely-sensed shallow water map by 12%

demonstrating the value that stakeholder engagement can add to this conventional geomatic technique. This improvement held true despite known differences in the perception of habitat classes and naming conventions amongst stakeholders. Notwithstanding this, it should be recognised that a large proportion (79%) of the remotely-sensed shallow marine habitat comprised habitat classes that both stakeholder groups agreed upon (i.e. reef, seagrass and sand). Further, for this exercise, in order to reduce the effect of the different stakeholder perceptions of habitat, stakeholders were given a detailed description along with a pictorial legend of the various habitat classes (based on the scientist classification scheme) thus allowing for a common space of understanding to be reached. This in itself may be an important implication, in that it shows that the differences between the habitat classification schemes of the two stakeholder groups can be bridged with appropriate techniques.

As was the case with the habitat flashcard exercise, reef and sand were the habitat types most accurately classified via remote sensing. Seagrass identification rendered an accuracy of 59%, with the errors in interpretation distributed uniformly amongst all the other habitat classes. Mixed live bottom on the other hand, was found to be the most misclassified habitat type (87%); yet interestingly was relatively consistently (62%) found to comprise reef habitat upon field verification. It should be recognised that both classes (i.e. reef and mixed live bottom) comprise reef-complex habitats, with the primary distinction being the presence or absence of coral species (e.g. hard or soft corals). This made the classification of these two habitats difficult with subtle differences found in similar spectral signatures (i.e. soft coral garden vs. sponge and/or algal-dominated habitat) and may explain the low accuracy in remotely sensed classification for these particular habitats. Hard bottom habitat was not identified in the shallow-water portion of the map derived via remote sensing image interpretation. This was corroborated through the ground-truthing survey, in which hard bottom was found to occur at less than 1% of all shallow water survey sites.

3.4.3 Deep water habitat map

In the deep water survey, PGIS was shown to be a practical mechanism to aid stakeholder collaboration as well as to integrate human-habitat interactions in the generated information. The collection of MRU's spatially-based understanding of the associations between the 'physical' benthic substrate, the 'biological' or associated species which occur, and the 'social' uses of habitat and incorporation into a number of habitat mapping products as part of the collected marine habitat field survey variables allowed for the creation of holistic ecosystem-based information.

Although there was relatively low overall agreement in the classification of habitat between MRUs and scientists, some interesting findings still emerged.

Both groups identified reef as the most predominate habitat type found across the Grenada Bank study area. *In situ*, MRUs classified approximately 87% of the Grenada Bank as either reef or hard bottom habitat and similarly scientists reported 88% of the area is made of reef, mixed live bottom (reef complex) and hard bottom habitats, which could easily all be considered as a reef-related habitat for most management purposes.

Comparative analyses on a site by site basis (for both deep and shallow water habitats) between MRU's and scientist's classification showed more than 75% agreement by fishers within the classes of reef, hard bottom, sand and seagrass. The largest amount of disagreement between the two groups was for 'mixed live bottom'. In the deep water, MRUs interpreted mixed live bottom most frequently as reef habitat followed by hard bottom or gravel; whereas in shallow water, MRUs classified mixed live bottom primarily as hard bottom, gravel or seagrass. Differences in classifications between these groups may be linked to observations that scientists tend to classify habitat on an ecological basis (by dominate species), whereas MRUs tend to determine habitat based on the geomorphology of the substrate. Likewise, discrepancies whereby mixed live bottom habitat (algal-dominated)was assigned to seagrass habitat in the shallow water sites can be attributed to MRUs lack of attention at the species level and thus failing to differentiate between moss (algae) and grass (seagrass).

In a final attempt to attain a locally-relevant and mutually acceptable (at least 75% agreement) habitat map, each scheme was collapsed into a more general (4 class) scheme (Figure 3-15). Since mixed live bottom was the habitat for which there was the largest amount of overall disagreement and gravel was not used in the scientific scheme, merging these two classes (as an ‘others’ class) with reef affords a scheme in which there is correspondence between the two classification schemes. Using the two original schemes, the overall agreement between MRUs and scientists for the *in-situ* habitat classification rendered 60% (Table 3-10). If the ‘others’ class is removed from the matrix, overall agreement jumps to 84%. Yet as ‘mixed live bottom’ is largely a reef-complex habitat, and was most frequently classified by MRUs as reef, if the ‘others’ class is merged with ‘reef’ an acceptable result of 77% overall agreement is attained (Table 3-11). The principal downfall of this approach is that this four class scheme (e.g. reef, seagrass, hard bottom and sand) may be at too coarse a scale to be useful for management (Figure 3-12). Other options include: the sole use of the scientific scheme for a final habitat map with a pictorial legend to aid understanding; or the use of either the MRU or scientific habitat map depending on the stakeholder group or purpose at hand (i.e. working with MRUs or scientists).

Table 3-11 Comparison matrix of 'best compromise' between scientist and MRU classification schemes for the shallow and deep water survey sites combined.

		MRU Classification					
		Reef	Seagrass	Sand	Hard bottom	Row total	Percent agreement
Scientist Classification	Reef	193	3	4	71	271	71
	Seagrass	0	24	1	2	27	89
	Sand	0	0	54	1	55	98
	Hard bottom	2	0	2	27	31	87
Column total		195	27	61	101	384	298
Percent agreement		99	89	89	27		Diagonal sum
			77.6%	Overall agreement			

In this study, an attempt was made to understand where the differences lay within and between these two stakeholder groups' perception of habitats, both in the number of classes and naming conventions applied, without influencing or biasing a stakeholder's classification scheme. In retrospect, a single scheme representing a 'best consensus' between the scientists and MRUs could have applied during the *ex-situ* and *in-situ* investigations and would perhaps been more useful. The application of one scheme would have allowed for an increased number of statistical analyses to be undertaken, thereby providing greater insight into the existing differences in perception of habitat between these two stakeholder groups.

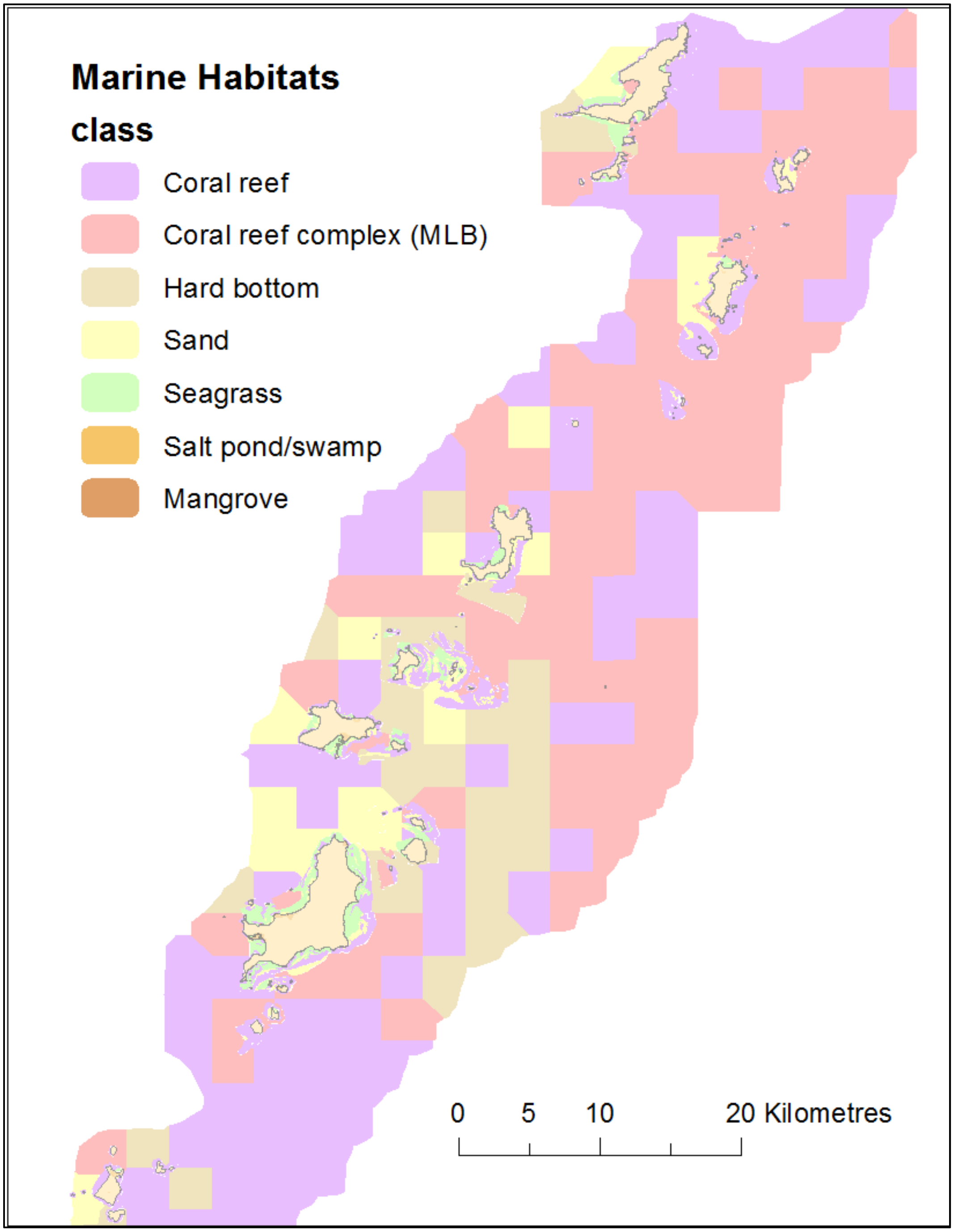


Figure 3-15 Marine habitat map representing the 'best compromise' both scientist and MRU stakeholder classification. ***N.B. MLB – mixed live bottom***

3.4.4 Additional mapping products

GIS easily permitted the creation of an improved bathymetry dataset for the Grenada Bank with *in-situ* sonar depth measurements collected during the marine habitat survey. Moreover the use of ArcScene aided stakeholder visualisation of the bathymetry of the Grenada Bank through 3D representations. These applications have allowed for increased understanding of spatial relationships between depth, habitat and identified fishing areas amongst stakeholders by permitting the overlay of habitat mapping products and other GIS data on a 'real-world' perspective of the Grenada Bank seafloor.

Participatory techniques to obtain fishing knowledge were found to be an easy and useful enhancement to the marine habitat survey instruments, and to be of functional use for ecosystem-based fisheries management. PGIS allowed for MRUs' knowledge of marine habitats, the associated biological communities, and fishing activities to be spatially represented and readily incorporated into the modelling of ecosystem-based marine mapping products. These modelled surfaces can contribute to an improved understanding of the interactions occurring among marine habitats, fishery resources and fishing preferences and allow for the production and visualisation of large-scale space-use pattern information, particularly of use in cases where there is limited baseline fisheries-related information. Understanding interactions occurring among marine habitats, fisheries resources and uses is invaluable for marine spatial planning and management, in particular to decipher areas for marine and fishery surveys or give insight to the potential fishery-related impacts of proposed protected area scenarios. To this end, PGIS allowed local knowledge to be easily integrated and modelled into useful fisheries and habitat related information.

3.5 CONCLUSIONS

In this study PGIS was comprehensively applied to marine mapping exercises and found to strongly support a practical and cost-effective approach to developing of a number of ecosystem-based marine mapping products. The trade-off between scientific rigour and stakeholder participation should be recognised, but the importance of engaging stakeholders in order to better tailor information to their needs and capacity, to allow for more effective use was seen to be imperative given the focus towards EBM.

The GIS interface itself was determined to be an invaluable tool in a number of ways. The GIS framework allowed for the seamless collation of a variety of secondary spatial information, and provided a good medium for collaboratively examining and evaluating the existing types and scales of information and determining a locally-relevant classification scheme and habitat mapping products. Additionally, the spatial visualisation of information aided stakeholder comprehension, not only of the limitations of existing information but improved understanding of the developed mapping products and their potential uses in management.

One of the clear results from the habitat flashcard exercise was the importance of constructing a simple and widely understandable habitat scheme for mapping products at a scale relevant for local and transboundary management. Many lessons were learned from this *ex-situ* experiment. For example, a notable shortcoming was the perspective from which the habitat flashcard photographs were taken. The flashcards could have been improved by photographing seascapes to give a better perspective of the habitat. Moreover, concession to develop a single scheme acceptable to both stakeholder groups should have been a priority. One derivative result of the local knowledge validation of the remotely sensed shallow water habitat map was the demonstration that, with the use of a simple predetermined classification scheme, stakeholders can be brought into a common space of understanding. Although clear-cut agreement in habitat classification was not reached, comparison of both the *ex-situ* and *in-situ* classifications did render sand, seagrass and reef as the most agreed upon habitat types between both stakeholder (i.e. scientist and MRU) groups for both shallow and deep water surveys. Hopefully the results of the habitat classification experiments can provide a medium through which MRUs and scientists can talk about habitats together.

The added value of incorporating MRUs as part of the research team and including their knowledge into the marine survey variables, not only enhanced habitat maps, but facilitated understanding of their tacit associations between fishing resources, uses and the marine environment. The various participatory processes involved to implement a PGIS not only allowed for the production of locally-relevant and useful information, but also served to: (a) build stakeholder capacity in the understanding of the marine environment and related human uses; (b) provided legitimacy to the ‘tacit’ knowledge of MRUs; (c) increased confidence and ownership in information produced; and (d) delineated the role stakeholders can and should play in marine governance (De Young and Charles 2008). For these reasons, the applied use of PGIS, both in terms of the process employed and the products developed, can readily aid interactive governance and an EA to developing holistic marine habitat mapping products, in particular for use in marine spatially planning and management decisions.

4 SUPPORT FOR ECOSYSTEM-BASED MANAGEMENT AND MARINE SPATIAL PLANNING

4.1 INTRODUCTION

Humans are reliant on coastal and marine ecosystems, yet marine activities alter the oceans though the extraction of resources, destruction of habitats, pollution and the changing of species compositions (Roberts 2007, Halpern et al. 2008, Wilkinson 2008). Marine resources are limited in both space and quantity, especially in coastal areas and increasing human pressure on them has resulted in conflicts. Recent assessments conclude that biodiversity in the world's oceans and coastal areas continues to decline as a consequence of unsustainable human activity and resource use (Wilkinson 2008, MEA 2005). This may in part be due to a failure of governance systems applied to manage human use of marine resources together with spatial and temporal mismatches of those governance systems with the biophysical systems they are intended to govern (Crowder et al. 2006, Young et al. 2007).

Successful ocean governance requires the capacity to deal with complex socio-ecological systems (Armitage et al. 2008, Crowder and Norse 2008, Mahon et al. 2008). As discussed in Chapter 1, marine spatial management can offer a constructive means to deal with the uncertainties associated with complex, diverse and dynamic systems by focusing on the distinctive features of an individual place and tailoring management to the local circumstance through an adaptive learning cycle (Young et al. 2007). Furthermore, an understanding and quantification of the spatial distribution of resources and human impacts is needed to evaluate the trade-offs or compatibilities between the protection of the ecosystem and the services it provides (MEA 2005). Effective ecosystem-based management (EBM) in the marine environment will consequently require measures that can rationalize and control the spatial and temporal development of human activities (Crowder and Norse 2008, Douvere and Ehler 2009).

This chapter examines some of the ways in which a collaborative geospatial approach (i.e. PGIS) can be applied in understanding, planning and managing marine resources in an integrated manner, particularly in data-poor regions such as the Caribbean. To demonstrate its potential for marine spatial planning and management (MSPM), the MarSIS participatory geospatial framework is used to provide a baseline picture of current conditions in the Grenadine Islands. Thus the main intention in this chapter is two-fold: (1) to provide a baseline of information on the extent and distribution of marine resources, associated patterns of use and the identification of threats for use in ecosystem-based management; and (2) to demonstrate to other practitioners the ways in which multi-knowledge information on coastal and marine resources and human activities can be brought together, analysed and used in scenario development as a starting point for interactive MSPM. Accordingly, this chapter does not presume to know or predetermine the management questions that would be considered important by managers and stakeholders for addressing MSPM. However, without this initial demonstration of the power and utility of PGIS, neither those responsible for promoting MSPM nor the other stakeholders may recognise what PGIS has to offer and may therefore fail to use its full potential.

4.2 METHODS

The focus of this chapter is on aspects of the research involved in the development of the MarSIS geodatabase (namely the collection, geoprocessing and management of GIS data); as well as the use of these data to conduct GIS analyses relevant for MSPM, specifically those that integrate 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 in the following subsections.

4.2.1 Data collection and definition of geodatabase structure

The process of collecting information for MSPM, from diverse sources and levels of scale is often laborious, time-consuming and costly (Tripathi and Bhattarya 2004). This is mainly due to the need to use data from multiple sources and different data formats, but is an essential procedure in the development of a geodatabase (Jude et al. 2006). The issues relating to this aspect of PGIS and the approach used in this study are described in detail in Chapter 2.

Ehler and Douvere (2007) identify five sources of information useful for MSPM. These include: scientific literature, expert scientific opinion, government sources, local knowledge and direct field measurement. To accomplish this, a preliminary appraisal was undertaken over an 18 month period. The preliminary appraisal consisted in part, of an extensive secondary literature and data search, for information on the status, uses and management of coastal and marine resources of the Grenada Bank (Chapter 2). All secondary information and GIS data were inventoried and reviewed. This information was shared with stakeholders through established communication and information exchange mechanisms to determine usefulness within the MarSIS geodatabase (Chapters 2 and 3).

The geographic scope of the transboundary study area spans the Grenadine Islands of Bequia in the north to Isle de Caile in the south extending to the 60 metre isobath (Figure 4-1). The Grenadines MarSIS was created as a personal geodatabase using ESRI’s ArcInfo version 10 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. The geodatabase design was driven by the need to understand the environment and the influence of human activities to support transboundary

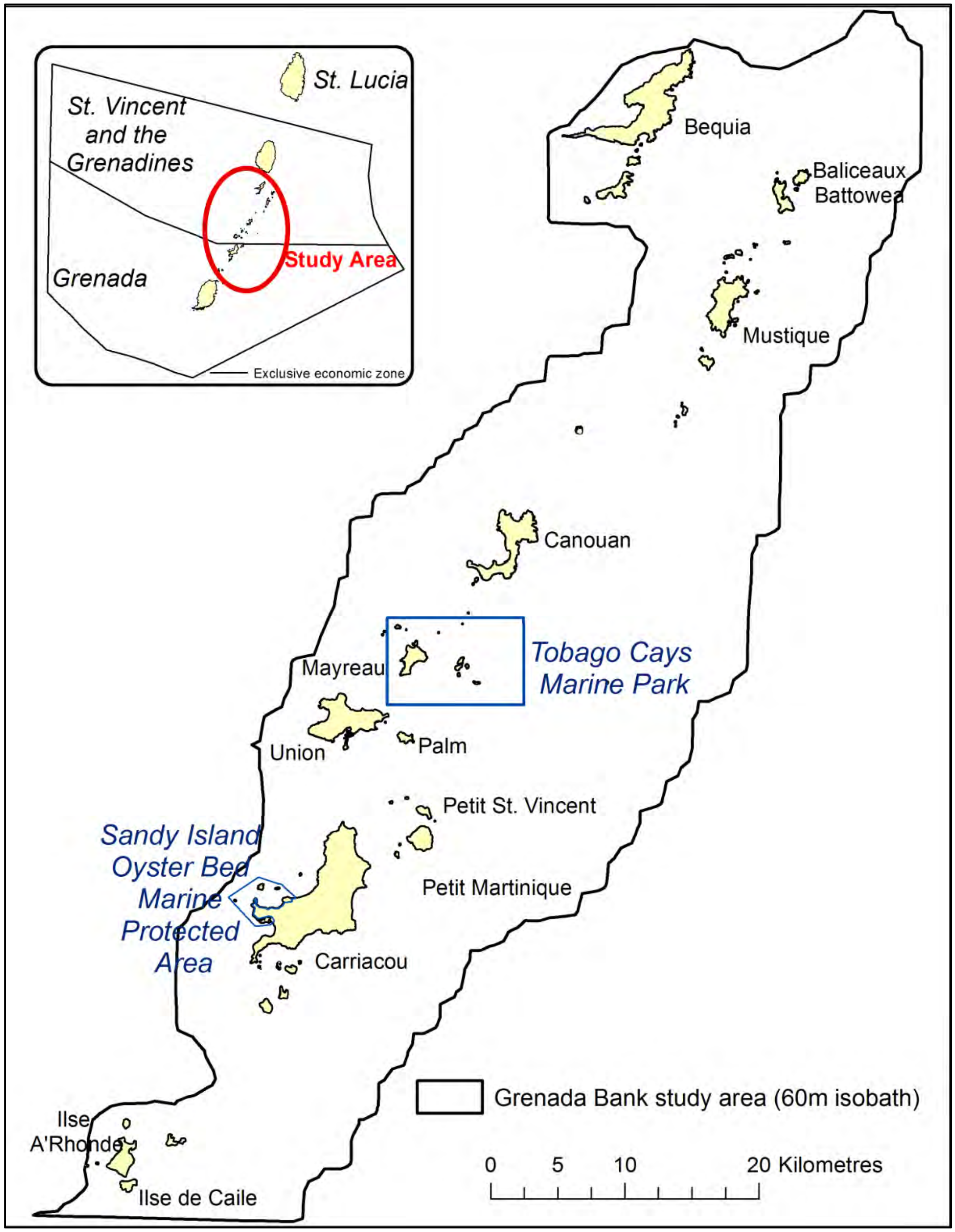


Figure 4-1 The geographic scope of the transboundary study area.
The study area includes the Grenadine Islands and the Grenada Bank (extending to 60 m isobath). The locations of the two designated no-take marine reserves are also shown. The inset map shows the extent of the EEZs of each country.

MSPM in the Grenadine Islands. The geodatabase was populated with the secondary information gathered and further primary information was collected from all available sources (using both scientific and local knowledge systems) to fill data gaps (Chapters 2 and 3). All data within the Grenadines MarSIS were 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. This created a baseline of the ecological distributions of marine resources, physical environmental features, human activities and jurisdictional boundaries.

4.2.2 Data compilation, standardisation and integration

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

To start, the ArcToolbox ‘Environment Settings’ were used to allow for a standard coordinate system (e.g. WGS 84 UTM Zone 20N), spatial extent, cell size (e.g. 100 m^2) and an analyses mask of the study area (e.g. scope of Grenada Bank) to be applied to all geoprocessed data. Thus existing GIS data determined to be of use were imported, clipped to extent of the Grenada Bank study area and re-projected if necessary to a common coordinate system. All imagery, topographic maps and nautical charts were scanned and saved as (*.tif*) images before being imported into ArcGIS. Next, 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) coordinates collected in the field using a Garmin CS76 handheld GPS unit. 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 (‘Bathymetry of the Lesser Antilles area’ by 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 (Chapter 3). To create a digital elevation model (DEM) from the enhanced bathymetry dataset, the 3D Analyst extension (Topo to Raster tool) was used. 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). From the TIN, bathymetry isolines (20 m and 100 m) were easily created (using the Contour tool).

A marine habitat map was created in two main parts as described in Chapter 3. One was a vector polygon shallow water habitat map derived using conventional remote sensing and ground-truthing to model the shallow water habitat (Figure 3-1a) in detail. The other was a vector polygon 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 (using the Spatial Analyst Expand geoprocessing tool) for the deep water portion of the Grenada Bank (Figure 3-1b). Although two marine habitat maps were created initially; ultimately 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).

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 (Chapters 2 and 3). A socioeconomic marine resource use assessment, comprising semi-structured interviews and surveys together with a series of mapping exercises, was undertaken to develop qualitative information on socio-demographics, livelihood strategies, resources and use patterns (temporal and spatial), threats as well as environmental practices (Chapter 2).

Spatial information derived from participatory mapping exercises was scanned, saved as (*.tif*) images, imported into ArcGIS and georeferenced (as described previously). Features of interest (Table 2-3; Table 2-4) were digitised. Corresponding attributes collected as part of socio-economic assessment surveys (Chapter 2) were first entered as tables into MS Excel and subsequently connected (using a table join) to relevant mapping exercises spatial datasets (Table 2-3).

Marine field survey variables were designed to collect local knowledge of fishing as point data (Chapter 3). An additional 12 fishing-related raster mapping surfaces were interpolated from the fisher 'judgement' of fishing suitability (species, gear type and ground quality) information (Table 3-5). Raster surfaces were created for each target species (conch, lobster, reef fish); each type of fishing gear (line, net, fish trap, SCUBA tank, 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 important 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).

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 and represent all data as polygon feature classes, buffers were applied to all point and line vector feature classes (as specified in Table 4-1). Next, all of the polygon feature classes were mapped onto a raster surface (using the Polygon to Raster tool). Given that all 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 using a weighted ranking scale. Since ranking impacts are known to be contentious (Ban and Alder 2008) and the analyses carried out in this study are for demonstration purposes; weighting was not applied to the rasters. Instead all features were determined 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.

Table 4-1 The geodatabase structure of the Grenadines MarSIS listed by type, feature dataset, layer name, geometry, source and geoprocessing applied.

Feature dataset	Layer name	Geometry	Source	Geoprocessing
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 (50 m)	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 *(1 - 4 m resolution)*	Image	Internet	Georeferenced
	Aerial photos *(SVG only)*	Image	Government	Georeferenced
	Nautical charts (4)	Image	3 Imary; 1 US Navy	Georeferenced
	Topographic maps (*1:25,000)* (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)	Raster	Field measurement	Spatial Analyst (IDW)
	Habitat cover *(high, med, low)*	Raster	Field measurement	Spatial Analyst (IDW)
	Reef geomorphology	Polygon	Coral Reef Millennium 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	Digitised from map; Analysis (200 m Buffer)
	Baitfish bays	Polygon	Mapping exercises	Digitised from map
	Sea turtle nesting beaches	Point	Mapping exercises	Digitised from map; Analysis (200 m Buffer)
	Seabird nesting areas	Polygon	West Indian Seabird Atlas	Digitised from survey data
	Iguanas	Polygon	Mapping exercises	Digitised from map

Table 4-1 (continued) The geodatabase structure of the Grenadines MarSIS.

Feature dataset	Layer name	Geometry	Source	Geoprocessing
Marine Resources	Nursery areas	Polygon	Mapping exercises	Digitised from map
	Oyster beds	Polygon	Mapping exercises	Digitised from map
	Shipwrecks	Point	Mapping exercises	Digitised from map; Analysis (200 m Buffer)
	Whelks	Line	Mapping exercises	Digitised from map; Analysis (100 m Buffer)
MRUs	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	Digitised from map
	Shipping lanes	Line	Mapping exercises	Digitised from map; Analysis (500 m Buffer)
	Dive sites	Polygon	Mapping exercises	Digitised from map
	Fish landing sites	Point	Socio-economic surveys	Digitised from map; Analysis (200 m Buffer)
	Recreational areas	Point	Mapping exercises	Digitised from map; Analysis (200 m Buffer)
	Historical sites	Point	Mapping exercises	Digitised from map; Analysis (200 m Buffer)
	Vending sites	Point	Mapping exercises	Digitised from map; Analysis (200 m Buffer)
	Shipbuilding sites	Point	Mapping exercises	Digitised 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	Raster	Field measurement	Spatial Analyst (IDW)
	Fishing preference (yes/no)	Raster	Field measurement	Spatial Analyst (IDW)
	Weighted fishery overlay (density)	Raster	Modeled 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	Modeled surface	Spatial Analyst (Weighted Overlay)

Table 4-1 (continued) The geodatabase structure of the Grenadines MarSIS.

Feature dataset	Layer name	Geometry	Source	Geoprocessing
Threats	Artificial structures	Polygon	Mapping exercises	Digitised from map
	Sand-mining	Polygon	Mapping exercises	Digitised from map
	Landfills	Point	Mapping exercises	Digitised from map; Analysis (200 m Buffer)
	Illegal dumping sites	Point	Mapping exercises	Digitised from map; Analysis (200 m Buffer)
	Quarries	Polygon	Mapping exercises	Digitised from map
	Land-based sources of pollution	Point	Mapping exercises	Digitised from map; Analysis (200 m Buffer)
	Desalination outfalls	Line	Mapping exercises	Digitised from map; Analysis (200 m Buffer)
	Dredging	Polygon	Mapping exercises	Digitised from map
	Goats	Polygon	Mapping exercises	Digitised from map
	Mangrove cutting	Polygon	Mapping exercises	Digitised from map
Other	Marine protected areas	Polygon	GPS coordinates	Digitised from points
	Exclusive economic zone	Polygon	VLIZ Maritime Boundaries	Analysis (Clip)
	Territorial seas	Polygon	Modeled from coastline	Analysis (3 km Buffer)
	Local name - coastal features	Annotation	Mapping exercises	Digitised from map
	Scope Grenada Bank	Polygon	Modeled from bathymetry	Analysis (Selection of 60 m bathymetry contour)

4.2.3 Visualisation, analyses and MSPM applications

The application of GIS to integrate spatial information from a variety of sources and scales; and the ability to display, query and analyse this information is widely recognised as a valuable tool for decision support and ecosystem-based MSPM (De Freitas and Tagliani 2009, Ehler and Douvere 2009). Basic requirements for an ecosystem approach (EA) 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 Ehler 2009, Tallis et al. 2010). To illustrate, the Grenadines MarSIS geodatabase is used to demonstrate practical GIS applications that could serve to define and analyse the existing environmental conditions of the Grenada Bank.

In this section the following analytical outputs are presented:

- Analysis 1 - Mapping of marine resources and associated human activity
- Analysis 2 - Summary statistics on coastal and marine habitats
- Analysis 3 – Locational query of representative reef ecosystems
- Analysis 4 - Spatial distribution of marine resource users
- Analysis 5 - Cumulative impact surfaces for conservation priority, human activity and threat

One benefit of GIS software is that it provides users with the ability to easily create maps to provide a better understanding of the interactions occurring with in a particular environment. There are currently two no-take marine protected areas (MPAs) located within the Grenadine Island study area: the Tobago Cays Marine Park (TCMP) under the jurisdiction of St. Vincent and the Grenadines; and Sandy Island Oyster Bed Marine Protected Area (SIOBMPA) under the jurisdiction of Grenada (Figure 4-1). Maps of the coastal marine resources and human activity were produced for each MPA to allow for increased understanding of the amount of conservation afforded and space-use patterns occurring the within each of these protected areas.

Geoprocessing tools can allow for the integration of data layers to help explore patterns that occur between and among resources as well as the relationships between resources and human use. Overlay analyses between features can be applied to calculate summary statistics (e.g. count, sum, mean, mode, minimum, maximum) based on a field in the database table. The spatial interface provided by GIS allowed for a number of statistics to be calculated to quantify the existing amount and percent total of the various coastal and marine habitats found within: the Grenada Bank study area; as well as by jurisdictional area; fishery species; fishing gear suitability and presumed fishing quality. In addition, overlay analyses of the jurisdictional boundary of each MPA with coastal and marine habitat has allowed for: (1) a summary of the amount of each of the different habitat types located within each conservation area; (2) an assessment of the amount of each habitat type afforded protection as compared to the total amount occurring on the Grenada Bank; and (3) an evaluation of the amount of habitat protected by each MPA to gauge each country's progress towards achieving their CBD's Caribbean Challenge marine conservation targets of 10% protection by 2012 and 20% by 2020.

Results of GIS analyses can also be represented graphically to further facilitate conceptualisation of the distribution of spatially-based information. Charts summarising marine livelihood demographics were found to be beneficial in providing a better spatial understanding of distribution patterns amongst the various Grenadine Islands' marine resource users.

Although basic GIS functions such as summarising and visualising information are valuable, the development of a marine space-use plan typically requires that advanced spatial queries be conducted (Ehler and Douvere 2009, Agardy 2010, Agostini et al. 2010, Ban et. al 2010, Maelfait and Belpaeme 2010). The development of effective conservation plans often necessitates the identification of priority areas such as the location and adjacency (e.g. proximity to each other) of critical marine habitats and resources. For example, a well-connected reef ecosystem is known to include adjacent areas of mangrove, seagrass and reef habitat. The identification of areas where these habitats occur in such a way as to represent a reef ecosystem can be an important step in identifying critical areas for conservation. To demonstrate how such reef ecosystem areas can be identified, a spatial query was applied to identify the location of all mangroves found within the Grenada Bank study area. Next, a locational query was used to detect the existence of seagrass habitat within a distance of 50 m of the selected mangroves. Finally, a further query was used to identify those mangrove/seagrass combination areas where coral reef habitat was located within 100 m.

An important aspect of managing marine resources effectively is to understand the location of resources and the influence that humans are having on them.

Identifying areas in which many different types of resources in need of conservation are located as well as areas where multiple human activities or threats are co-occurring can be of relevance for MSPM. To quantify the intensity and patterns of human use, multiple-use (or hotspot) areas (where either resources of concern may be abundant or human activity impacts may be high and/or there may be conflicts among users) can be identified through the development of ‘cumulative impact’ surfaces. To generate a cumulative impact surface, each resource or space-use information layer is mapped onto a gridded raster surface and where resources or activities overlap in the same location (or grid cell), the values are added.

To represent the capacity to use the MarSIS to identify hotspot areas of importance for conservation, human activity and threat in the Grenadine Islands, three cumulative impact mapping surfaces were created based on the feature classes listed in Table 4-2. Each cumulative impact mapping surface, represents the total number of raster cells where a resource or activity of interest was tabulated to co-occur (using the SUM overlay of the Cell Statistics geoprocessing tools) so as to highlight 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.

Table 4-2 The feature classes used to create each of the three cumulative impact surfaces; one each for conservation, human use and threat.

Conservation	Human use	Threat
Coral reefs	Anchorages	Artificial structures
Historical sites	Aquaculture	Desalinisation outfalls
Mangroves	Baitfish bays	Dredging
Nursery grounds	Dive sites	Illegal dumping sites
Oyster beds	Landing sites	Land based sources of pollution
Seabird nesting sites	Recreation areas	Landfills
Sea turtle nesting beaches	Seaports	Mangrove cutting
Seagrass beds	Ship building sites	Sand mining
Whelks	Ship wrecks	
	Shipping lanes	
	Vending sites	

4.3 RESULTS AND DISCUSSION

4.3.1 Data collection and definition of the geodatabase structure

The process of collecting data, defining the geodatabase structure and establishing the database was an iterative process taking approximately 18 months, yet continued to be an on-going activity throughout the remainder of the research (additional 36 months). A total of 16 satellite imagery datasets, 4 nautical charts and 7 topographic maps (Table 3-1); 36 technical reports containing maps or atlases (Table 3-2), and more than 230 GIS files were collected and reviewed for use. The main challenge in the review of existing GIS data was an absence of metadata in almost all cases. Much time was therefore spent communicating with the data creators when possible, in order to determine the accuracy, scale and methods that were applied to each GIS dataset when it was originally created. Despite these efforts none of the existing GIS datasets were found to be useable without some form of remedial geoprocessing. Besides the imagery and mapping datasets, only six pre-existing GIS shapefiles were found to be relevant for inclusion in the MarSIS geodatabase (Table 4-1). This was primarily due to the fact that the methods of data creation applied were undocumented and could not be adequately determined. However, in some cases, GIS data had been modelled but not validated through ground-truthing, thereby resulting in unknown accuracy estimation. Finally, there were cases where the data had been created at a scale that was too broad for effective local, national or even transboundary management.

The development of the MarSIS as an ArcGIS personal geodatabase was advantageous in that it provided for data quality control and assurance. The use of a personal geodatabase guaranteed that the spatial reference (i.e. coordinate system) applied to all feature classes was consistent. Likewise the use of subtypes and domains ensured uniformity in the ascribed attribute values applied to each of the various developed feature classes. The application of feature datasets aided the arrangement of feature classes into similar themes thereby increasing the organisation of and access to GIS information (Table 4-1).

4.3.2 Data compilation, standardisation and integration

The collection and conversion of data from disparate sources, scales and participatory research methods (e.g. surveys, mapping exercises, field surveys) constituted the main challenge during this phase. The ‘Environment Settings’ allowed for the production of a consistent spatial extent to be applied to all geoprocessed data. Ultimately the Grenadines MarSIS geodatabase consisted of 11 feature datasets comprising 81 feature classes (e.g. 49 vector, 31 raster and 1 annotation). As discussed in Chapter 2, fifty-four feature classes (63% of the geodatabase) were derived in part, based on the use of local knowledge sources (Table 4-1).

4.3.3 Visualisation, analyses and MSMP applications

One of the main benefits of using GIS is to allow for the visualisation of features which occur within an area of interest. Even without any spatial analyses having been conducted, an examination of each human activity map illustrates the various space-uses that occur within the boundaries of the TCMP (Figure 4-2a) and SIOPMPA (Figure 4-2b). Both of these maps reveal a large number of overlapping space-uses occur within each of the two marine parks.

The TCMP contains the inhabited island of Mayreau, in which the largest amount of human activity within the park is seen to occur (Figure 4-2a). The residents of Mayreau utilise the coastal and adjacent marine areas for many activities; including recreation, fishing (i.e. two fish landing sites, four baitfish bays, and five areas for the collection of whelks), transportation (i.e. one seaport, one water-taxi and two shipping lanes). In addition, a variety of tourism related activities are prevalent in the TCMP (Figure 4-2a). The area is known to contain some of the most popular anchorages for yachting in the Grenadines (ECLAC 2002), in which seven different anchorages are located within the boundary of the TCMP. There are also two hotels, three vending sites, five major dive/snorkel sites as well as two ship wrecks which are utilised as dive sites. Saline Bay, the major seaport of Mayreau, contains the largest amount of space-use overlap (Figure 4-2a).

Likewise, the SIOBMPA is located adjacent to the inhabited island of Carriacou, and therefore the residents of L'Esterre, Laureston and Harvey Vale frequently utilise coastal and adjacent marine areas for many activities (Figure 4-2b). Within the marine park, there are eight identified areas utilised for baitfishing, two fish landing sites and four recreational areas identified to be important for community use (Figure 4-2b). In addition, a variety of tourism-related activities are prevalent in the SIOBMPA. These comprise three yachting anchorages (of which Tyrell Bay is the most popular yacht anchorage in the island of Carriacou), four major dive areas, four ship wrecks, one vending site and three hotels (Figure 4-2b). Sandy Island, a small sandy cay is one of the most popular tourism areas within the SIOBMPA, in which there are three overlapping activities. Sandy Island is frequently used for picnicking and the marine area surrounding is a favourite snorkelling site and yacht anchorage in addition to being identified as an area important for baitfishing. The Careenage (Oyster Bed) mangrove area provides a natural safe harbour for boats during hurricane season. Although outside the

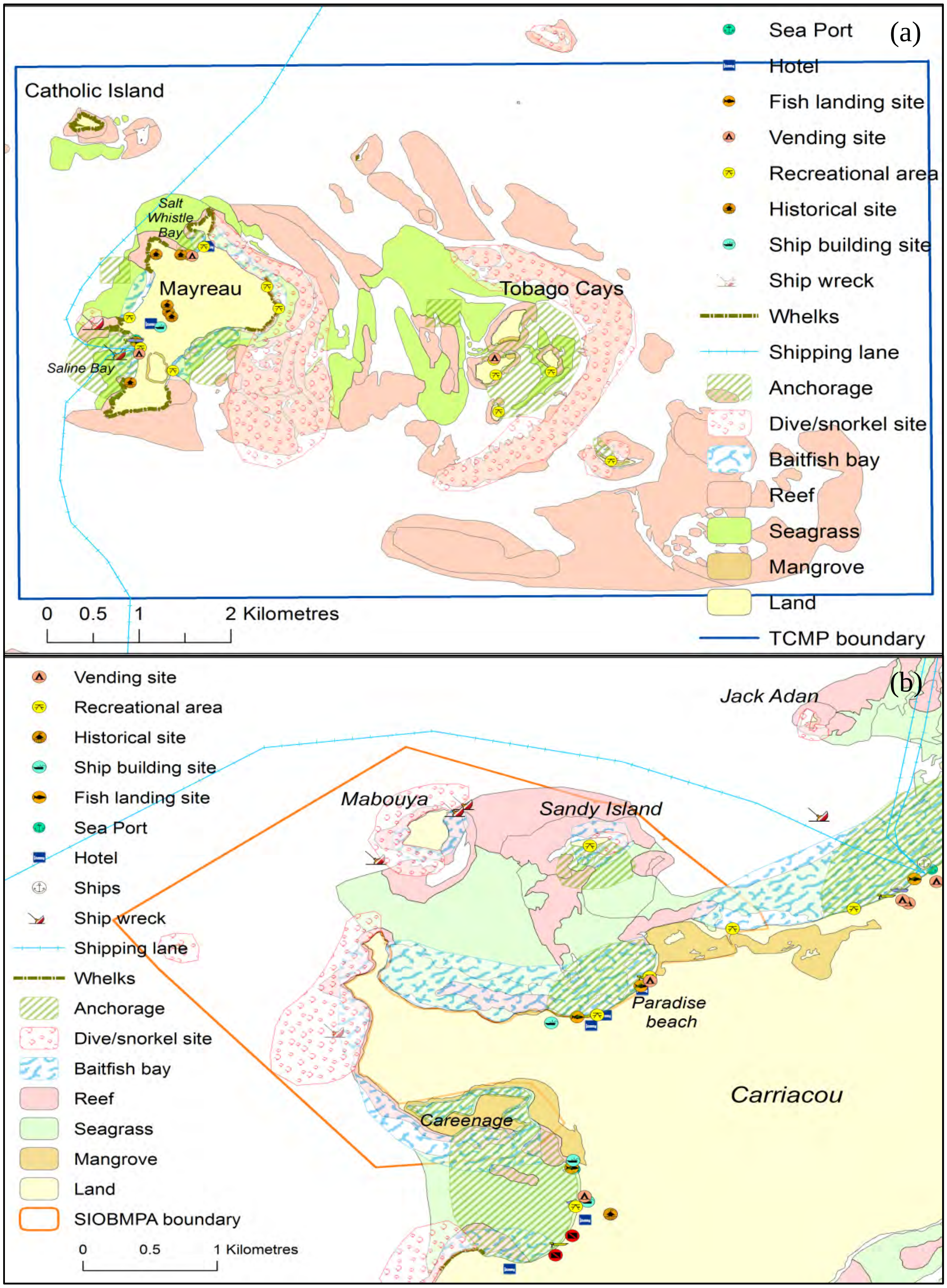


Figure 4-2 Maps showing the location of human activities that occur within: (a) the Tobago Cays Marine Park, St. Vincent and the Grenadines; and (b) the Sandy Island Oyster Bed Marine Park, Grenada.

marine park, it is important to recognise that along the southern boundary of the SIOBMPA there are multiple conflicting human space-uses occurring (Figure 4-2b). There is a marina development under construction which includes dredging activities as well as a major seaport and associated shipping lanes located in Tyrell Bay; both of which may be a threat to the adjacent conservation efforts of the SIOBMPA.

A rapid review the maps shown in Figures 4-3a, b; provides an overview of the various types and locations of coastal and marine resources that each park encompasses. In the TCMP marine habitat map, one can see the large reef system encompassed within the park boundary (Figure 4-3a). All marine and coastal habitats are represented, including a salt pond and two small patches of mangrove. There are eight sea turtle nesting beaches, five fish nursery areas and three cays identified as seabird nesting areas. From an examination of Figure 4-3b, one can see that SIOBMPA contains nearly equal amounts of both reef and seagrass marine habitats. There is also the presence of a small salt pond as well as two extensive and one minor stand of mangrove. There are four sea turtle nesting beaches, one island (Mabouya) identified for seabird nesting and seven fish nursery areas. An area of special conservation interest within the SIOBMPA is the Careenage (Oyster Bed) mangrove (Figure 4-3b). This area comprises a large healthy mangrove which hosts a large number of birds and a fish nursery as well as contains the only known oyster bed in the entire Grenadine Island chain.

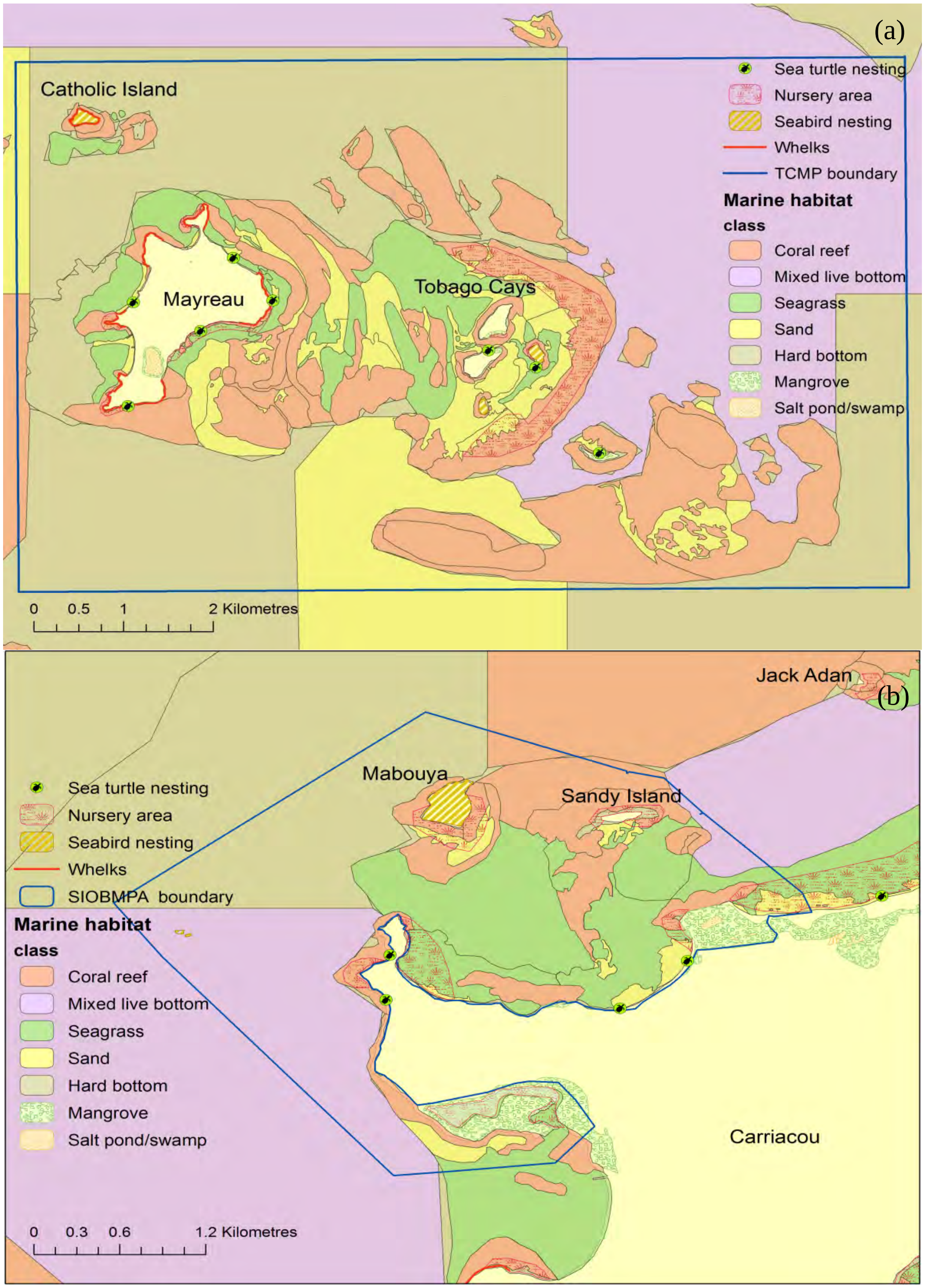


Figure 4-3 Maps showing the location of important marine resources found within (a) the Tobago Cays Marine Park in St. Vincent and the Grenadines and (b) the Sandy Island Oyster Bed Marine Protected Areas in Carriacou, Grenada.

Oysters are harvested on a small-scale from this area and this semi-enclosed natural mangrove harbour has the potential to be developed for bird-watching eco-tourism activities.

Understanding the amount and distribution of ecosystems, structurally and functionally is essential in the implementation of an ecosystem approach and MSPM initiatives (Shepherd 2004, Ehler and Douvere 2009). The total area and percent of the various types of coastal and marine habitat located in the Grenada Bank study area were calculated and are presented according to a number of different spatial variables of interest (Table 4-3). The Grenada Bank study area consists of 190,985 hectares; of which 71% (or 135,782 hectares) belongs to the country of St. Vincent and the Grenadines, and the remaining 29% (55,209 hectares) to Grenada. The shallow water habitat map comprises 8% (15,131 hectares) and the deep water habitat map the remaining 92% (175,854 hectares) of the Grenada Bank study area. The country of St. Vincent and the Grenadines was found to have proportionally more of each habitat type, except for mangrove in which 60% is located on the Grenada portion of the study area.

With regard to fisheries, lobster and reef fish fishing grounds are found to have a greater distribution (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 among mixed live bottom (45%), reef (23%) and hard bottom (20%) habitats. Reef and reef-related (mixed live bottom) habitats comprise the largest amount of habitat (79%) found on the Grenada Bank and are reported to be the most preferred habitat for all five types of fishing gear used.

Three quarters of the Grenada Bank is identified to be of high quality (defined as very good or good) fishing habitat. Likewise the areas that marine resource users (MRUs) indicated to be 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, MRUs prefer only 10% (20,027 hectares) of the Grenada Bank for fishing. This finding is of particular importance to MSPM in that it indicates a spatial preference by fishers despite the large occurrence of high quality fishing grounds. Visual examination of the location of preferred fishing grounds may be of use to reveal spatial patterns that are not obvious from summary statistics such as these (Table 4-3).

Table 4-3 Table of marine habitats found in the study area; summarised as total area (hectares) and percent (%) total of the Grenada Bank broken down by location, fishery, fishing gear suitability and fishing quality. ***(N.B. GB = Grenada Bank).***

Variable			Reef	Mixed live bottom	Hard bottom	Sand	Seagrass	Mangrove	Salt pond	Area (ha)&% total
Grenada Bank	Study area	Area (ha)	73,383	77,800	22,685	13,974	2,932	161	50	**190,985**
		% total	38	41	12	7	2	0	0	**100**
	St. Vincent and the Grenadines	Area (ha)	42,179	67,534	13,575	10,977	1,420	64	33	**135,782**
		% GB	57	87	60	79	48	40	66	**71**
	Grenada Grenadines	Area (ha)	31,204	10,266	9,110	2,997	1,512	97	17	**55,203**
		% GB	43	13	40	21	52	60	34	**29**
	Shallow water habitat map	Area (ha)	7,284	1,878	1,196	1,630	2,932	161	50	**15,131**
		% GB	48	12	8	11	19	1	0	**8**
	Deep water habitat map	Area (ha)	66,099	75,922	21,489	12,344	NA	NA	NA	**175,854**
		% GB	38	43	12	7	NA	NA	NA	**92**
Fishery species	Conch	Area (ha)	11,006	21,543	9,420	4,903	1,274	NA	NA	**48,146**
		% GB	23	45	20	10	3	NA	NA	**25**
	Lobster	Area (ha)	65,501	63,752	7,581	3,714	909	NA	NA	**141,457**
		% GB	46	45	5	3	1	NA	NA	**74**
	Fish	Area (ha)	68,220	73,149	11,588	4,647	1,414	NA	NA	**159,018**
		% GB	43	46	7	3	1	NA	NA	**83**

Table 4-3 (continued) Table of marine habitats found in the study area.

	Variable		Reef	Mixed live bottom	Hard bottom	Sand	Seagrass	Mangrove	Salt pond	Total
Fishing gear Suitability	Fish trap	Area (ha)	58,239	53,611	9,125	2,815	774	NA	NA	**124,564**
		% GB	47	43	7	2	1	NA	NA	**65**
	Line	Area (ha)	64,532	68,530	8,969	3,610	865	NA	NA	**146,506**
		% GB	44	47	6	2	1	NA	NA	**77**
	SCUBA tank	Area (ha)	43,007	62,176	13,816	6,040	692	NA	NA	**125,731**
		% GB	34	49	11	5	1	NA	NA	**66**
	Seine net	Area (ha)	52,475	31,187	8,317	1,635	764	NA	NA	**94,378**
		% GB	56	33	9	2	1	NA	NA	**49**
	Spear gun	Area (ha)	38,814	59,442	7,909	3,851	1,080	NA	NA	**111,096**
		% GB	35	54	7	3	1	NA	NA	**58**
Fishing quality	Very good	Area (ha)	36,452	22,923	744	456	105	NA	NA	**60,680**
		% GB	60	38	1	1	0	NA	NA	**32**
	Good	Area (ha)	26,429	39,310	11,281	3,821	731	NA	NA	**81,572**
		% GB	32	48	14	5	1	NA	NA	**43**
	OK	Area (ha)	8,417	12,854	8,087	4,870	1,372	NA	NA	**35,600**
		% GB	24	36	23	14	4	NA	NA	**19**
	Poor	Area (ha)	2,086	2,713	2,574	4,828	725	NA	NA	**12,926**
		% GB	16	21	20	37	6	NA	NA	**7**
	Preferred fishing grounds	Area (ha)	7,930	5,820	2,491	2,513	1,273	NA	NA	**20,027**
		% GB	40	29	12	13	6	NA	NA	**10**

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 no-take MPAs (Table 4-4). In terms of size alone, the TCMP consists of 6,201 hectares and is 7 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 a total of 4.6% of the country's total marine area as protected; whereas the SIOBMPA (or Grenada Grenadines) only provides protection of 1.6% of its marine area.

Table 4-4 Area (in hectares) of each habitat type contained within the Tobago Cays Marine Park (TCMP) and Sandy Island Oyster Bed Marine Protected Area (SIOBMPA), also represented 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	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		

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, 7.4% (66 ha) mangrove, 25.5% (227 ha) seagrass and 18.7% (166 ha) of the marine park comprises coral reef. The TCMP on the other hand hosts less than one percent (4 ha) mangrove habitat, 5.9% (365 ha) seagrass and 22.1% (1,370 ha) coral reef habitat. These types of straightforward analyses exemplify the ability of GIS as a tool to easily and quickly access and summarise spatially-based data into useful information for evaluating the effectiveness of MSPM initiatives.

Spatial queries can be valuable for marine conservation prioritisation. GIS was applied to pinpoint the location of adjacent coastal mangroves, seagrass beds and coral reef habitats (areas considered to be representative reef ecosystems) found on the Grenada Bank. Based on these criteria, 13 representative reef ecosystems were identified in the Grenada Bank study area (Figure 4-4). These are areas considered to be important to reef and fisheries conservation and resilience. Next these identified areas can be used in MSPM to evaluate the location of existing conservation efforts or the selection of additional areas for management protection.

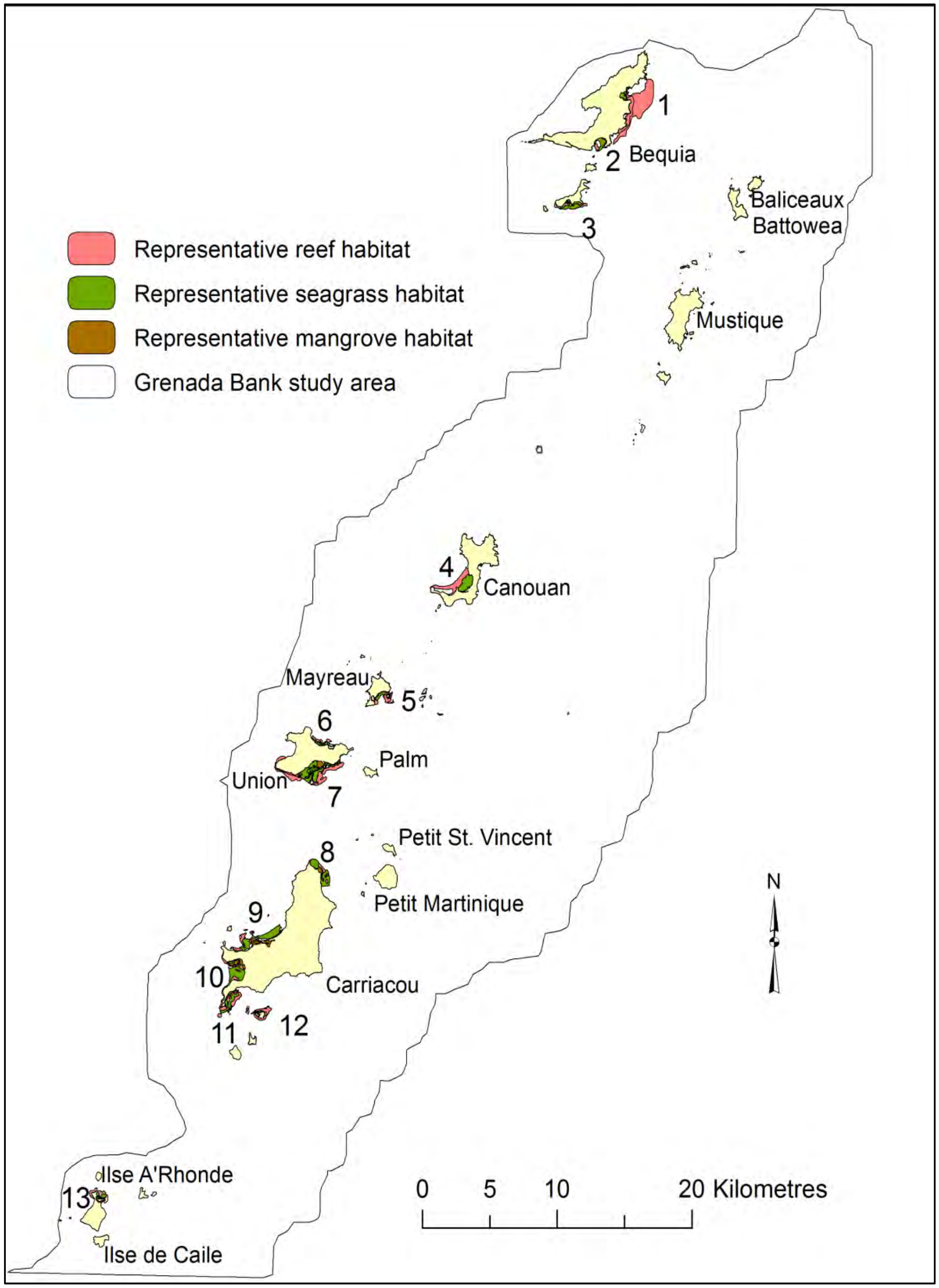


Figure 4-4 A map showing the location of representative coastal and marine reef ecosystems identified for the Grenada Bank.

Once the locations of these representative reef ecosystems have been identified, these areas can be scrutinised with regards to their suitability for conservation to determine the prioritisation of management efforts. This starts with a spatial examination of the physical location of other features with regard to the location of the identified representative ecosystems. For example, the location of representative reef ecosystems and areas of identified threat should be explored to evaluate trade-offs and prioritise conservation efforts on areas with higher environmental integrity. In terms of social acceptance of management, consideration should be given to the human activities which occur in the area so as to weigh the impact on the various livelihoods and assess possible displacement of MRUs. Finally, the location of towns and supporting coastal infrastructure can be considered so that the feasibility of enforcing the conservation area can be determined. These types of socio-economic factors are critical in determining the effectiveness of potential conservation measures.

Applying the above approach to Union Island, two representative reef ecosystems are identified (Figure 4-5); one located in Richmond Bay (1) and the other surrounding the Ashton Lagoon harbour (2). An overlay of the jurisdictional boundary of the Union-Palm marine conservation area reveals that the boundary of this conservation area may not be appropriately located to allow for the most effective protection of the identified representative reef ecosystem. Presenting this information in a map such as Figure 4-5 can provide not only a clear understanding of the location of critical habitats, but also can allow its users to visualise a possible relocation of the jurisdictional boundary to provide for the maximum conservation effectiveness. Furthermore, a GIS interface can allow users to easily obtain point coordinates for a proposed boundary which can be inputted into a GPS for a field-check and demarcation to ensure the desired outcome has been accurately achieved.

Once ecosystem conservation priorities have been identified, the potential impact on livelihoods and management feasibility should be assessed. To illustrate how this can be approached one can examine the map representing human activities that presently occur in Union Island (Figure 4-6) and their relationship to the two possible representative reef ecosystem conservation areas. On examination of this human activity map, one can see that these two identified representative reef ecosystems contain very different levels of human activity. In Richmond Bay, there is one hotel, two recreational areas used for picnicking and swimming, two historical sites and the coastal area is used for baitfishing. Ashton Harbour, on the other hand is home to one of the two main communities in Union Island. Ashton is a major seaport: the base of a ferry operation; the largest fish landing site in the island; a yacht anchorage; and is used for seamoss mariculture. Furthermore, the harbour hosts three recreational picnicking areas, a shipbuilding site, two historical sites and is used for harvesting whelks and baitfish.

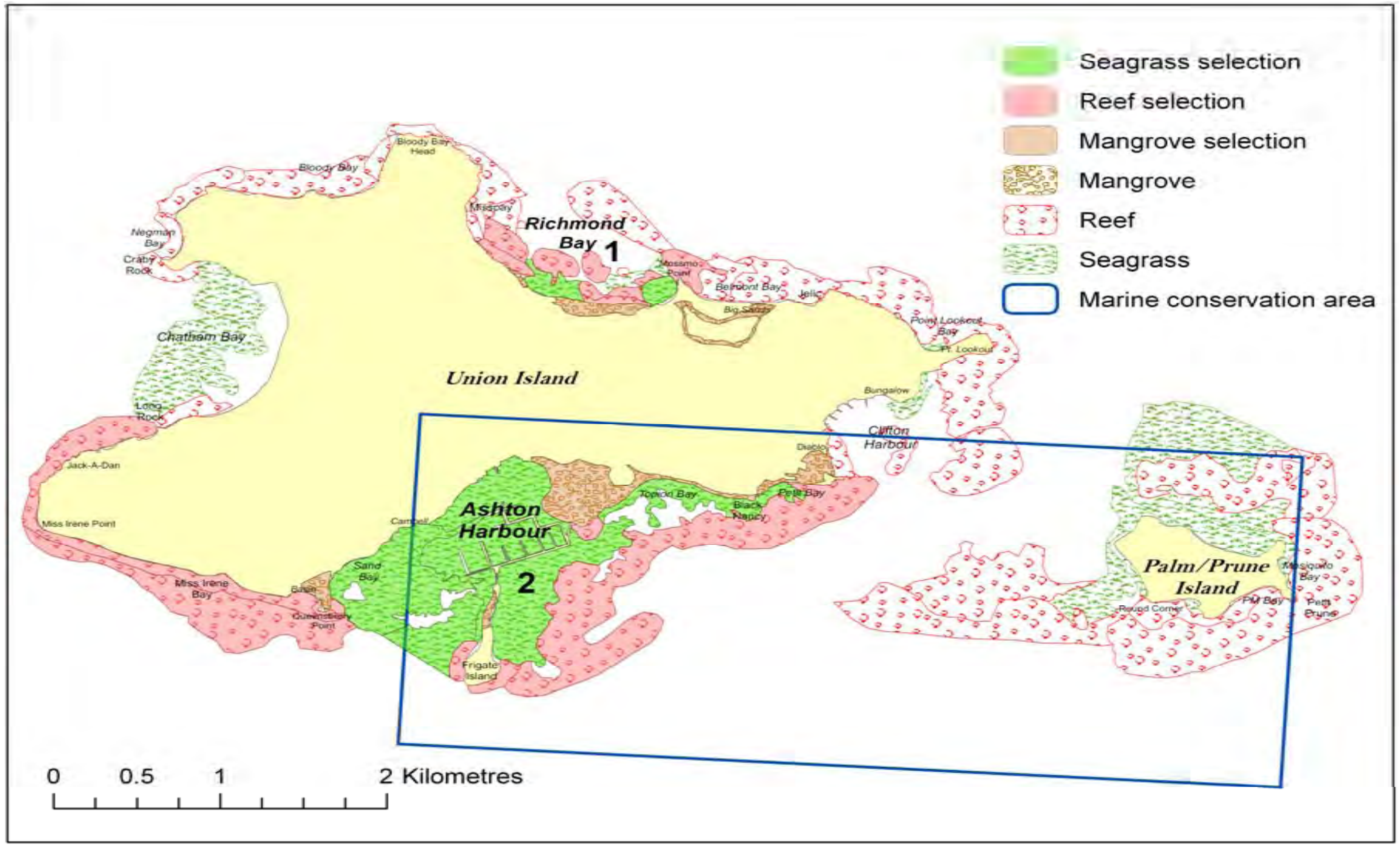


Figure 4-5 A map of critical marine habitats (reef, seagrass and mangrove combinations) found around Union and Palm Island.

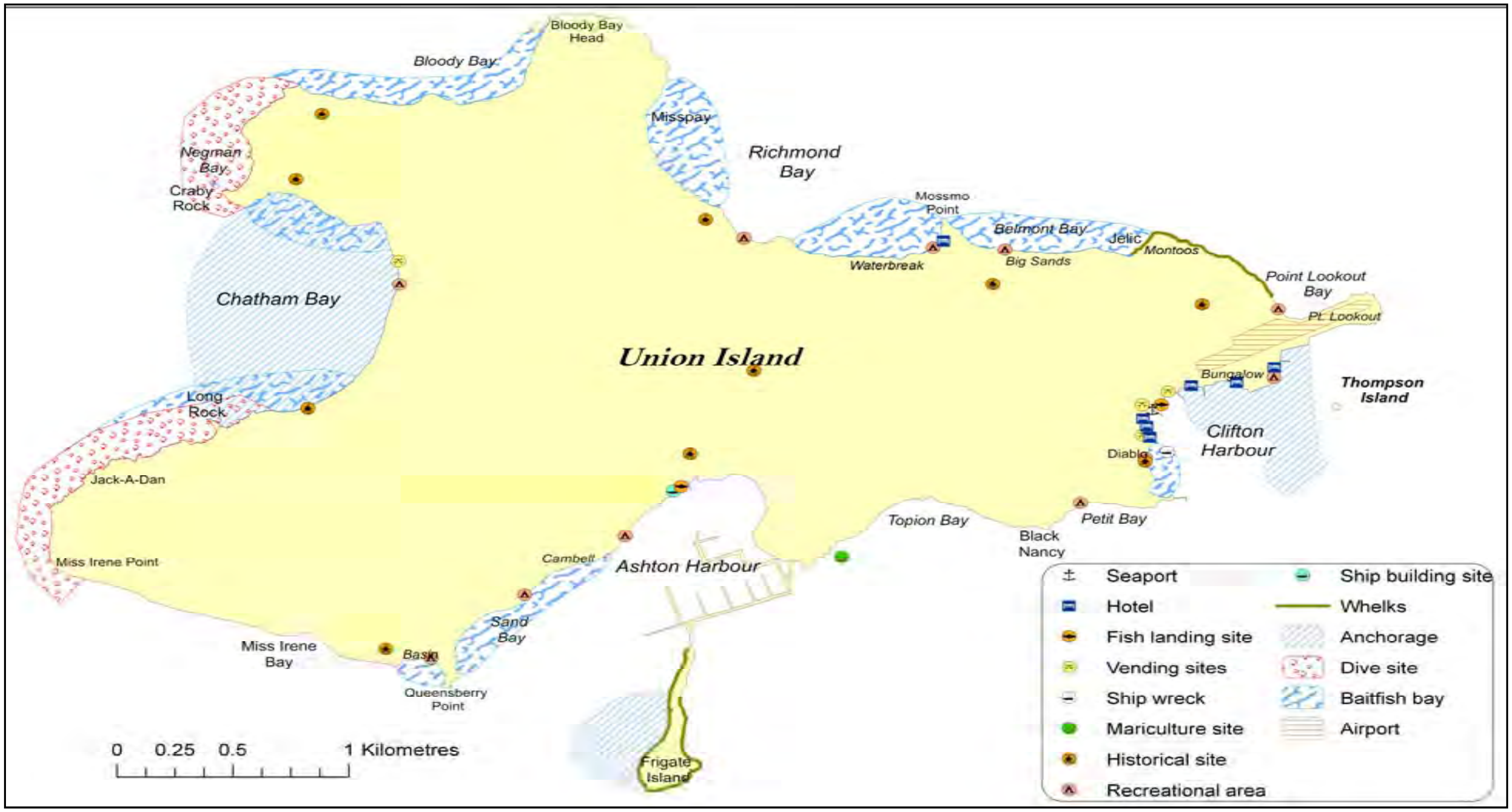


Figure 4-6 A map of the human activities which occur in Union Island, St. Vincent and the Grenadines.

Although Richmond Bay hosts less human activity and therefore may offer less threat to conservation effectiveness, Ashton Harbour may be seen as a more suitable location for management success in terms of its existing coastal infrastructure for management and enforcement of the area. Again the purpose of this analysis is merely to demonstrate how these types of information can assist integrated MSPM through the development of scenarios and the evaluation of trade-offs required for decision-making and the determination of management priorities.

Spatial understanding of the distribution of human activity can be enhanced by querying associated attribute information. An attribute query, with the results displayed as a series of pie charts, one for each of the Grenadine Islands, provides a clear spatial picture of the distribution of MRUs (Figure 4-7). The largest numbers of MRUs are found in the two largest islands of Bequia (203) and Carriacou (138). Fishers comprise the largest MRU group, again with the islands of Bequia (90) and Carriacou (57) containing the most fishers. The northern Grenadine Islands (i.e. Bequia, Mustique and Canouan) have a wider diversity of MRUs than the southern Grenadine Island communities, perhaps indicating a heavier reliance on the sea for livelihood opportunities. The two smallest private resort islands (i.e. Palm and Petit St. Vincent) contain the smallest number and variety of MRUs. Water taxi operators are found to comprise the largest proportion of all MRUs across all of the remaining islands.

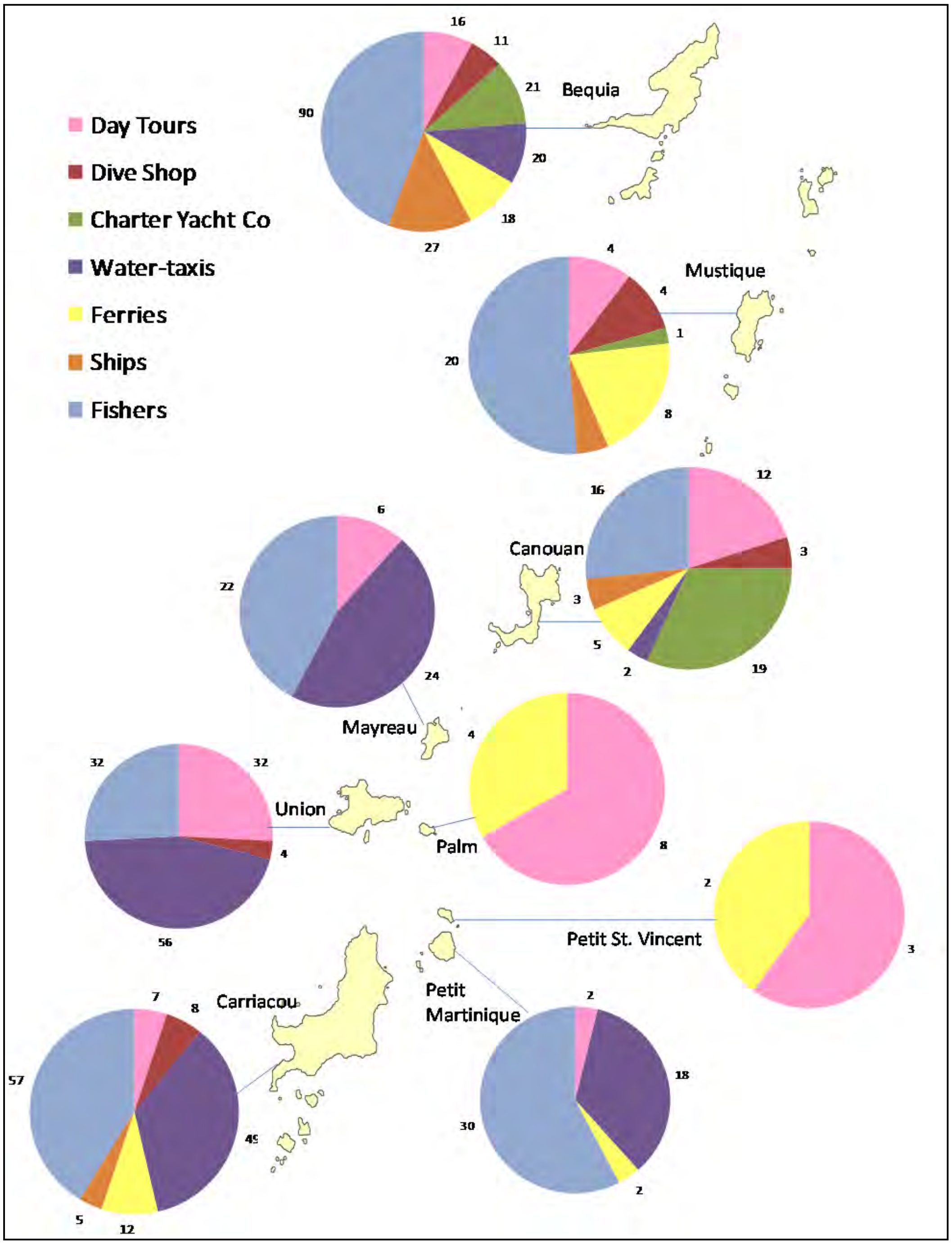


Figure 4-7 The distribution and make up of Grenadine marine resource users found in each inhabited island. ***N.B. Numbers indicate the numbers of MRUs for each island.***

This type of analysis can be of use for understanding the areas and patterns of resource use as well as the linkages between the resources and livelihoods and thereby aid the assessment of possible social implications of various management options and decision-making.

Overlaying the location of high quality (i.e. 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. As previously mentioned, Grenadine fishers indicate a preference to fish only 10% of the Grenada Bank, despite the presence of a large amount (75%) of high quality fishing ground within the study area (Table 4-3). When this information is viewed spatially, some interesting distribution patterns become apparent (Figure 4-8). It becomes obvious that despite the presence of good quality fishing grounds fishers prefer to fish close to shore in shallower water. This pattern is most likely 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. Thus, spatial analyses reveal a large amount of high quality fishing grounds are not currently exploited on the Grenada Bank. This finding may not be apparent in the review of summary statistics alone (i.e. Table 4-3). This type of finding may 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

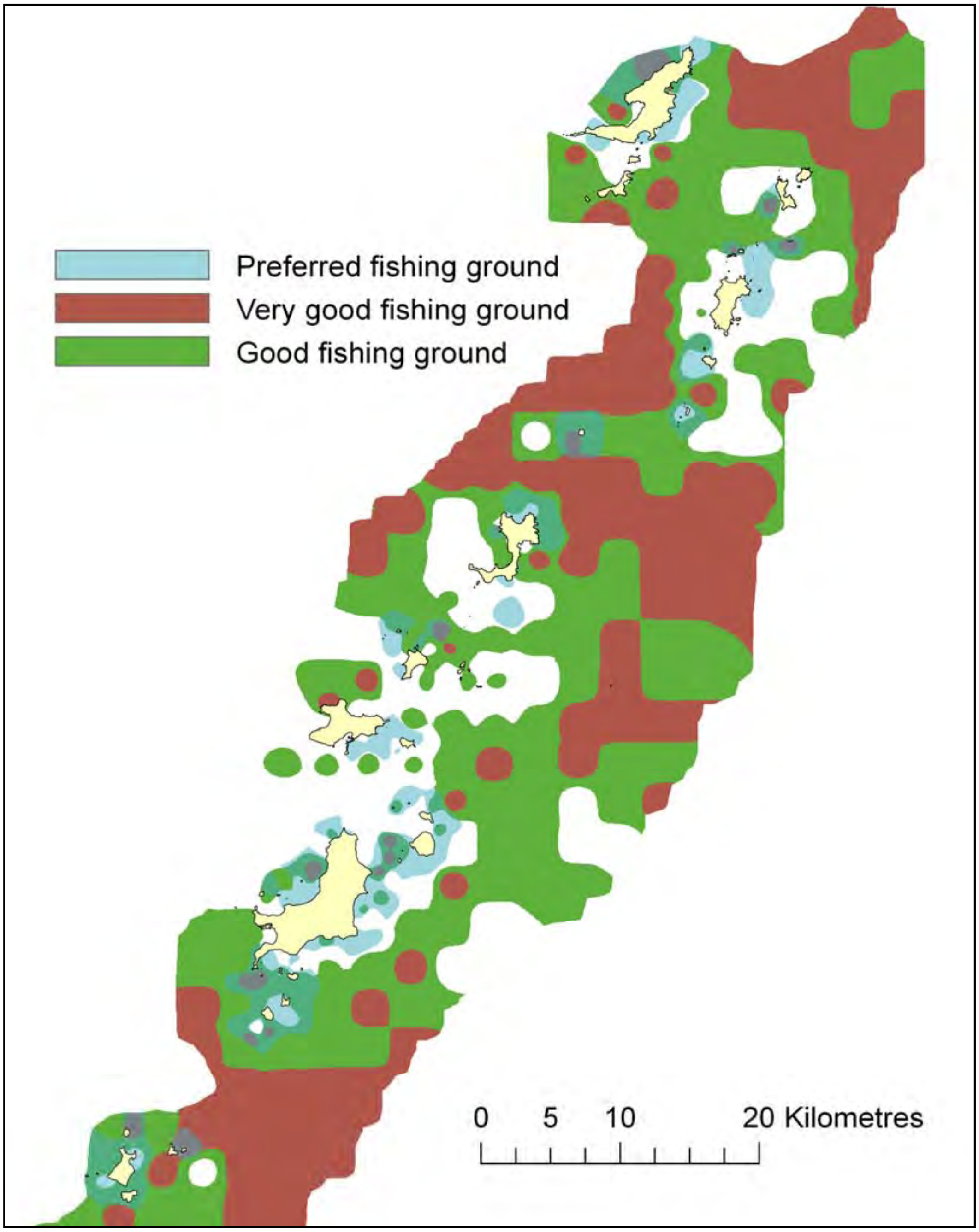


Figure 4-8 A map of the spatial distribution of preferred fishing areas overlaid on the location of high quality (very good and good) fishing grounds.

place by virtue of the limitations of fishing methods and vessels that are currently in use. Those who may seek to develop or modernise the fishing industry of the Grenadines should be conscious of how their initiatives may affect this current situation. Additionally, this information may be of use in the determination of feasible conservation or 'no-take' fishing areas by aiding the selection of areas which are not high priority fishing banks. Thus these types of analyses can contribute to MSPM through identification of potential conservation zones in areas with low use by fishers. This approach may meet with little resistance from or have little impact upon fishers thereby assisting management acceptance and compliance.

GIS can be applied to integrate a variety of information to explore the interactions among variables and prioritise MSPM initiatives. To identify areas where many features of interest are co-occurring, three cumulative impact surfaces (one for conservation, one for human activities and one for identified threat) were created for the Grenada Bank study area. These integrated surfaces can lend insight on areas of priority for conservation and livelihoods as well as identify areas that contain a high amount of threat or may be counteractive to management effectiveness. It should be recognised that due to data limitations, these results are biased towards the near-shore marine and coastal environment. Nonetheless, this is where most human activity takes place and valuable information for planning can be generated using this approach to analysis of multiple variables.

The Grenada Bank study area was converted to a raster surface which comprised a total of 20,808 $100m^2$ grid cells. A total of 11,060 grid cells (or 53%) of the Grenada Bank study area (Table 4-5) was found to be of importance for at least one conservation feature of interest (Table 4-2) and as many as five of the nine features were overlapping in three of the grid cells. Similarly, a total of 11,447 grid cells (or 55%) of the study area is used for human activity or livelihoods and as many as eight of eleven human activities (Table 4-2) were found to be co-occurring in one grid cell. Activities of threat were identified on 1% (or 1,261 grid cells) of the Grenada Bank and three of the eight mapped featured (Table 4-2) were found to overlap in 15 of the grid cells. For each cumulative impact surface (conservation priority, human activity and threat), the total number of identified grid cells was also calculated as a frequency of overlapping cells and a percent total of each respective surface (Table 4-5). A hotspot (or area with at least three overlapping features) was found in 319 grid cells (or 2.4%) of the conservation impact surface; 385 grid cells (or 2.9%) of the human use cumulative impact surface; and 15 (or 1%) of the cumulative threat surface.

Overlaying the Grenada Bank cumulative impact surfaces with the marine habitat can give insight on the linkages between the environment and human activity. For example, 76% of the areas identified to be important for conservation are located in reef areas (59%) or on land (17%) (Table 4-6). Likewise, reef (36%) was most

Table 4-5 Summary of the frequency of overlapping features by the number of grid cells (10m x 10m) and as a percent total for each of the cumulative impact surfaces created of human uses, conservation features and threat.

Conservation			Human use			Threat		
frequency	# grid cells	% total	frequency	# grid cells	% total	frequency	# grid cells	% total
1	11,060	82.4	1	11,447	86.0	1	1,261	85.4
2	1,982	14.8	2	1,199	9.0	2	201	13.6
3	319	2.4	3	385	2.9	3	15	1.0
4	54	0.4	4	176	1.3	4	0	0
5	3	0	5	68	0.5	5	0	0
6	0	0	6	15	0.1	6	0	0
7	0	0	7	13	0.1	7	0	0
8	0	0	8	1	0.0	8	0	0
	13,418			13,304			1,477	

Table 4-6 Proportion (as percent total) of habitat type comprising each of the cumulative impact surfaces (conservation priority, human activity and threat).

Habitat	Conservation % total	Human use % total	Threat % total
Hard bottom	1.5	13.2	0.9
Land	17.0	5.0	66.2
Mangrove	0.1	< 0.1	0.3
Mixed live bottom	3.9	20.8	2.7
Reef	58.5	35.6	12.8
Sand	4.4	20.1	5.3
Seagrass	14.5	5.3	11.7

heavily used habitat for human activities. On the other hand, the vast majority (66%) of identified threat was found to occur on land.

Cumulative impact overlays can also be of relevance in the development of spatial management scenarios. For example, overlaying the conservation priority surface with the cumulative threat impact surface can highlight areas of potential space-use conflict which can ultimately undermine conservation effectiveness. Likewise, overlaying the human activity cumulative impact surfaces and the conservation priority surface may be of use in weighing various scenarios and assist in the identification of the most cost-effective options in which to pursue conservation efforts or the management of high use areas.

A closer examination of the three cumulative impact surfaces for the island of Carriacou (Figure 4-9) reveals some interesting patterns. Figure 4-9a is a composite conservation map of Carriacou which highlights priority areas for conservation; Figure 4-9b 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 4-9c 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 village of Harvey Vale. The Careenage mangrove is identified as being an area of high (five overlapping features) conservation priority (Figure 4-9a). Tyrell Bay is also a major seaport in the island of Carriacou being heavily used by tourists as a preferred yachting anchorage. In addition Tyrell Bay hosts a number of human activities important for the surrounding communities (as previously discussed) (Figure 4-9b). There are also a number of threats identified including mangrove cutting, artificial coastal structures and dredging that result from the construction of a marina in the area (Figure 4-9c). These types of finding can be utilised in MSPM, especially as the location of human use and threat hotspots are bordering the boundary of the newly established SIOBMPA (Figure 4-1). Essentially, the high amount of threat and human activity identified in this analysis may not be consistent with the conservation action and may serve to weaken the ultimate effectiveness of this 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.

Ultimately, these types of GIS analyses can be of value to understand the extent and distribution of existing resources and their relationship to coastal livelihoods by assisting with the assessment of trade-offs between uses and management action. This type of information can be useful 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 be important to allow for integrated and holistic MSPM by adressing complexity of marine ecosystems in a practical and socially-acceptable manner.

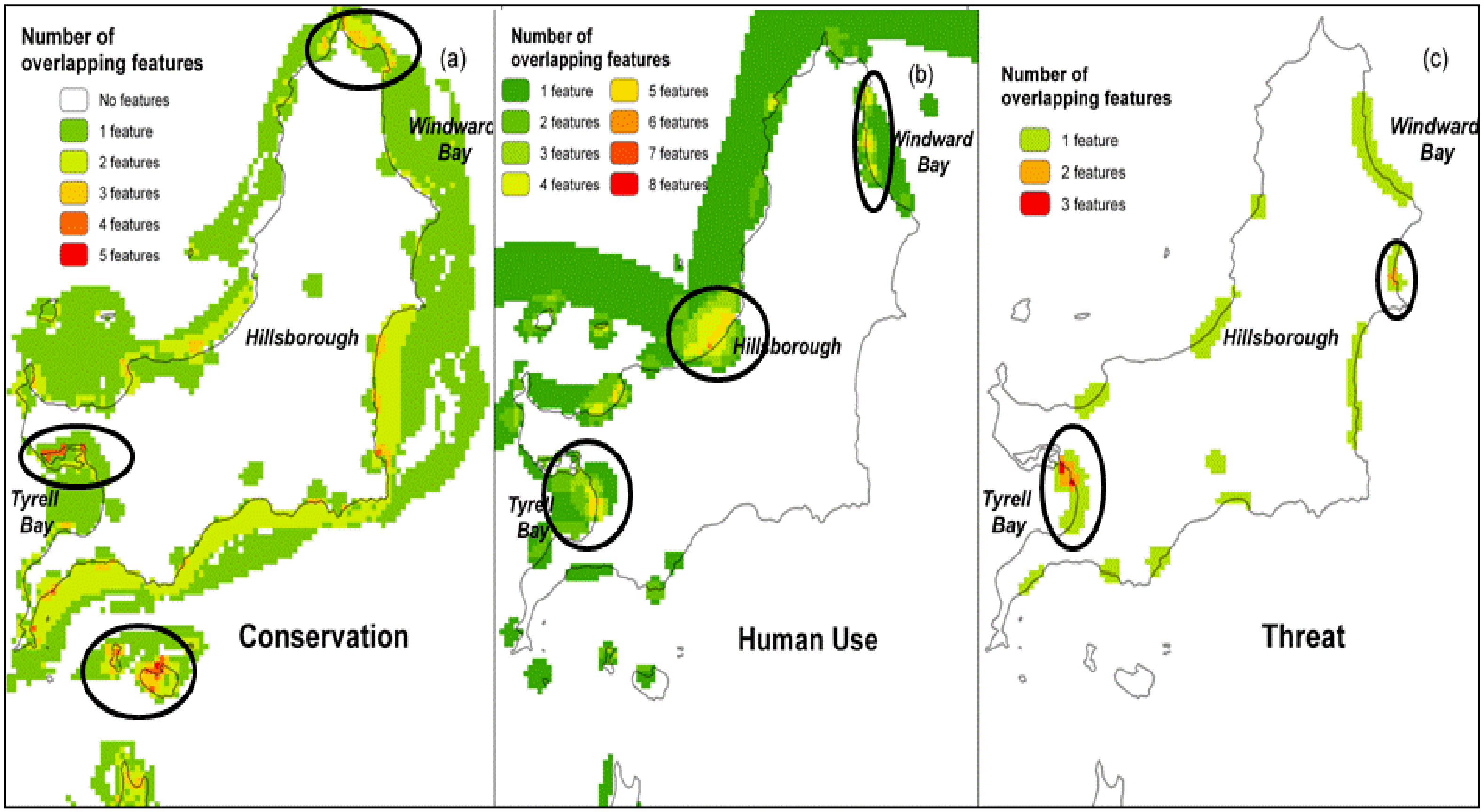


Figure 4-9 Cumulative impact surfaces (conservation, human use and threat) and identified hotspots of space-use overlap for the island of Carriacou, Grenada.

4.4 CONCLUSION

The usefulness of integrating interdisciplinary multi-knowledge information for EBM and marine spatial planning is well documented (De Young and Charles 2008, De Freitas and Tagliani 2009, Dalton et al. 2010, Tallis et al. 2010). However, as previously outlined, the actual framework and practical methodologies for achieving holistic information for MSMP is lacking (Crowder and Norse 2008, Douvere and Ehler 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 supporting interactive governance.

To implement an EA to the management of marine resources of the Grenada Bank, it is important to collect, integrate and interpret large volumes of data from disparate sources of the distribution of marine resources and associated human activity that occur. Thus the benefits of using a systemised spatially referenced multi-knowledge PGIS approach for MSPM includes: (1) effectiveness in data collection, information generation and data management including the identification of information gaps; (2) the promotion of ecosystem-based spatial thinking and increased stakeholder understanding of space use patterns; and (3) the definition of existing areas of importance for conservation, human activity and threat in order to weigh trade-offs and determine the most effective course of action for MSPM initiatives. PGIS can support collaborative MSPM by increasing stakeholder confidence and understanding for information produced that is required to allow for meaningful deliberation and consensus in order to collaboratively generate a scientifically appropriate and socially acceptable marine space-use plan for the transboundary Grenada Bank.

5 SYNTHESIS OF RESEARCH AND OVERALL CONCLUSION

The application of a comprehensive strategy using multiple sources of information to address complex socio-ecological problems is recognised as essential for an ecosystem approach (EA) to marine governance (Bavinck et al. 2005, Hughes et al. 2005, Kooiman et al. 2005, Berkes 2007, Ostrom et al. 2007, Armitage et al. 2008, Mahon et al. 2008). In this study of marine space use in the transboundary Grenadines Islands, a participatory geographical information system (PGIS) approach was employed as a conceptual framework to integrate conventional biophysical and management information with information derived from the practical knowledge of marine resource users.

This dissertation details the ways in which stakeholders were engaged to develop a participatory geographical information system (PGIS) entitled the Grenadines Marine Resource and Space-use Information System (MarSIS), in terms of both the research approach (process) and the final geodatabase (product). The MarSIS geospatial framework underscores the power and utility of PGIS for marine spatial planning and management (MSPM). This research was undertaken for two reasons: (1) to investigate ways of developing an integrated baseline of the extent and distribution of marine resources, associated patterns of use and the identification of threats for use in planning ecosystem-based MSPM; and (2) to explore the feasibility of various approaches to illustrate for other practitioners the ways in which multi-knowledge information on coastal and marine resources and human activities can be brought together, analysed and used in scenario development as a starting point for collaborative MSPM.

To evaluate the utility of PGIS for an ecosystem-based approach to marine management and planning the research was designed to address two propositions set out in Chapter 1. This final chapter synthesises the research in the context of those propositions and evaluates them in light of the findings. The chapter concludes with a discussion of how the application of PGIS can serve as a practical mechanism to improve governance by promoting inclusiveness, transparency, appropriateness, ownership, equitable access and partnership, which are important values for effective governance. Recommendations for the sustainability of the project and implications for transboundary management are also provided.

Box 1. Research Proposition 1

Merging local knowledge on ecology of marine resources, space-use patterns related to the resources and the socio-economic situation regarding users with conventional biophysical environmental information in the Grenadine Island setting will provide significant improvements in the development of information for ecosystem-based management over the use of the latter alone.

With regard to proposition 1 (Box 1), the usefulness of integrating interdisciplinary multi-knowledge information for EBM and marine spatial planning is well documented (Aswani and Vaccaro 2008, De Freitas and Tagliani

2009, Dalton et al. 2010, Tallis et al. 2010). However, as outlined in Chapter 1, both a structured framework and a suite of practical methodologies for achieving holistic information for MSMP are lacking (Crowder and Norse 2008, Douvere and Ehler 2009, Tallis et al. 2010, Fanning et al. 2011). In this study a framework for PGIS was developed, applied and found to be a practical approach to aid the collection, integration and understanding of multi-knowledge interdisciplinary information. This information was shown to present significant opportunities for realising ecosystem-based MSPM on the Grenada Bank.

Extensive stakeholder engagement in the development of the MarSIS provided a means for civil-society to contribute to the information base for transboundary decision-making and management of the Grenada Bank. Moreover effective marine resource management further requires information that is at a scale and format comprehendible to stakeholders. A PGIS approach was found to be valuable not only in obtaining and integrating a wide range of knowledge from an array of stakeholders and sources, but to guide the production of locally-relevant ecosystem-based information and increase inter- and intra-stakeholder understanding of interdisciplinary marine resource information.

In a complex geopolitical environment such as the Grenadine Islands nearly two years were required to conduct a thorough preliminary assessment; yet this was found to be essential for a PGIS in many ways. A variety of participatory research methods, including: collaborative data scoping, stakeholder meetings, key informant interviews, personal observation and mapping exercise methods were found to be useful in gathering information from stakeholders (Chapter 2). The preliminary assessment also allowed the time and the opportunity to understand the local context of the various levels of stakeholders and the implications of the differences among them. Although time consuming, this process was crucial in providing a clear understanding of the capacity for participation of each of the various stakeholder groups that could not have been gained through surveys or short field visits. Time was also required to allow stakeholders, many of them not accustomed to thinking in terms of data and information, to understand the research objectives and what knowledge they could contribute. The preliminary appraisal ultimately aided the stakeholder groups in understanding the research aims, provided for mutual learning and supported the formation of partnerships. In particular, the MarSIS egroup was noteworthy in that it allowed for easy access to information and provided transparent two-way communication across such a multi-level cross-scale range of stakeholders. Insights gained from the preliminary assessment were seen as essential to develop appropriate engagement mechanisms, to produce relevant information and to gain creditability from such a large and diverse set of stakeholder groups.

The importance of assembling simple and widely understandable information is a tenet of PGIS. Thus it was essential to develop a habitat classification scheme and base maps that were locally-relevant (Chapter 3). The GIS interface allowed for the effective collation of a variety of source and scales of secondary spatial information in an accessible format. The PGIS approach provided a mechanism to share and collaboratively evaluate the information acquired and mapping products. Likewise, the need to develop a habitat scheme and mapping products at a scale relevant for local and transboundary management was resonated in interviews with marine resource managers and the results of the habitat flashcard exercise further substantiated this need. Ultimately the collaboratively developed habitat scheme was shared with the wider stakeholder group using the e-group before being finalised and applied.

A central premise of EBM is the need to integrate human agency in the study of the environment and the development of appropriate management initiatives. Participatory research practices made it possible to incorporate stakeholders' practical knowledge within the GIS framework for the Grenadines. Ultimately local knowledge accounted for 63% (54 feature classes) of the MarSIS geodatabase, the majority of which comprised distinctive, spatially-based, socio-ecological information. This integration of information has led to significant improvements in the development of ecosystem-based information as summarised below.

In the first instance, an improvement to the coastline basemap ensured that place names were recognisable to stakeholders and served to assure the quality of information on mapped features in subsequent exercises. The alternative importance of this process was realised during the validation meetings and distribution of these 'local name' maps in each island. As this type of map had never been developed in the Grenadine Islands before, the production and distribution of these maps made spatially-explicit community discussion and debate possible, further aiding community knowledge and acceptance of the research.

Spatial information that highlights livelihood space-use patterns is a critical component for realising ecosystem-based MSPM. Merging the results of socio-economic surveys with spatial data derived from mapping exercises allowed for the development of socio-economic space-use profiles for the various Grenadine marine resource users (i.e. day tour and water taxi operators, charter yacht companies, dive shops, ferries and ships) to be incorporated in the GIS interface (Chapter 2). Local knowledge was found to be useful to map the distribution of key coastal and marine resources and uses as well as areas of concern or threat (Chapter 2). Use of key informants allowed for the efficient identification of the most knowledgeable person(s) for each of the mapped features. The incremental approach to mapping exercises (starting with the toponymy, then identifying livelihood space-use patterns and lastly moving on to resources, uses, and areas of threat) was thought to be advantageous in that it allowed the time needed to build capacity in the MRUs as well as the trust required for them to share sensitive information (such as illegal activities). Thus, mapping exercises and the production of unique socio-ecological information were found to aid the understanding of the human uses of coastal and marine resources.

Little has been done to incorporate local knowledge into remote sensing and habitat mapping techniques despite the recognition of its usefulness (Aswani and Lauer 2008, Lauer and Aswani 2008). In this study, local knowledge validation exercises easily improved the accuracy of the remotely-sensed shallow water habitat map by 12% demonstrating the value that stakeholder engagement can add to this conventional geomatic technique (Chapter 3). Incorporating MRUs as part of the field research team and including their knowledge in the marine survey variables allowed for the production of information on human-habitat interactions. Improvement to conventional marine field survey with variables to record fisher's spatial understanding of the 'physical environment' or benthic substrate and the 'biological resources' or associated species which occur, allowed for the tacit associations to be captured and modelled in the GIS. These modifications to integrate local knowledge with conventional scientific approaches allowed for ecosystem-based information to be created and incorporated into habitat mapping products useful for MSPM.

Stakeholder feedback was instrumental in ascertaining the technological capacity of stakeholders and the appropriate type of technology to be used for the MarSIS geodatabase and other informational end products (Chapter 2). For example, during the planning for usability workshops, 67% of stakeholders surveyed suggested the Google Earth interface as the most appropriate software application and 84% identified the internet as the most appropriate avenue for widespread stakeholder access to the MarSIS information. Stakeholder evaluations confirmed that the process of PGIS resulted in the production of information that was relevant and accessible.

Since the release of the MarSIS Google Earth geodatabase, a variety of Grenadine stakeholders have independently accessed and used the MarSIS. The United Nations Economic Commission for Latin America and the Caribbean used the MarSIS to quantify the economic value provided by reef ecosystem services in St. Vincent and the Grenadines (Joslyn, O. personal communication). With the support of SusGren, the countries of St. Vincent and the Grenadines and Grenada have used the MarSIS (June 2012) to generate information in support of a transboundary application to the UNESCO World Heritage Committee to designate the Grenadine Islands as a marine mixed (natural and cultural) heritage site (www.whc.unesco.org). Both of the national planning departments have reported that they use the MarSIS to check the validity of environmental impact assessments submitted to the government. Two local NGOs have used the MarSIS to contest environmentally unsustainable coastal development projects. In one case this was to show the implication of a dredging and sand reclamation project in Canouan (Price 2011) and in the other to rally against a proposed freeport development in Carriacou (PIA 2011). Primary and secondary school teachers were trained in and are using Google Earth and the MarSIS data in environmental and geography curricula (Baldwin 2010). Furthermore, the MarSIS website (www.grenadinesmarsis.com) had to be upgraded due to a large amount of internet traffic and downloading of information.

The application of a PGIS platform allowed the production of a wide variety of comprehensive qualitative and quantitative socio-ecological information that is relevant at a transboundary scale and at the levels of communities, islands and nations. Albeit time consuming, open and transparent communication and information exchange among stakeholders, including the validation of information produced from the merging of local knowledge with conventional environmental information, provided for quality assurance and resulted in the shared understanding of ecosystem-based information.

Box 2. Research proposition 2

Integrating information from the full range of stakeholder groups and their respective sectors through the use of GIS will provide management insights that cannot be acquired by examining the data and information separately.

MSPM requires the collection, integration and interpretation of large volumes of data from disparate sources on the distribution of marine resources and associated human activity occurring in the planning area. GIS technology allowed for the integration of social and ecological information and spatial analyses that led to unique management insights. Furthermore, the application of PGIS (in terms of information integration, visualisation, modelling and summarisation) proved beneficial in that it allowed for spatially-based ecosystem-level analyses of the Grenada Bank to be conducted and presented in ways that increased stakeholder understanding of information generated.

The GIS interface was found to aid stakeholder comprehension by allowing spatial information to be visualised. Simple marine resource and associated human activity maps of the two marine protected areas allowed for an understanding of human-environmental interactions that occur. Geoprocessing tools were used with marine survey data and information from MRUs to model the deep water habitat, the location of fishing grounds and human fishing preferences of the Grenada Bank (Chapter 4). Geoprocessing tools also permitted an existing regional bathymetry dataset to be enhanced by integrating sonar point data collected during field surveys (Chapter 4). ArcScene software allowed the model of the Grenada Bank seafloor to be viewed three-dimensionally thereby providing stakeholders with a realistic conceptualisation of the physical environment of the Grenada Bank. Overlaying mapping products on the 3D seafloor model facilitated stakeholder understanding of spatially-explicit patterns and the tacit associations between the marine environment and uses. These improvements were found to help to create a shared reality among stakeholders that would be expected to support consensus-building and collaborative decision-making in MSPM.

PGIS was found to be useful to facilitate stakeholder understanding of the abundance and distribution of resources and use patterns. Geoprocessing tools were used to quantify the coastal and marine habitats and of resource use occurring on the Grenada Bank (Chapter 4). Overlay analyses allowed for the effectiveness of the existing MPAs to be assessed (in terms of spatial quantification of habitat) and for each country's progress towards the achievement of marine conservation targets to be gauged (Chapter 4). Locational queries were used to identify representative reef ecosystems and provide management insight regarding the important areas for conservation on the Grenada Bank (Chapter 4). Cumulative use analyses identified conservation priority, human activity and potential threat areas thereby increasing the understanding of space-use patterns on the Grenada Bank (Chapter 4). By further overlaying conservation areas with areas of high use and threat, the impact of various MSPM options was assessed and allowed for the evaluation of potential management trade-offs. These analyses have implications for management by identifying relationships between the coastal marine environment and human activity and can assist in the determination of management feasibility and the identification of options with the fewest user conflicts.

5.1 CONSTRAINTS OF THE APPROACH

Despite the overall success of the application of the PGIS approach, there are constraints that should be considered. A PGIS approach requires a considerable amount of time, namely to build partnerships and capacity for participatory research as well as to share and validate information. Accordingly the timeframe and objectives of a PGIS project should be thoroughly investigated before undertaking a similar endeavor. Furthermore, the cost of implementing a PGIS should be carefully evaluated. In comparison to conventional GIS MSPM projects, this research was relatively low cost. Yet it should be recognised that the majority of the cost of this research was born by the stakeholders. For example, stakeholders contributed over 2,500 hours of their time to participate in surveys, interviews and attend validation meetings. In terms of financial support stakeholders contributed approximately US $50,000 in grants and private sector support over the course of the research.

A tenet of PGIS is that ownership and maintenance of information by stakeholders should be an outcome. This PGIS research utilised an academic-NGO partnership; to work between and within the existing institutional frameworks of each country, as well as to bridge the various levels of stakeholders across the geographical scale of the Grenada Bank. The researcher possessed the multi-disciplinary skills required to: determine and conduct participatory research methods; build the GIS and other data products; as well as facilitate meetings. Although stakeholders learned new skills as a result of participating in the research, ultimately the maintenance of the MarSIS will require additional capacity building. Unfortunately in terms of GIS capability, only nine stakeholders (all from government agencies) were identified as having the capacity to actively use ArcGIS software. The fundamental role of the SusGren NGO as a local bridging organisation should not be underestimated, yet they do not have the technological capacity or funding to maintain the MarSIS.

A substantial result of this research is that the multi-leveled cross-scale linkages among the stakeholders have been established and the geodatabase has been built; both of which can be the most time-consuming aspects of similar projects (De Freitas and Tagliani 2009). Despite the fact that the sustainability of the MarSIS will require further capacity building and long-term financing from a trained professional, this collaborative research has shown that a transboundary PGIS can be implemented within existing institutional frameworks. Likewise, stakeholders were of the opinion that the academic-NGO partnership was a credible institutional approach to work with. Surveys and group discussion at stakeholder evaluation workshops underscored the importance of a continued wide-ranging collaborative effort to maintain the information system.

5.2 IMPLICATIONS OF PGIS FOR INTERACTIVE GOVERNANCE

The PGIS philosophy (Balram et al. 2004, Tripathi and Bhattarya 2004, Corbett et al. 2006, Rambaldi et al. 2006b, Aswani and Lauer 2006, Dalton et al. 2010) shares many of the same procedural principles that are prominent in interactive governance. Engagement of stakeholders is a central element of a PGIS. It facilitates stakeholder networking through increased dialogue and partnerships. The high degree of engagement of stakeholders required to develop a relevant PGIS product, suggests that it has the potential to strengthen interactive governance. For example, mapping local knowledge for input in the MarSIS and holding validation and feedback meetings after each series of mapping exercises fostered a collaborative working and learning atmosphere thereby creating a common space of understanding amongst stakeholders. The legitimisation of local knowledge with conventional science proved to be encouraging to the island communities and stakeholders at large. For example, the accuracy of the changes made to the shallow water habitat map by marine resource users (MRUs) validated their tacit knowledge of the marine environment. Stakeholder feedback helped to determine appropriate communication mechanisms and information products developed. Furthermore, taking the time to share with stakeholders the findings and highlight the importance of their knowledge promoted ownership in the information produced and legitimised their participation in the research. Feedback obtained from the egroup discussion forums and at validation meetings showed that stakeholders were pleased that time and resources were allotted to periodically share, validate, and easily access information.

Likewise, the PGIS approach helped to foster stakeholder trust and cooperation in the research. This was seen in the collection of local knowledge which became easier (i.e. identification of key informants, willingness to participate) requiring less time over the course of the research. Although not measured quantitatively, the researcher also observed an increasing amount of participation by MRUs in discussions and debates at meetings and workshops over the course of the research. These empowering effects of participation were further substantiated in the final evaluation of the research. All stakeholders surveyed indicated that the compilation of the MarSIS was seen to be a collaborative or group effort and 89% of community and 74% government stakeholders reported a sense of ownership in the final product. Promoting an inclusive and collaborative working environment from the outset supported participation and cooperation amongst a wide range of stakeholders.

This study found that the application of PGIS promoted a range of characteristics that are considered to be indicators of good governance (Mahon et al. 2011). These include inclusiveness, transparency, partnerships, appropriateness, equitable access, ownership and legitimacy. Considering the geographical and socio-political complexity of the study area, the importance of transparency, inclusiveness and communication in management planning should not be underestimated. Communication and information exchange were reported by stakeholders to be an important aspect of the research. The importance of wide-ranging collaboration with local and regional stakeholders must be emphasised. From the outset, this study sought to engage different levels of stakeholders (e.g. upper level decision-makers, government agencies, MRUs and general public) in multiple ways. For example, the use of both formal government and informal community meetings after each stage of the research (including the distribution of periodic summary/technical reports and maps) combined with the use of the media, the e-groups and the website as a platform for transparent information exchange and communication provided access to information and a common space of understanding amongst the diversity of stakeholders. Eighty-seven percent of stakeholders who evaluated the research felt that consulting with stakeholders before each stage of the research and seeking feedback allowed for adaptability in research methodologies. Likewise, 90% of stakeholders who evaluated the research felt that information has been developed according to local needs. All stakeholder groups felt that the information produced is meaningful, easy to understand and will be of use for their respective agency or group. Stakeholder feedback was used to adapt the methods applied (i.e. stakeholder engagement mechanisms, habitat classification scheme, data products) and has shown how stakeholders can contribute to the development of relevant ecosystem-based information and governance overall.

The application of PGIS has strengthened the capacity for collaboration and participatory research amongst Grenadine marine resource users, managers and NGOs. All of the evaluation respondents reported to have learned new information and skills. Moreover these processes were considered by the researcher to be instrumental in building partnership amongst MRU, NGO and government stakeholders across geographic scale levels from island communities, to each of the two countries as well as across the transboundary Grenada Bank area. The benefits derived from the process of using participation have been stated by stakeholders to have occurred, and may be as important as the production of an appropriate geodatabase itself, particularly in such a multi-level multi-scaled participatory project.

The application of PGIS, both in terms of the process employed and the products developed, support interactive governance. The study found PGIS and stakeholder engagement to support collaborative MSPM by increasing stakeholder confidence and understanding of information produced. Furthermore PGIS was found to support meaningful deliberation on management and planning trade-offs and decisions that are required to generate a scientifically appropriate and socially acceptable marine space-use plan for the transboundary Grenada Bank.

5.3 RECOMMENDATIONS FOR LONG-TERM SUSTAINABILITY AND FURTHER RESEARCH

Since the conclusion of the research, the NGO SusGren Inc. has been awarded funding to carry out an 18 month marine spatial planning exercise to build on this initiative and the Protected Area Systems Plans of St. Vincent and the Grenadines and Grenada to increase the effectiveness of MPAs. The project, entitled "Developing a Framework for a Comprehensive Marine Multi-use Zoning Plan for the Grenadine Islands", is funded by the US National Ocean and Atmospheric Administration (NOAA). In tandem, funding has been received through the Global Environment Facility Small Grants Programme (GEF SGP) to ensure the involvement of Grenadine marine resource users (MRUs) in this marine spatial planning process through a complementary grant entitled “Incorporating the Knowledge and Resource Values of Stakeholders in Marine Resources Management in the Grenadines”. In addition, The Nature Conservancy’s Eastern Caribbean Programme has provided technical support, namely assistance with running GIS decision support tools for the zoning plan.

The primary objective of the joint exercises just described is to collaboratively develop a draft multi-use zoning design for the Grenadine Islands in order to increase the capacity to protect, manage and sustainably use the resources of the Grenada Bank. Based on the findings of this study, several issues should be carefully considered in the implementation of such a broad course of action, particularly in a transboundary small island developing state context such as the Grenadine Islands. Transboundary cooperation will only be effective if there is a shared understanding of the space to be managed. The production of the ecosystem-based MarSIS presents significant opportunities for the achievement of such a vision. One consideration is that the MarSIS information should not be static and must be frequently updated to allow for effective decision-making and management. Thus formal arrangements for the responsibility for maintenance of information including the roles, time period and funding should be established. Although framework legislation and national environmental management strategies are in place, formal institutional systems for national and transboundary marine management need to be clearly established. Further research on the realisation of effective transboundary cooperation and regional governance is needed to determine the appropriate and feasible institutional arrangements. Likewise the fostering of environmental political will is essential for the development and implementation of new environmental management policies, plans and institutions. It is recognised that when stakeholders engage and work together to collaboratively develop and support management plans it can increase political will (Birner and Wittmer 2003, Adger et al. 2005, Christie et al. 2005). It is under this premise that the current MSPM project for the Grenadine Islands has been initiated and hopes to be implemented.

5.4 OVERALL CONCLUSION

This research has explored a variety of methods and approaches for PGIS ina small island developing state coastal marine situation and shown them to be capable of generating valuable information for EBM and MSPM. There are clear benefits to utilising a PGIS approach in the development of marine resource space-use information system in the Grenadine Islands. As compared to conventional GIS, a more complete socio-ecological understanding of the human uses of coastal and marine resources in regards to conservation and to the livelihoods of the Grenadine people was realised. In addition, the various participatory processes involved in implementing a PGIS not only allowed for the production of locally-relevant and useful information, but also: (a) built multi-level stakeholder capacity in the understanding of the marine environment and related human uses; (b) provided legitimacy to the 'tacit' knowledge of MRUs; (c) increased confidence and ownership in information produced; and (d) demonstrated to other practitioners the role that stakeholders can and should play in marine governance. This process also engendered a willingness to participate by the various stakeholders (e.g. community, NGO and government) across a transboundary scale.

The collaborative development of a PGIS can lay the foundation for an ecosystem approach to place-based marine resource management. The advantages of the approach are seen as being two-fold. It creates engagement of the stakeholders and also supports informed decision-making for the transboundary management of marine resources. This engagement takes several forms: the definition of the role of participation in research and governance, ownership of information produced, increased inter- and intra-stakeholder understanding and access to information as well as a platform for transparent multi-scale and multi-level communication, information exchange and problem-solving. To this end, this study found a PGIS approach to be a practical mechanism to realise EBM as well as can serve to strengthen interactive governance.

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7 Appendices

Appendix I. Government stakeholder data scoping questionnaire distributed stakeholder meetings.

Grenadines MarSIS - Questionnaire
For Kim Baldwin

Name ____________________

Organisation ____________________

Position ____________________

Phone # ____________________

Fax # ____________________

Email ____________________

Best Way to Contact You ____________________

Suggestions of other Depts/Persons to Contact ____________________

____

Will the MarSIS be useful to your work? yes ____ no ____

How? ____________________

____

Do you have any relevant information for inclusion in the MarSIS? ____

(Spatial/GIS Data, Ecological Data, Socio-Economic Data, Statistics, etc.)

____

____

Suggestions for Additional Attributes/Information to Add to MarSIS

____

____

Comments ____________________

____

Do you want to join an email group for the MarSIS? ____________________

Do you want to join Sustainable Grenadines Project e-group? ____________________

For more information please contact me at: **kbaldwin@uwichill.edu.bb**

APPENDIX II. KEY INFORMANT - PRELIMINARY APPRAISAL SURVEY QUESTIONNAIRE.

Date ________________ Location ______________________

Community-Level Demographics

C1. Population: How many people live on ___________?

C2. Study Area: Where are there landing sites? (map)______________________

C3. Occupation: Complete table comparing to SVG Stats

Main Occupation/Work in island	% of population as primary occupation	# of people conducting as primary occupation	% of population as secondary occupation
1.			
2.			
3.			
4.			
5.			

C4. Community Infrastructure and Development for Marine Activities:

Circle which services exit in study area (ask KI if questions arise):

> Schools (primary/secondary), doctor, nurses, hospital, clinic, police station, coast guard, electricity, telephone, internet access, sewage treatment plant, ice plant, hard top road access, water supply to homes, banking services, restaurants, fish market, processing plant, waterfront gas station, dock/jetty, marina services, haul-out facility, immigration, customs, gift shops, dive shops, water-taxis, tour operators, fishing guides, guesthouses, hotel, resort

C5. Marine Resources: List resources, location (on map), names & envtl condition (1-5)

Mangroves: ____

Seagrass: ____

Coral Reefs: ____

Anchorages: ____

Nursery areas:____

Spawning areas: ____

Fishing Banks: ____

Turtle Beaches: ____

Recreational/Cultural Areas: ____

Stakeholders - Marine Resource Users:

S1. List resource users, number, formal groups, and locations of activity (show on map)

Coastal Activity	**Goods & Services**	**Types of Use**	**Number of people**	**Formal Association?**
1.				
2.				
3.				
4.				
5.				
6.				
7.				

S3. Do you know of or have any previous studies/research/legislation/management plans relating to marine resources or users? ____

S5. Marine Resource Users: Location (on map), Gear, Importance, # of people involved

Fishing

Type	Gear Used	Seasons	Areas	# People
Baitfish				
Conch				
Lobster				
Reef fish				
Bottom Fish				
Pelagics				
Other fishing activity: whelks, seamoss, oysters				

S6. Other Marine Resource Users:

Location (on map), # of companies (and names), # boats and seasonality

Type	# of Companies / Names	# Boats	Seasons
Dive Operators			
Day Charters			
Sailing/Cruisers Bareboat/Charter			
Cruise Ships			
Ferries			
Shipping			
Coast Guard			
Recreation			

S2. Stakeholder Identification:

Stakeholder Group	Name of KI	Role / Village	Contact Information
1.	a.		
	b.		
2.	a.		
	b.		
3.	a.		
	b.		
4.	a.		
	b.		
5.	a.		
	b.		

Detailed KI Information (specific to area of expertise):

D1. Areas important for your marine resource use (on map) ____________________

D2. Infrastructure existing for your marine resource use (on map): _______________

D3. Sources of pollution and/or environmental threats (on map): _________________

D4. Conflicts with other marine resource users (on map): _______________________

Other notes/comments:

APPENDIX III. MRU PARTICIPANT OBSERVATION QUESTIONNAIRE.

MRU Participant Observation Questions

KI Name: ____________ Date: ________ Time – Start:_________ End:__________

Village: _________Island: ___________ MRU type:______________________

Boat type/name: _________ Length: _____ #Crew: ______ #Trips/wk: _________

Gear(s)Used:_________________________________Total time of trip: ______
Distance from home dock:_____ Total time spent working: ____________

GPS Waypoints: _____________ Average Depth of areas used: ____________

Daily Activities

	Activities	**#hrs**	**Services / Species Fished**
Morning			
Afternoon			
Evening			

Fishing Effort - # Hauls_____ # Hooks ______ Length of net _______ Size ___
Divers __# Dives __Avg Depth__# Areas/Sites ___Avg. Time/Site ____

Total Catch(lbs) _________ Price/lb__________________ %Sold _____________
To Whom__________ Why_________Remaining goes? _____________________

Cost of trip ___gas ____ oil ____ ice ____bait ____food _____other ____total

Seasonality

Species	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
1												
2												
3												

Who else uses the areas you use? How often? What activities occur?

Are there any conflicts that occur between the different users?

What marine areas are the most important for your use?

What makes these areas important?

Which areas are not important for your use?

What makes these areas unimportant?

What changes have you seen in the marine environment? Explain

How important is the marine environment to your community?

How does the community use the sea/ marine environment?

WHAT	WHO	#HRS/DAYS

Is there anything you see as negatively impacting the marine environment today?

Do you think any of these marine areas/resources should be protected? Yes / No WHY?

Do you use any of the established MPAs? Yes / No

Do you think they are effective?

How should the sea/coastal areas be planned for?

Who should be involved in the decision making process? Would you get involved? WHY?

What is the biggest problem/threat you face in your livelihood / occupation?

Causes / Solutions ?

How do you feel about the future of your livelihood?

What is the best way to communicate to your community about the environment?

Radio TV Email Newspaper Street Jam Flyer Church

APPENDIX IV. MRU SURVEY ADMINISTERED TO DIVE SHOP OPERATORS.

‘Grenadines MarSIS’ Marine Resource Users Profile – Dive Shops

Interviewer _______ Date _________________ Location ______________________

Phone #: ____________Email: ____________________________ MarSIS Egroup?____

The University of the West Indies together with the Sustainable Grenadines Project is conducting surveys in order to establish a database on the marine resources, their user and uses and values to livelihoods to the people of the Grenadines. This information will be used to fill information gaps for the MarSIS as well as provide insight on the activity profiles of the various marine resource users of the Grenadines. Over the next year, several surveys will be conducted on related subjects. Your business information will be used in the MarSIS database, to inventory marine resource users and space use patterns among various resource users. Thank you for participating.

1. Name of Dive Shop:______________________ # of Boats: _______________
2. Size of Boats: ____________ Capacity: ____________ # of Compressors: _____
3. Type of Engine:_____ Stroke:_____ HP&#:_______ Brand:______Fuel: _____
4. Registration Number:________________ Country: _______________
5. (a) Name of Owner:________________________ Male______ Female ______
6. (b) Name of Captain(s):______________________ Male______ Female ______
7. Where do you dock your boat(s)? _______________________________________
8. How many persons work for this dive shop?__ full time __ part time; __ M __ F
9. What are your top 5 dive sites? ____
10. What is high season? ________ How many dives/week? H:_____ L:_____
11. Services: % you provide for? Tourists _______ Locals ______ Other _____
12. Do you give an environmental briefing? _______ About? ______________
13. What do you do when a client harms the environment? ____________________
14. At dive sites do you use? ______ % moorings ______ % anchors _____ % drift
15. Maintenance: How often do you service engine? _____ Bottom Paint? _______
16. Cleaning of Boats: Where? _______________ With? ______ How Often? _____
17. Do you have conflicts with others that use sea? _____ What? _______________
18. What is the biggest problem in the marine envt.? __________________________

Cause___________________________________Solution_________________________

19. Do you use GPS? ________________ Will you mark your dive sites for me? ___
20. Is there any information you want others to know about your operation?______
21. Do you want all of this information to be known__________________________

List other dive shops I should contact: ____

APPENDIX V. MRU SURVEY ADMINISTERED TO DAY CHARTER BOAT OPERATORS.

'Grenadines MarSIS' Marine Resource Users Profile – Day Charters

Interviewer ________ Date ________________ Location ______________________

Phone #: ___________ Email: _________________________ MarSIS Egroup?____

The University of the West Indies together with the Sustainable Grenadines Project is conducting surveys in order to establish a database on the marine resources, their user and uses and values to livelihoods to the people of the Grenadines. This information will be used to fill information gaps for the MarSIS as well as provide insight on the activity profiles of the various marine resource users of the Grenadines. Over the next year, several surveys will be conducted on related subjects. Your business information will be used in the MarSIS database, to inventory marine resource users and space use patterns among various resource users. Thank you for participating.

22. Name of Boat(s):________________________ # of Boats: ________
23. Type of Boat(s): ________ Size of Boat(s):____________ Capacity: _________
24. Type of Engine:___ Stroke:___ HP&#:_____ Brand:_________ Fuel: _____
25. Registration Number:___________________ Country: _______________
26. (a) Name of Owner:__________________ Male____ Female ____ Age: _____
27. (b) Name of Captain(s)______________ Male____ Female ____ Age: _____
28. Where do you dock your boat(s)? ____________________________________
29. How many persons work for this company? __full time__ part time; __ M __ F
30. What are your top 5 anchorages?____
31. At an anchorage do you use? ___ % moorings_____ % anchors ______ % drift
32. What is high season? _________ How many tours/week? H:_______ L:_______
33. Services: % you provide for? Tourists _______ Locals ______ Other _____
34. Do you give an environmental briefing? _______ About? ________________
35. Do you do when a client harms the environment? ________________________
36. Do you have holding tanks? For sewage: ____ For grey-water: ___Disposal?___
37. Maintenance: How often do you service engine? _____ Bottom Paint? ________
38. Cleaning of Boats: Where? _______________ With? ____ How Often? _____
39. Do you have conflicts with others that use sea? _____ What? ________________
40. What is the biggest problem in the marine envt.? __________________________

Cause___________________________________Solution__________________________

41. Do you use GPS? _______ Will you mark your routes/sites for me?__________

Is there any other information you want others to know about your operation?________

Do you want all of this information to be known? _______________________________

List other day tours I should contact: ____

APPENDIX VI. MRU SURVEY ADMINISTERED TO YACHT CHARTER COMPANIES.

‘Grenadines MarSIS’ Marine Resource Users Profile – Yachting Co.

Interviewer _______ Date _________ Location _____________________

Phone #: _________________ Email: ____________________ MarSIS Egroup? ____

The University of the West Indies together with the Sustainable Grenadines Project is conducting surveys in order to establish a database on the marine resources, their user and uses and values to livelihoods to the people of the Grenadines. This information will be used to fill information gaps for the MarSIS as well as provide insight on the activity profiles of the various marine resource users of the Grenadines. Over the next year, several surveys will be conducted on related subjects. Your information will be used in the MarSIS database; to inventory marine resource users and space use patterns among various resource users. Thank you for participating.

42. Name of Company:___________# Mono: _____# Cats: _____# Power:_____
43. Will you provide me with a list of type/length/capacity of your boats: Y__ N __
44. Type of Engines:____Stroke:___ HP & #: _______ Brand: _______ Fuel: _____
45. Registration Numbers:________________ Country: __________________
46. (a) Name of Owner:___________________ Male____ Female ____ Age____
47. (b) # Skippers: ______ # Male: _____ # Female: _____
48. How many persons work for this company? __full time __part time; M__ F___
49. Where do you dock your boats? _____________________________________
50. Services at marina? ____
51. Services: % you provide for? Tourists ____ Locals___ Chartered__ Bareboat___
52. What is high season? ________ How many boats rented/week? H:_____ L:____
53. What are the top 5 anchorages your customers use? _______________________
54. Do you give an environmental briefing? _______ About? ___________________
55. Do you have holding tanks? For sewage: __ For grey-water: __ Disposal?_____
56. Maintenance: How often do you service engine? _____ Bottom Paint? _______
57. Cleaning of Boats: Where? ______________ With? _______ How Often? _____
58. Do you have conflicts with others that use sea? _____ What? _______________
59. What is the biggest problem in the marine envt.? _________________________

Cause___________________________________Solution_________________________

60. Do you use GPS? _______ Will you track your main routes / sites for me? _____
61. Any other information you want others to know about your operation?____
62. Do you want all of this information to be known? _______________________

List other Yachting Companies I should contact: ________________________________

APPENDIX VII. MRU SURVEY ADMINISTERED TO SHIP AND FERRY OPERATORS.

‘Grenadines MarSIS’ Marine Resource Users Profile – Shipping/Ferries

Interviewer ________________ Date __________ Location ________________________

Phone #: __________________ Email: _______________________ MarSIS Egroup? ____

The University of the West Indies together with the Sustainable Grenadines Project is conducting surveys in order to establish a database on the marine resources, their user and uses and values to livelihoods to the people of the Grenadines. This information will be used to fill information gaps for the MarSIS as well as provide insight on the activity profiles of the various marine resource users of the Grenadines. Over the next year, several surveys will be conducted on related subjects. Your business information will be used in the MarSIS database, to inventory marine resource users and space use patterns among various resource users. Thank you for participating.

63. Name of Boat:______________ Type of Boat: ________ # Boats: __________
64. Length of Boat(s): ____ by width: ____ Draught of Boat: ____ Tonnage: _____
65. Type of Engine:__________ HP & #: _____ Brand: ____________ Fuel: _____
66. Registration Number(s):______________________ Country: _______________
67. (a) Name of Owner:_____________________ Male____ Female____ Age _____
68. (b) Name of Captain: ____________________Male____ Female ____ Age _____
69. How many persons work for this boat? __ full time __ part time; %M__ %F___
70. Services: % Cargo ___ %Passenger___ (%Local___ %Tourist____)Capacity___
71. Type of Cargo: ___________ Where do you dock your boat? _________________
72. What are the routes your boat runs? ____________________________________
73. What is your route schedule? ____
74. Does it change? __________________ Busy Season: ________________________
75. Services: % you provide for? Tourists ____ Locals ____ Goods ___ Other _____
76. Do you have holding tanks? For sewage: __ For grey-water:__ Disposal?______
77. Maintenance: How often do you service engine? ___ Bottom Paint? ___________
78. Cleaning of Boats: Where? ___________ With? ________ How Often? _____
79. Do you have conflicts with others that use sea? _____ What? ________________
80. What is the biggest problem in the marine envt.? ___________________________

Cause_____________________________________Solution_________________________

81. Do you have a GPS? _______ Will you track your main routes / sites for me? __
82. Is there any other information you want others to know about your operation?___
83. Do you want all of this information to be known? __________________________
84. List other ships I should contact:_______________________________________

APPENDIX VIII. MRU RAPID SURVEY ADMINISTERED TO FISHERS.

Location: ________________ Respondent #:__________Date: ___________

Respondent Information& Fishing Practices

1. a) Respondent name:_______________________ b) M F
2. a) Age: ________ b) Address: ________________________________
3. a) Is fishing your primary occupation? Y N

   b) Do you get most of your income from fishing? Y N

   c) What percentage of your income is from fishing? _______%

4. How long have you been fishing (years)? _______

Boat Information

5. Name of Boat:___________________ Registration Number:____________
6. a) Name of Owner:____________________ b) M F
7. Average number of crew working on boat: __________
8. Name and sex of other crew:____________________________________
9. What gear is used on the boat? __________________________________
10. Length of Boat: _______
11. Type of Boat (wood, fibreglass, pirogue, cigarette, flatstern, other):
12. # of engines: ____Brand: _____________________ Horsepower ________

    Brand: _____________________ Horsepower ________

13. Where do you operate from? ______________________________________
14. What kind of fishing do you do? What islands do you mostly fish around?
15. a) Do you know of any places where fish gather to breed? Y N

    b) What kind of fish? ____

    c) Location/s ____

16. Will you be willing to take part in a more in depth interview? Y N

APPENDIX IX. PRELIMINARY MRU SURVEY ADMINISTERED TO WATER-TAXI OPERATORS.

Preliminary Survey of Water Taxi Operators

Purpose of Questionnaire: To establish a database of water taxi operators throughout the Grenadines for the Sustainable Grenadines Project. It will also provide a basis for selecting a sample size for the in-depth survey to be carried out on the livelihoods and green boat practices of water taxi operators.

Surveyor Name:__________________

Respondent #:________________ Date:________________

1. Name of Boat:___________________
2. Registration Number:_________________
3. (a) Name of Owner:_________________

   (b) ☐ Male ☐ Female
4. (a) If name of boat operator is different from the owner of the boat, please provide the name of the person: ____.

   ☐ Male ☐ Female
5. How many persons operate this water taxi? _____________________ .
6. Name and sex of Operator/s:

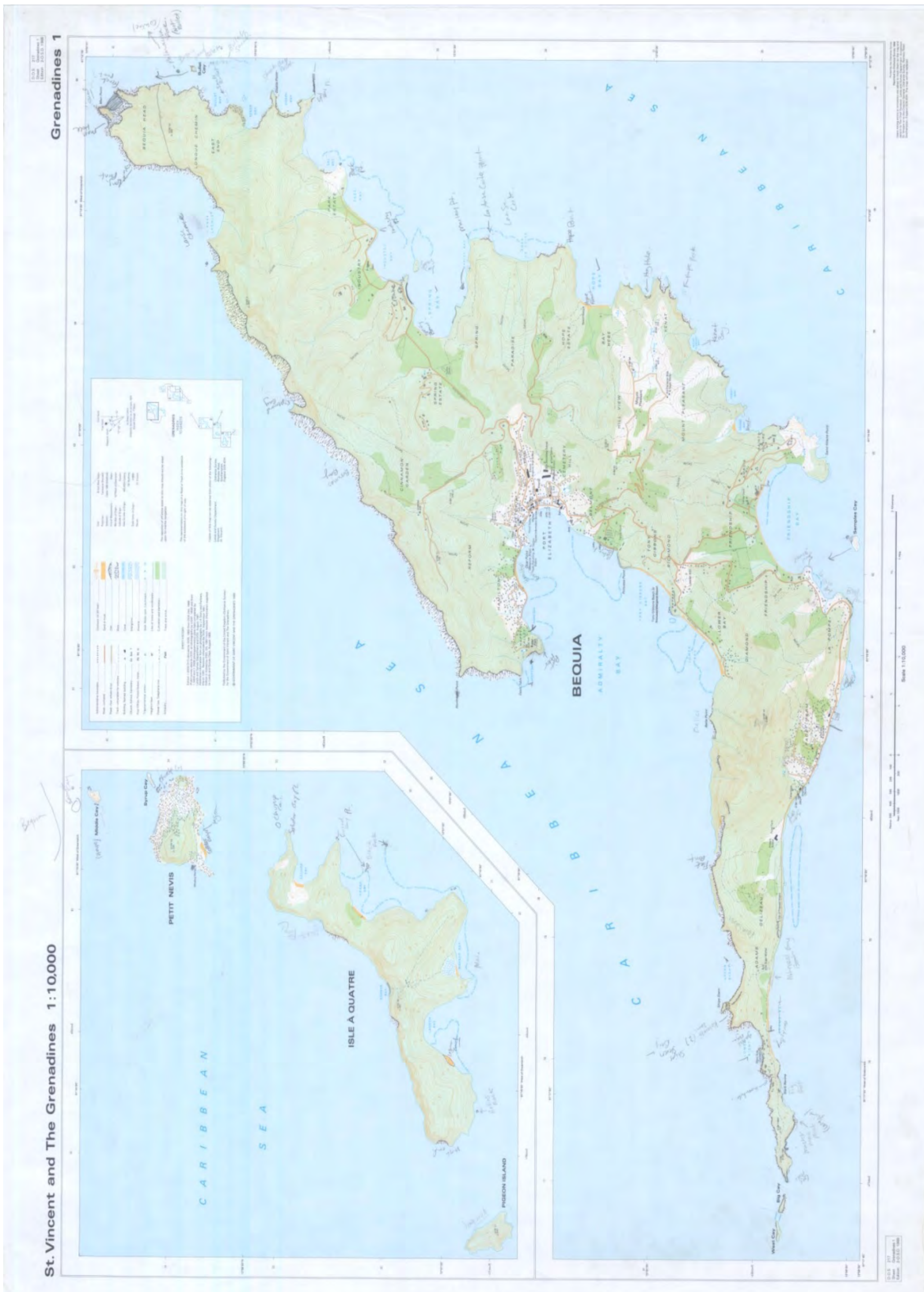
   Name: _____________________ Sex: _______________________

   Name: _____________________ Sex: _______________________
7. Length of Boat: ________________________________.
8. Type of Boat: __________________________________.
9. Where do you dock your boat? ________________________________.
10. Are you a member of a Water Taxi Association (WTA)?

    ☐ **Yes** ☐ **No**
11. Which WTA? ____________________________.
12. Number of Engines:_________________.
13. Type of Engine: ____________________.
14. Horse Power: _________ and _________.

We will be conducting two in-depth surveys in approximately two weeks on your livelihoods and your boating practices. We would therefore appreciate if we could interview you again at your convenience.

APPENDIX X. EXAMPLE OF SCALE MAP USED FOR TOPONYMY MAPPING EXERCISE IN THE ISLAND OF BEQUIA, ST. VINCENT AND THE GRENADINES.



APPENDIX XI. PICTORAL LEGEND (AND CORRESPONDING LETTER CODES) OF FEATURES OF INTEREST FOR MARINE RESOURCE, USES, LIVELIHOOD AND ISSUES/CONFLICT MAPPING EXERCISES.

RESOURCES: areas that provide food or other materials of value to community


Sea Turtle - Nesting Beaches & Feeding Areas (T)


Sea Birds - Roosting Area (B)


Baitfish Bay (BB)


Seamoss (M)


Whelks (W)

 **Oysters (O)**

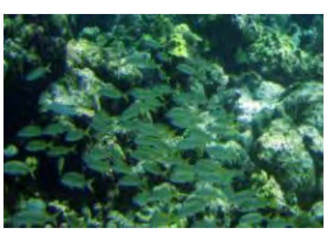
 **Iguanas (I)**

 **Sea eggs (SE)**

 **Wild Goats (G)**

USES, LIVELIHOODS & OPPORTUNITIES: areas that provide benefits to community

 **Recreational Area (RA)**

 **Nursery Area (NA)**


Shipwreck (SW)



Historical Area (HA)


Anchorage (A)


Landing Site (LS)


Shoreline Protection (SP)



Livelihood Areas: Ship Building (SB), Aquaculture (A), Vending (V)

 **Cultural Area (CA)**

PROBLEMS, CONFLICTS & ISSUES:

**Sand-mining (SM) / Beach Erosion (BE)**

 **Mangrove Cutting (MC)**

**Dredging(D), & Desalination Plant / Outfall (DS)**

**Artificial Structure (ASx) / Breakwater (BW)**

 **Dumping Site (DS) / Areas of Pollution (P)**

APPENDIX XII. EXAMPLE OF A TOPONYMY MAP OF CANOUAN CREATED AS A RESULT OF THE LOCAL NAME MAPPING EXERCISE.