MARINE BIODIVERSITY AND NATURAL RESOURCE ASSESSMENT

For the

ASSESSMENT AND MAPPING OF THE SOUTHWEST REGION OF ANTIGUA FOR THE RIDGE TO REEF DEMONSTRATION PROJECT OF THE SUSTAINABLE ISLAND RESOURCE MANAGEMENT MECHANISM

SUBMITTED TO:

Small Island Resource Management Mechanism (SIRMM) Project

Environment Division (National Executing Agency, NEA)
Government of Antigua and Barbuda

SUBMITTED BY:

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December 30, 2011

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1. PROJECT DESCRIPTION AND AREA OVERVIEW

The Sustainable Island Resource Management Mechanism's (SIRMM) "Integrated 'Ridge to Reef' management of the SW coast of Antigua (Boggy Peak, Wallings Forest, Fig Tree Drive Forest and Cades Bay Marine Reserve)" project document tp provide an understanding of the long-term aspiration for the development of the South West Watershed (SWW) demonstration area. The document explains that the purpose of the integrated 'Ridge to Reef' management of the SWW of Antigua project (more commonly known as the Ridge to Reef Demonstration project):

> *"…is to establish an integrated management plan for the SW region that incorporates an interlinked chain of marine and forest reserves to protect both the key biodiversity assets and the functional habitats within this environmentally sensitive area. The need to sustain economic growth often overshadows conservation goals and it is therefore important that any activities are financially sustainable and provide real benefits to the local communities."*

The objective of SIRMM's 'Ridge to Reef' demonstration project is:

> *"to implement integrated management to promote the maintenance of the environmental integrity, conserve key assets with active stakeholder participation, and to generate revenues to support management activities"*

The original vision for the demonstration area provides considerable arguments for the creation of an integrated management zone with multiple use options, communities and to ensure the protection of key marine and terrestrial ecosystems, species and landscapes.

The SIRMM argues that:

> *"[A]fter decades of ineffective management there is an urgent need to re-evaluate the management of natural resources and to ensure their effective conservation and sustainable use of biological diversity"*

> *"Some of the key assets that Antigua has to offer are situated in the SW region of the island and include Wallings Forest (WF) and Fig Tree Drive Forest (FTDF), and Cades Bay Marine Reserve (CBMR)"*

> *"Cades Reef is one of several reef complexes found around Antigua and the main reef on the south coast of the island. The* Cades Bay Marine Reserve *was declared in 1999 by the Fisheries Division, under the Fisheries Act, following observed destruction in the wetland system at Cades Bay. The Cades Bay Marine Reserve includes three wetland systems, a major reef system (Cades Reef), several beaches and relatively healthy seagrass beds"*

"Wallings Forest and Fig Tree Drive are areas of outstanding natural scenic beauty and repositories for a significant portion of the nation's biodiversity (flora and fauna). The forests are classified as moist semi-evergreen forest and, although secondary in growth, they support a wide number of tropical plant species (trees, shrubs, lichens, ferns and orchids). The forests also support a wide range of fauna (31 species of resident and migratory birds), including the Bridled Quail Dove, considered to be extremely threatened and in need of special conservation"

"Individually these assets are of national importance from an economical, social, historical and biodiversity perspective. Collectively they form part of a broader landscape on the SW region of the island (Doiggs, Barters, Rendezvous, Boggy Peak and Christian Valley) that is in need of special conservation management. In fact the entire south west coast of Antigua has spectacular scenery with offshore coral reefs, mangroves, sandy beaches backed by the mountains with tropical moist forests. The natural scenic landscape had made the SW coast a major tourist attraction on the island. Coupled with traditional uses in these resources, the collective value of these assets to the country's economic sectors cannot be underestimated. While tourism developments have already impacted the coastal resources in this area (e.g. removal of mangroves for the Carlisle Bay Hotel) the area is not as heavily development as the NW tourism zone. The country's needs to expand the tourism potential and promote economic growth may result in more environmental decline if the proper measures are not put in place."

"While each of the assets could be managed individually there would be several additional benefits accrued from embedding these areas within a broader integrated management framework. There would be economical advantages due to the economies of scale to be gained from developing and promoting the entire SW region as a premiere eco-tourism destination, for example. The most compelling evidence for embedding these areas in an integrated management framework however relates to the impacts of land-based sources of pollution on coastal and marine system. Coral reef health around Antigua has declined over the years and recent studies have shown that the decline is most likely due to a series of human induced and natural impacts and rather than one single catastrophic event. The most likely cause of the decline is cumulative impacts of increasing sediment loads as a direct result of drought conditions, coastal erosion and removal of healthy mangrove forests, (coupled with anchor damage from boating activities, storm and hurricane damage as well as natural disease, and predation). This therefore requires zoning for sustainable use and maintenance of ecosystem functionality within the landscape SW region"

The most salient issues that the SRIMM document's authors pinpointed as critical factors in relation to management of the coastal and marine environments within the demonstration project area include:

- Biological diversity protection and conservation
- Watershed integrity, conservation and rehabilitation
- Scenic landscapes
- Heritage protection
- Stakeholder/community involvement
- Parks and protected areas
- Forest protection
- Ecotourism potential

The process also allowed IRF to identify many other areas listed below:

- Biodiverse areas under increasing threat
- Biodiversity corridors
- Areas considered priority for science and research areas of high biodiversity
- Strong potential for community co-management options
- Areas where if protected and managed provide enhance coastal habitat values

The mapping area for the South West Watershed (SWW) Mapping Project was agreed after proposals were made to the SIRMM Committee and certain adjustments were made to the proposed boundaries following these discussions.

The terrestrial boundaries are largely determined by the component watersheds and comprise the following watershed groups (Watershed map of Antigua – EIMAS):

- The eastern part of Group 4-11
- All of Group 12-20
- All of Group 21-26

Roughly this describes a landward boundary that, starting from East to West, commences at the tip of Proctor Point, proceeds north westerly along the ridge to Cherry Hill, Sugar Loaf Mountain, Signal Hill, Wallings, Sage Hill and Mt McNish. From there, the boundary follows the proposed boundary of the Mt Obama National Park, generally westward to Willocks Hill and thence to the sea at Coco's headland at the southern end of Lignumvitae Bay.

The marine boundary is determined by the limits of acceptable satellite imagery as the outer limit except where water depth limits visibility. In execution, this meant a boundary starting in the west at Coco's headland as mentioned above – following the limits of available satellite imagery south to the NW corner of the Cades Bay Marine Reserve (CBMR), then south west in steps as imagery allowed, to the southern boundary of the CBMR and thence east following

the CBMR boundary and then the 25 metre depth contour to a point off Proctor Point and thence to meet the terrestrial boundary at the tip of Proctor Point.

The terrestrial area included amounts to 3,640 hectares, the marine area amounts to approximately 2,290 hectares, totaling approximately 5,930 hectares. As can be seen, the Mapping Area includes several important Protected Areas, proposed protected areas and important landmarks. These include:

- All of the Mount Obama National Park (not yet gazetted);
- Parts of Nelson's Dockyard National Park, and Cades Bay Marine Reserve;
- Part of the Wallings Forest Reserve (proposed); as well as
- Most of the mountain summits above 1,000 feet including the nation's highest point, Mt Obama (previously Boggy Peak) at 402 metres.

The marine biodiversity and natural resources assessment of the SWW project area (Figure 1) was undertaken in order to assess and map the status of the marine environment with reference to the above management concerns. To accomplish this, two field visits were made. The first visit was during August 2010, in which preliminary contact with a number of marine stakeholders, experts, agencies and officials, and the IRF team was made. Existing data and information were collected as well and a plan for fieldwork and methods for engagement throughout the life of the SWW demonstration project were developed. The second field visit was held in March 2011, in which the marine and coastal field surveys were made and the mapping exercises were conducted. These included a stakeholder validation and feedback meeting at the Cades Bay Fisheries Centre.

This report reviews the methodology applied to map and quantify the coastal and marine habitat, resources and the space-use patterns that currently exist in the coastal and marine areas of the SWW demonstration area. Additionally a review of the existing datasets and associated data limitations, the structure and development of the marine geodatabase and management recommendations for the SIRMM project are provided.

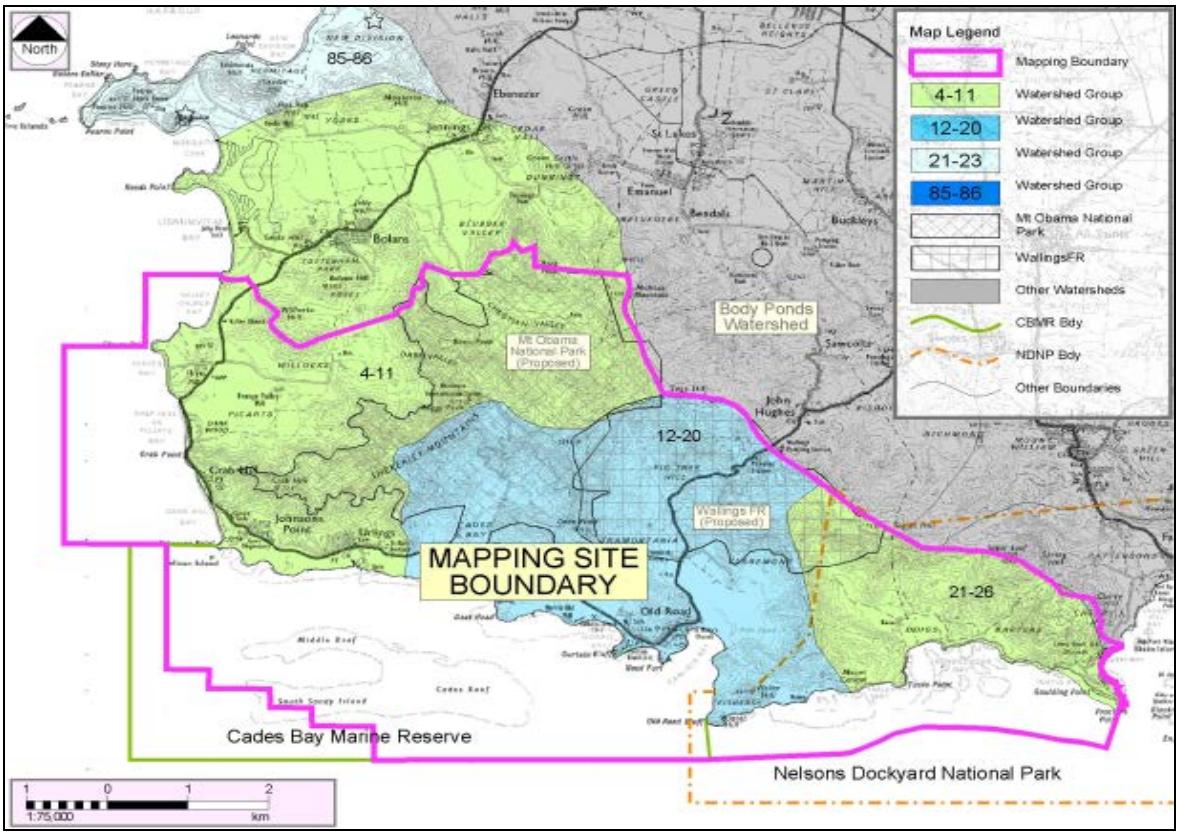


Figure 1. The SWW mapping project site boundary showing its location in south west Antigua.

The following information and data were collected and found to be of use for marine and coastal habitat mapping. A brief description of each dataset and its' limitations are given in the following section.

1.1. IMAGERY DATASETS

1. IKONOS 2000 satellite imagery: SW coast of Antigua including some marine coverage
    - Image extends approximately 2 km offshore
    - Resolution unknown (approximately 1m)
    - Not complete coverage of Cades Reef
    - Cloud cover over key parts of reef

2. LandFolio 2004 aerial photos: SW coast of Antigua
    - Resolution (0.5 m) colour photos
    - Marine area as little as 0.2 km in places
    - Reflection extremely high on the sea

3. Survey10K_1991 aerial photos: Carlisle Bay, Cades Lagoon, Cades, Johnsons Pt. (4

images)

- 1:10,000 colour photos
- Resolution (0.5 m)
- Marine area as little as .02 km offshore in places (1.5 km max)
- Little reflection on sea
- Images were used where they provide coverage of SWW marine area

1.2. MAPS

1. ANU25K_1969 West1
    - 1:25,000 Directorate of Overseas Surveys (DOS) map of West part of Antigua
    - Place names and general outline of Cades reef

2. Caribbean Yachting Chart
    - 1:90,000 nautical chart
    - Corrected in 1998
    - Bathymetry on map
    - Location of reefs (although more as related to navigational hazards)

3. Modern Reefs and Sediments of Antigua Map
    - 1:40,000 colour map of marine habitats
    - Based on a report from Weiss and Multer (1988)
    - Most scientific baseline map of reefs available

4. International Travel Map: Antigua and Barbuda
    - 1:35,000 map of Antigua
    - Used as a scale basemap for marine and coastal resource, use and threat mapping exercises

5. A number of freely distributed Antigua tourist maps and travel guides
    - Provided baseline information on popular tourism infrastructure, operators and activities

1.3. SHAPEFILES

Obtained from the Environmental Information Management Advisory System (EIMAS)

1. Land use
    - Tourism and wetland information were extracted
2. Coastline of Antigua

3. Ponds
    - This is simply an outline of ponds – no attributes
    - No metadata of source, date or how information was produced
4. Coral reefs
    - This is simply an outline of reef area – no attributes
    - No metadata of source, date or how produced
5. Wetlands
    - This is simply an outline of weltands – no attributes
    - Limited metadata – see below all included:

'Mangrove communities are a critical habitat and were mapped at the smallest mapping unit possible to capture this rare and dwindling environment. Using habitat knowledge, field verification and photogrammetric mapping methods, a highly accurate map of mangroves and coastal wetlands was developed. After aerial interpretive mapping, a field and air tour provided ground verification of the extent and location of mangrove communities. These additional coastal fringes were verified and added to the layer shapefile. Review by Environment experts provided additional corrections which have been added as appropriate to the map.'

Obtained from the Environmental Awareness Group (EAG)

6. Declared and Proposed Protected Area Boundaries
    - Cades Reef Marine Reserve
    - Nelsons Dockyard National Park
    - Mt Obama National Park

Obtained from Food and Agriculture Organisation (FAO)

7. Bathymetry contours
    - Extracted from a larger Lesser Antilles Caribbean dataset
    - Regional broad-scale dataset (Scale of 1:100,000 to 1:300,000)
    - Limited use for project area

1.3. RELEVANT COASTAL AND MARINE LITERATURE

(**Indicate documents which were obtained*)

Eastern Caribbean Natural Areas Management Program (ECNAMP), 1980. Antigua: Preliminary data atlas. Survey of Conservation Priorities in the Lesser Antilles.

Caribbean Conservation Association and Island Resources Foundation, 1991. Antigua and Barbuda Country Environmental Profile. Island Resources Foundation, Washington, DC.*

Goreau, M. and J.G. Thomas. Ecological assessment of Antigua and Barbuda reefs: report to the Environmental Awareness Group. Global Coral Reef Alliance.

Bunce, L. 1997. Integrated Coastal Zone Management of Common Pool Resources: A case study of coral reef management in Antigua, West Indies. PhD Dissertation, Department of Environment, Duke University Marine Laboratory.*

Cooper, B. R. and V. Bowen. 2001. Integrating Management of Watersheds and Coastal Areas in Small Island States of the Caribbean, National Report for Antigua and Barbuda. Environment Division, Ministry of Tourism and Environment, Government of Antigua and Barbuda.*

James, P. 2002. Management plan for Cades Bay Marine Reserve, Antigua, West Indies. Organisation of American States Small Project Facility.*

Weiss, M. P. and H.G. Multer. 1988. Modern reefs and sediments of Antigua, West Indies. Department of Geology, Northern Illinois University, DeKalb.*

Widecast. 1992. Sea Turtle Recovery Action Plan for Antigua and Barbuda. Authored by J. Fuller, K. Eckert and J.I. Richardson for CEP Technical Report No. 16.*

Bacon, P.R. 1993. Mangroves in the Lesser Antilles, Jamaica, and Trinidad and Tobago. LD Lacerda (ed.), Conservation and Sustainable Utilization of Mangrove Forests in Latin America and Africa Regions. Part I-Latin America. International Society for Mangrove Ecosystems.

Environmental Impact Assessment (EIA) reports:

a. Jackson, I. *South Coast Horizons Boardwalk*. Ivor Jackson and Associates.

b. Goodridge, R. and K. Baldwin. 2005. *Baseline identification of nearshore sensitive marine habitats for the Ffreyes beach development, Antigua*. Smith Warner, Jamaica.*

1.4. DATA GAPS AND LIMITATIONS

There were a number of data gaps and limitations related to the mapping of coastal and marine areas. Key considerations are listed as follows:

1. 2010 Land Folio Aerial Dataset

- This dataset has not yet been made available as a mapping resource thus far due to technical problems with geo-referencing and the mosaicking of approximately 4000 + images making up the island of Antigua. Furthermore this dataset comprises a very large file size (1.5 TB) and its ultimate use for mapping is presently unknown.

- As a result, the mapping of the coastal and marine features of the SWW project area ensued using the available datasets. The main disadvantage of this approach was that the existing imagery datasets are outdated and have limited marine coverage of the SWW project area. Despite this, underwater marine habitat changes in abundance are relatively slow over time as compared to changes typically seen in terrestrial environment; therefore the mapping of these habitats may not be as significant as compared to using outdated imagery for terrestrial mapping during the past 6 years. Notwithstanding, coastal mangrove and wetland habitat boundaries in the SWW project area are known to have changed during this period (2004-2010) and it is recommended that these features will need to be remapped once 2010 imagery is made available.

2. Bathymetry (underwater DEM) and contours

- There has been no comprehensive detailed bathymetric mapping of the seafloor for the EEZ of Antigua and Barbuda. Nautical charts with broad-scale (1:100,000 to 1:300,000) depth information exist as seen in the FAO but marine bathymetric dataset but finer-scaled more detailed surveys (i.e. LIDAR) would be useful to allow for the creation of an underwater digital elevation model (DEM) of the seafloor.

3. Access and usefulness of the EIMAS

- Currently the EIMAS is not organised into a geodatabase. Shapefiles of interest (listed previously) were made available by the GIS officer Mr. Alvah Guishard. Existing EIMAS shapefiles reviewed were found to be primarily spatial in nature with limited (or lacking) associated attribute data and thus of limited use for management and decision-making purposes. Moreover, this problem is compounded due to a lack of detailed metadata (including the referencing of sources of information and automation methods such as the digitizing scale applied and overall informational accuracy attributes).

4. Access to existing literature

- Access to existing literature and EIA reports was found to be limited as there is not a central repository for environmental documents. Although assistance in locating existing reports was provided by EAG, the Fisheries Division and the Ministry of Environment but many documents were unable to be found.

2.0. MARINE HABITAT MAPPING METHODOLOGY AND RESULTS

A brief review of mapping methodology is given in the following sub-sections.

2.1. REMOTE SENSING TECHNIQUES

To start, all aerial imagery sources and nautical charts were scanned, imported and georeferenced to a common coordinate reference system (i.e. Antigua 1943 British West Indies Grid) using ArcGIS. NOAA's Habitat Digitizer ArcGIS extension was used to assist in the production of digital coastal marine habitat polygon features for the SWW project area. The Habitat Digitizer application is based on passive remote sensing techniques, in which habitats are delineated by the user using a point-and-click menu based on a predetermined classification scheme. The minimum mapping unit restriction was set to one acre based on the scale of the imagery as well as the objectives of the SWW mapping project. The digitizing scale was set to 1:6,000 due to extensive experimentation (Kendall *et al*. 2001) indicating that there is no appreciable loss in polygon detail and accuracy by digitizing at this scale while mapping time is dramatically reduced. Therefore all polygons were digitized at this scale except when subtle habitat boundaries are not easily discernable in which a more broad scale (1:10,000) was used to place larger scale habitat boundaries correctly.

Habitat boundaries were delineated around signatures in the satellite imagery and the corresponding habitat types were assigned based on the pre-determined marine classification scheme (i.e. reef, sand, seagrass, mixed live bottom, hard bottom, wetland, salt pond). Each new polygon was attributed with the appropriate habitat designation according to the classification scheme. Additional collateral literature and information, including personal knowledge of the marine environment, was used with the collected habitat maps, nautical charts, and other descriptive reference materials dealing with benthic and coastal habitats of the SWW in order to aid the image interpretation where possible.

2.2. "GROUND-TRUTHING" OR VALIDATION OF REMOTE SENSING HABITAT MAP

The resulting shallow-water coastal and marine habitat map of the SWW project area was subdivided and printed as six colour posters using a satellite imagery background (Appendix I). The centroid of each designated habitat polygon (i.e. 80 points total) as a x,y GPS coordinate

was derived using standard ArcGIS geoprocessing tools. These resulting GPS points were exported and imported into a Garmin GPS to allow for validation of the remote sensing habitat map (or ground-truthing) to test and improve the accuracy of the final derived habitat map. Ground-truthing was conducted with the assistance of two local fishermen (Jamison Mannix and Reginald Nicholas) and surveyed depending on the depth by either snorkel or SCUBA diving using a small fishing boat. Survey sites found to have misinterpreted habitat polygons were corrected using ArcGIS, thus increasing the accuracy of the final shallow water portion of the habitat map.

2.3. MAPPING EXERCISES

In order to fill a number of information gaps, including information on marine resources and human use patterns; a variety of techniques were applied. Coastal and marine infrastructure (e.g. recreational areas, vending sites, artificial structures) was created through either the digitization of features based on maps, aerial photos and remote-sensed imagery or spatially referenced through the importation of (x,y) coordinates points collected using a Garmin CS76 handheld GPS unit. Corresponding attribute information for infrastructure spatial datasets was obtained using informational pamphlets (e.g. tourism guides and literature), phone calls, informal conversation and personal observation. To solicit and incorporate spatially-based local knowledge within the geodatabase, a number of participatory research mechanisms were used, including: field surveys, informal conversation and mapping exercises. Information collected was initially reviewed by stakeholders when it was collected and validated at the community meeting. This not only allowed for quality control and assurance, but aided a collaborative learning environment amongst stakeholders.

Mapping exercises were conducted over a one-week period with a number of key informants (Table 1) in order to quantify the distribution of key coastal and marine resources, uses, livelihood areas and areas of threat or perceived problems. Semi-structured interviews were used to map marine and coastal resources, space-use patterns and threat features (Table 2) on a scale basemap of the SW coast of Antigua. Based on their respective livelihood, stakeholders were asked to identify the location of marine resources and their respective areas of space-use. For example, charter yacht and day tours companies were asked to identify the location of all yacht anchorages and anchorages that they regularly use; whereas dive shop operators assisted in mapping of dive sites for the SWW area. A total of 26 interviews were conducted and 23 GIS datasets were compiled as a result.

Table 1. SWW stakeholders interviewed for mapping exercises
(conducted between the 15th -22nd of March 2011)

Information obtained	Stakeholder
Day tour anchorages and snorkelling areas	Eli Fuller
	Treasure Island Cruises
	Tropical Adventures Cruises
	Wadadli Cats
Dive sites / water sports	Ashton Williams
	Carlisle Bay Hotel
	Curtain Bluff Hotel
	Jolly Dive
Environmental issues and protected areas	Ministry of Environment (Diann Black)
	Ministry of Environment (Ruleta Camacho)
	SIRMM Planning Committee
Fisheries data, issues and EIA reports	Fisheries Division (Tricia Lovell, Steve and Ian)
Fishing and community use areas	Kublai Mannix
	Reginald Nicholas
Mangroves	South Coast Horizons
Mapping exercise	Coco's Hotel
	Darkwood Bar
	Dennis Restaurant
	Mystic & Excellence Cruises
	OJ's Bar and Restaurant
	Sheer Rocks Restaurant
	The Nest Bar and Restaurant
	Turners Beach
Sea turtle nesting beaches	Jepson Prince
Shore birds and wetlands / mangroves	Junior Prosper
Vending and recreational Areas	Beach Vendors – Darkwood
	Beach Vendors - Little Ffreys
	Beach Vendors - Turners
	Beach Vendors - Valley Church
Yachting anchorages	Horizon Yacht Charters

Table 2. Marine and coastal mapping exercise survey variables.

Resources	Uses and livelihoods	Problems and issues
Baitfish bay	Dive site	Artificial structure / breakwater
Cockles	Anchorages	Coastal erosion
Fish pond	Cultural / historical sites	Desalination outfall pipe
Mangroves / wetlands	Landing site	Dumping / pollution
Marine habitat	Nursery area	Mangrove cutting
Sea turtle nesting beach	Recreational area	Sand-mining
Shore birds	Sailing lane	Sedimentation plume
Whelks	Ship wreck	
	Shore fishing	
	Vending site	
	Water sports	

2.3.1. Stakeholder validation and feedback

Three composite maps were produced for stakeholder validation (i.e. critical coastal and marine habitats; coastal and marine resources; and space-use patterns and areas of threat or issues) (Appendices II-IV). These maps were shared with SWW stakeholders during a marine community meeting held March 23, 2011 at the Urlings Fisheries Complex to validate information and obtain feedback before being rendered complete. All stakeholder feedback and corrections were updated using ArcGIS, thus increasing the accuracy of the final coastal and marine mapping products.

3.0. GEODATABASE COMPILATION, STANDARDISATION AND INTEGRATION

A personal geodatabase was created for the coastal and marine features of the SWW using ESRI's ArcGIS version 10 software package. All existing shapefiles and mapping products were scanned, imported and geo-referenced to a common coordinate reference system (*e.g.* Antigua 1943 British West Indies Grid) using ArcGIS geoprocessing tools. ArcCatalog was used to created new features and attribute schema (Table 3) developed based on information collected during the mapping exercises. Information from mapping exercises was digitized from the respective paper basemaps (either as points, lines or polygons) and integrated into the geodatabase. All feature classes were further organised into seven themes or feature datasets (Table 3) categorised by geometry, attributes and data source. Upon completion of the second site visit and a final validation meeting, the SWW marine geodatabase and associated metadata were updated and a number of marine maps useful for management were created.

Table 3. Geodatabase structure for the SWW coastal and marine habitat, resource and space use inventory

Feature dataset	Feature class	Geometry	Attributes	Data source
Marine habitats	Coral reefs	Polygon	None	EIMAS
	Marine habitats	Polygon	class, description, fishing grounds, area (ha)	Baldwin, K. 2011
	Ponds	Polygon	None	EIMAS
	Wetlands	Polygon	None	EIMAS
Marine resources	Baitfish bay	Polygon	None	Baldwin, K. 2011
	Cockle	Line	None	Baldwin, K. 2011
	Nursery area	Polygon	species	Baldwin, K. 2011
	Fishing ponds	Polygon	type of fish	Baldwin, K. 2011
	Sea turtle nesting beach	Point	species, status	Baldwin, K. 2011
	Shore birds	Polygon	habitat class, description, area (ha), species, fishing	Baldwin, K. 2011
	Whelks	Line	None	Baldwin, K. 2011
Marine resource users	Dive shops	Point	name, number, email	Baldwin, K. 2011
	Landing sites	Point	name, # fishers, # boats, services	Baldwin, K. 2011
	Tour operators	Point	name, number, email	Baldwin, K. 2011
	Yachting companies	Point	name, number, email	Baldwin, K. 2011
Space-use patterns	Anchorage	Polygon	name	Baldwin, K. 2011
	Dive site	Polygon	name	Baldwin, K. 2011
	Historical sites	Point	name, type, infrastructure, protection	Baldwin, K. 2011
	Recreational area	Point	name, type, description, uses, infrastructure	Baldwin, K. 2011
	Sailing lanes	Line	name	Baldwin, K. 2011
	Ship wreck	Point	name, type, depth, year sunk	Baldwin, K. 2011
	Shore fishing	Line	name	Baldwin, K. 2011
	Vending site	Point	name, description, # vendors	Baldwin, K. 2011
	Water sports	Polygon	name, sports	Baldwin, K. 2011
Threats	Artificial structure / breakwater	Line	Type	Baldwin, K. 2011
	Beach erosion	Line	severity	Baldwin, K. 2011
	Desalination outfall	Line	None	Baldwin, K. 2011
	Dumping / pollution	Point	none	Baldwin, K. 2011
	Mangrove cutting	Polygon	none	Baldwin, K. 2011
	Sand-mining	Point	none	Baldwin, K. 2011
	Sedimentation plume	Polygon	name, reason for sedimentation, comments	Baldwin, K. 2011
Other	Cades Bay Marine Reserve	Polygon	area (ha)	Cooper, B. EAG 2011
	Mt Obama National Park	Polygon	area (ha)	Cooper, B. EAG 2011

Feature dataset	Feature class	Geometry	Attributes	Data source
	Nelsons Dockyard National Park	Polygon	area (ha)	Cooper, B. EAG 2011
	Coastal names	Anno.	name, type	Baldwin, K. 2011
	Marine survey sites	Point	site number, habitat type, fishing, comments	Baldwin, K. 2011
	Bathymetry (5m contours)	Line	depth	FAO 2005

4.0. COASTAL AND MARINE HABITAT, RESOURCE AND SPACE-USE MAPPING RESULTS

4.1. MARINE HABITAT

The SWW marine area comprises a total area of 2,618.5 hectares (Figure 2). The SWW marine environment consists largely of coral reef habitat. Nearly half (48%) of the marine area was found to contain coral reef (876. 40 ha) and reef-related or mixed-live bottom (381.94 ha) habitat. Barrier, fringing spur and groove and patch reefs are the three type of reef complexes that comprise the area. These are made of a variety of commonly-found hard coral species (*Agaricia agaricites, Acropora palmata, Colpophyllia natans, Diploria labyrinthiformis, Diploria strigosa, Millepora alcicornis, Millepora complanata, Montastrea annularis, Porites astreoides, Porites porites, Siderastrea radians, Stephanocoenia michilini*) and soft coral species (*Eunicea sp., Erythropodium caribaeorum, Gorgonia ventalina, Plexaura sp., Plexaurella sp., Pseudopterogorgia sp.)* were observed. It should be noted that the less commonly found endangered species of coral *Acropora palmata* was observed at several sites during the marine survey. A variety of macroalgae species are present in the SWW area, although various species of the calcareous algae *Halimeda* was the most abundant. The importance of the *Halimeda* species in the production of sand for beaches is well documented. Other common species of macroalgae observed include: *Dictyota* spp., *Penicillus* spp., *Padina* sp., *Caulerpa* spp. and *Udotea* spp.

Seagrass is another important marine habitat providing a number of benefits including: food source for fish, sea urchins and turtles; a nursery for the young conch, spiny lobsters, shrimp and reef fishes; helping to trap suspended sediment washed from the land or stirred from the bottom; an effective stabilising mechanism for bottom sediment during storms; and as a substrate for many small lime-secreting organisms, such as *Foraminifera* and *Serpulid* worms, which are in part responsible for the production of sand. Seagrass was the second most prevalent habitat in the SWW area comprising 23% (613.74 ha) of the area. The two most prominent seagrass species observed were *Thalassia testudinum* and *Syringodium filiforme*, as well as a smaller abundance of *Halodule wrightii*.

Based on 2004 imagery, there are nine wetlands (a total of 157.92 ha) identified in the SWW project area (Table 4), seven of which contain stands of mangrove forest (Figure 2). Four species of mangrove trees were identified: red mangrove *(Rhizophora mangle)*, black mangrove *(Avicennia germinans)*, white mangrove *(Laguncularia racemosa)* and buttonwood *(Conocarpus erectus)*. Thus based on the 2004 imagery dataset, a total of 151.86 hectares of mangrove habitat presently exists in the SWW project area.

Sand bottom habitat makes up 586.91 ha of the SWW marine area. Hard bottom was the least abundant habitat covering only 1.60 ha of the SWW project area.

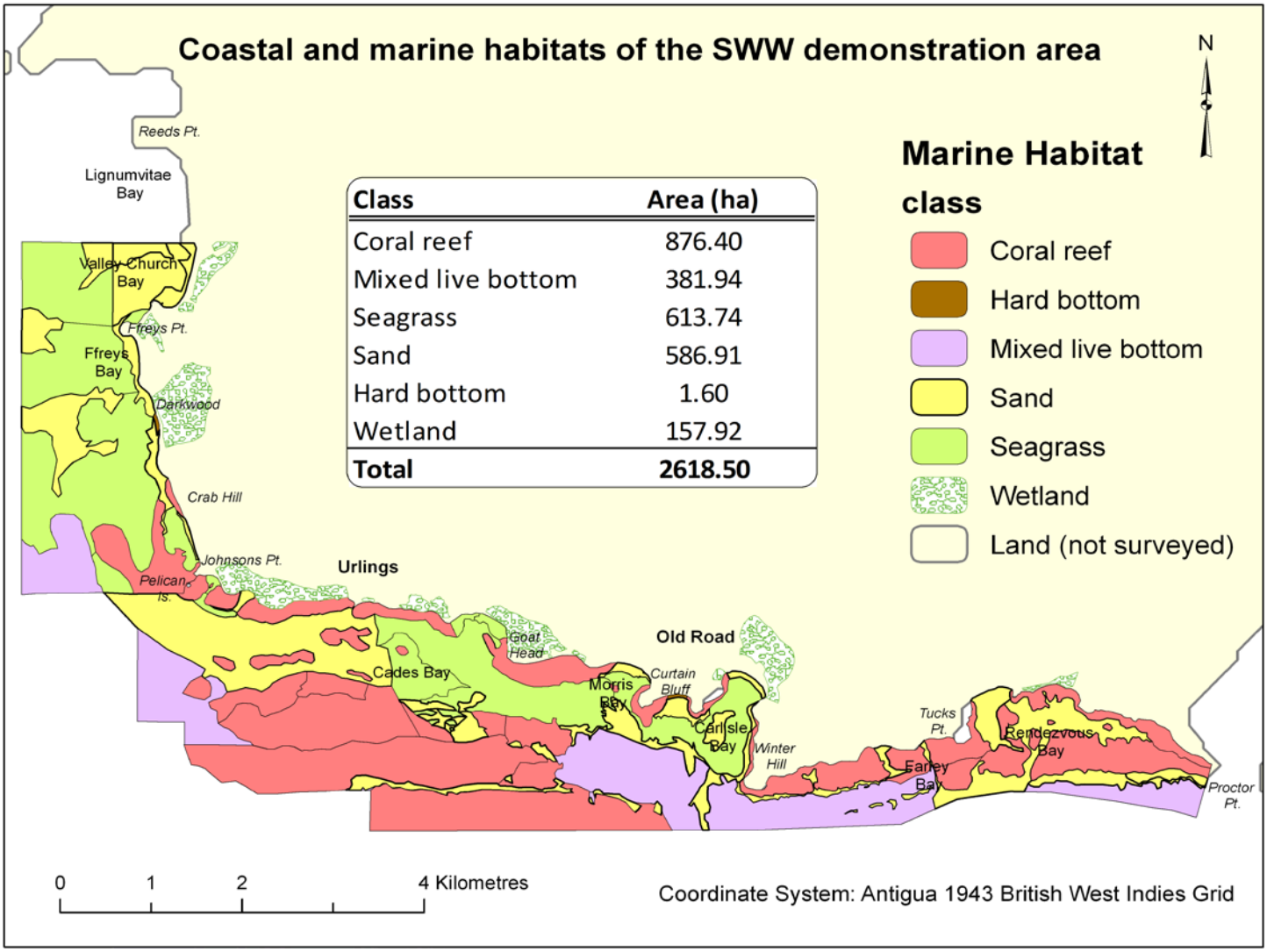


Figure 2. Map of the location and area (in hectares) of coastal and marine habitats found in the SWW project area.

Table 4. List of wetlands within in the SWW demonstration site, with associated mangrove species found, uses, and area.

Wetland name	Area (ha)	Mangrove species	Fishing ground
Valley Church	1.93	Red, white and black mangroves	No
	9.09	Red, white and black mangroves	No
	1.38	Red, white and black mangroves	No
Ffreys	5.25	No mangroves	Yes
Darkwood	42.36	Red, white and black mangroves	Yes (mullet and cali)
Johnsons Point	33.04	Red, white and black mangroves	No but important for crabbing

Wetland name	Area (ha)	Mangrove species	Fishing ground
Urlings	0.43	Red and white mangroves	No
	6.96	Red, white and black mangroves	No but important for crabbing
Cades	22.69	Red, white, black and buttonwood mangroves	Yes (fish, crabbing and cockles)
	0.68	Red and white mangroves	No
Old Road Salt Pond	1.23	No mangroves	Yes
Carlise Bay / Fish Pond	29.42	Red, white, black and buttonwood mangroves	Yes (fish and crabbing)
Rendezvous	3.46	Red, white and black mangroves	No but important for crabbing

4.2. MARINE RESOURCES

The SWW demonstration area is of significant ecological importance as it also provides a number of important coastal and marine resources (Figure 3). These resources are individually reviewed in the following section.

4.2.1. Mangrove ecosystem

Notwithstanding their utmost importance for coastal protection, the unique ecosystem found within the intricate mesh of mangrove roots offers a quiet and protective marine environment for a number of young fish and organisms. Mangrove roots in the SWW were found to host a variety of algae, barnacles, sponges, and bryozoans. These types of organisms are known to be important filter feeders serving to reduce sedimentation from coastal run-off. Salt ponds and mangroves of the SWW project area are used for fishing and include species such as: tilapia, Atlantic tarpon (Megalops atlanticus), yellow fin mojarra (Gerres cinereus), and a variety of snappers; shrimp and crabs. Crab species, including the blue land crab (Cardisoma guanhumi), ghost crab (Ucides cordatus), blunt-tooth swimcrab (Callinectes bocourti) and the blue crab (Callinectes sapidus) are also reported to be harvested on a subsistence basis within the SWW mangrove wetland areas. Besides their use as a food source, shrimps and mangrove crabs are also of importance in that they mulch the mangrove leaves thereby adding nutrients to the food web.

4.2.2. Shore Birds

Thirteen Important Bird Areas (IBAs), or areas identified to be of vital importance to birds and other biodiversity (Auduban Society 2011) were identified in the wetlands of the SWW (Figure 3). There are a large number of seabird species known to frequent the SWW area, namely the West Indian whistling duck, white-cheeked pintail duck, blue-wing ducks; brown pelican; sandwich terns, royal turn and least turns; laughing gulls; snowy egrets, great egrets and cattle egrets; little blue heron, great blue heron, green heron, tricolor heron and yellow-crowned heron; osprey; sandpiper; blue- winged teal and green-winged teal; Wilson's plover, snowy

plover and semi-palmated plover and the broad winged hawk (Prosper 2011 - personal communication).

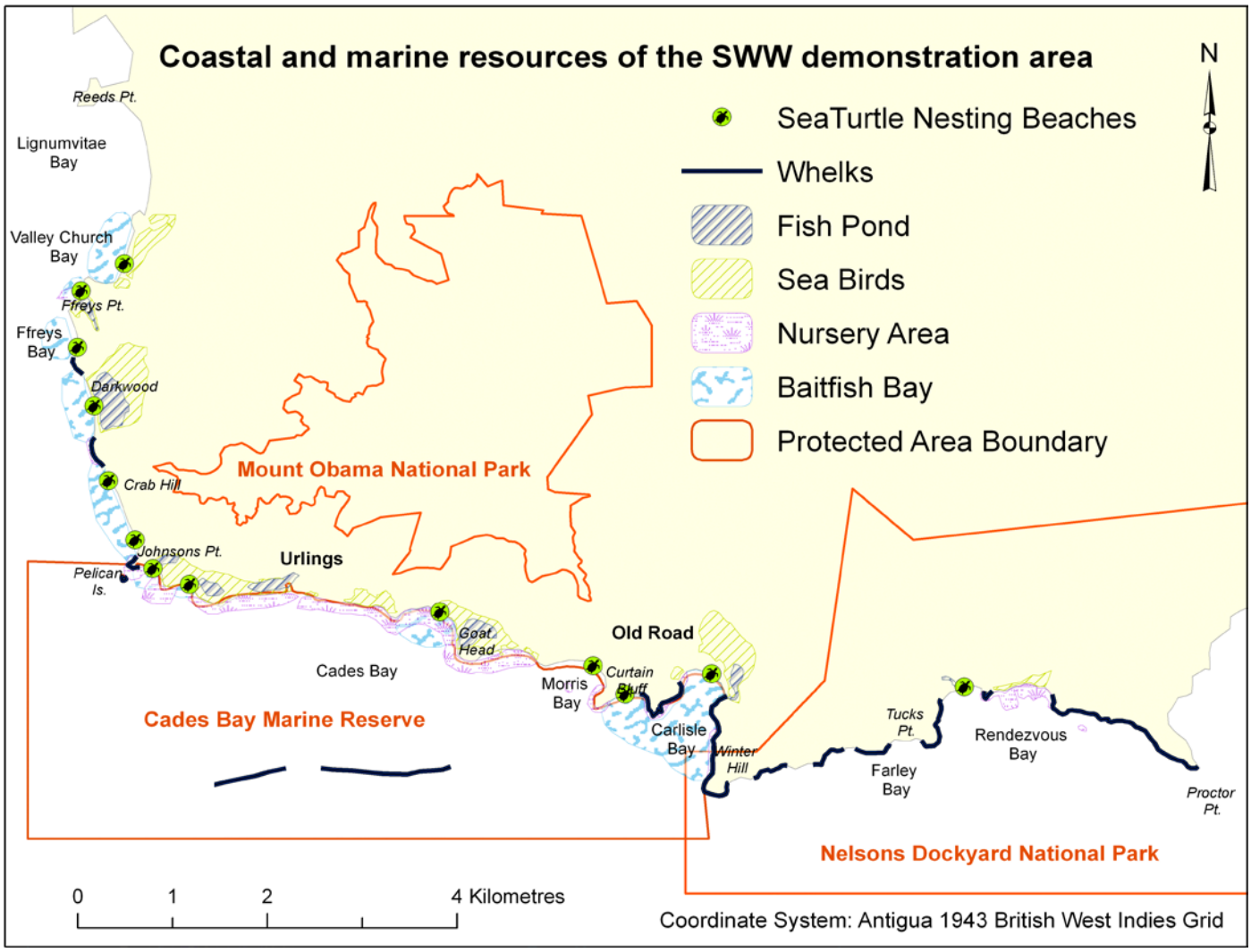


Figure 3. Map of the coastal and marine resources of the SWW demonstration area.

4.2.3. Fish and Other Marine Organisms

Although a comprehensive inventory of fish species was not the aim of this mapping initiative, a variety of reef fish species were observed while conducting the marine habitat field survey. The majority of fish observed were juveniles demonstrating the importance of the SWW as a representative reef ecosystem habitat and the importance of protecting the connectivity of coastal mangroves and seagrass beds with coral reef habitat. Although the following list is not exhaustive, species observed during the field survey include: barracuda (*Sphyraena barracuda*) (adult), four-eyed butterflyfish (*Chadetodon capistratus*) (juvenile), ocean surgeon (*Acanthurus bahianus*) (juvenile/adult), clown wrasse (*Halichoeres maculipinna*) (juvenile),

slippery dick (*Halichoeres bivittatus*) (intermediate/juvenile phases), longfin damselfish (*Stegastes diencaeus*) (adult), sergeant major (*Abudefduf saxatilis*) (juvenile), french grunt (*Haemulon flavolineatum*) (adult) smallmouth grunt (*Haemulon chrysargyreum*) (juvenile), spotted goatfish (*Pseudupeneus maculates*) (juvenile), mahogany snapper (*Lutjanus mahogoni*) (juvenile/adult), lane snapper (*Lutjanus synagris*) (adult), yellowtail snapper (*Ocyurus chrysurus*) (juvenile) and a number of parrotfish (*Scaridae*) (juvenile/adult). Reef organisms include: Caribbean spiny lobster (*Panulirus argus*), queen conch (*Strombus gigas*), fighting conch (*Strombus pugilis*), amber pen shell (*Pinna carnea*), cushion sea star (*Oreaster reticulatus*), donkey dung sea cucumber (*Holothuria mexicana*), long spine sea urchin (*Diadema antillarum*) and the variegated feather duster (*Bispira variegata*).

4.2.4. Sea Turtles

Three species of sea turtle, namely the **Green** (*Chelonia mydas*), Leatherback (*Dermochelys coriacea*) and Hawksbill (*Eretmochelys imbricata*) are known to nest on thirteen of the beaches within the SWW project area (Table 6; Figure 3) (Jepson Prince personal communication 2011). Likewise, adult sea turtles were spotted swimming on several occasions during the marine field survey.

Table 6. A list of beaches known to have active sea turtle nesting sites and other related attributes (*Prince personal communication 2011*).

Beach name	Hawksbill	Leatherback	Green	Monitoring	Beach infrastructure	Other uses
Valley Church	Yes	No	No	No	None	Picnics and bathing
Little Ffreys	Yes	No	Yes	No	Yes	Picnics, bathing, tourism
Ffreys	Yes	Yes	No	No	None	Bathing, fishing, tourism
Darkwood	Yes	Yes	No	Yes	Yes	Bathing, fishing, tourism
Crab Hill	Yes	Yes	No	Yes	Artificial structure / groine	Bathing, fishing, tourism
Turners	Yes	Yes	No	Yes	Yes	Tourism, community
Pelican Island	Yes	No	No	Yes	None	Bathing, fishing
Johnsons Pt.	Yes	No	No	Yes	None	Community
Cades Bay	Yes	No	Yes	No	None	Tourism
Morris	No	Yes	No	No	None	Tourism, community
Curtain Bluff	No	No	Yes	No	None	Tourism, community
Carlisle Bay	No	Yes	No	No	Yes	Tourism, community
Rendezvous Bay	Yes	Yes	Yes	No	None	Community

4.2.5. Coastal Resources

Shellfish resources including whelks (*Muricoidea*) and cockles (*Codakia orbicularis)* were identified as other important coastal resources that are collected from along the rocky shoreline areas of the SWW project area (Figure 3).

5.0. IDENTIFICATION OF CRITICAL CONSERVATION AREAS

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 representative reef ecosystem is an area that includes areas of mangrove, seagrass and reef habitat in close proximity to each other. The identification and conservation of areas where these conditions occur (or well-connected reef ecosystems) can be an important step to maintain the resilience of reef-related fishery resources. GIS analysis was found useful to query relevant marine habitat data to identify the location of representative reef ecosystem habitat (or areas of adjacent mangrove forest, seagrass bed and reef habitat) with in the SWW project area. To do this, mangrove habitat polygons were queried to locate all of the seagrass beds found within a distance of 50 meters of the mangroves that exist in the SWW project area. Based on these results, another locational query was run to identify any coral reefs within 50 metres of the selected seagrass beds. A total of 3 representative reef ecosystems were identified (Figure 4) and along the coastal areas of each of these are also shore bird and sea turtle nesting areas. These areas are known to be of importance for the maintenance of each of the life stages, and therefore the sustainability of, reef fish, conch and lobster fishery resources of Antigua and may require management attention. Likewise, it is interesting to note that the boundary of the Cades Bay Marine Reserve encompasses the vast majority of these identified representative reef ecosystem areas.

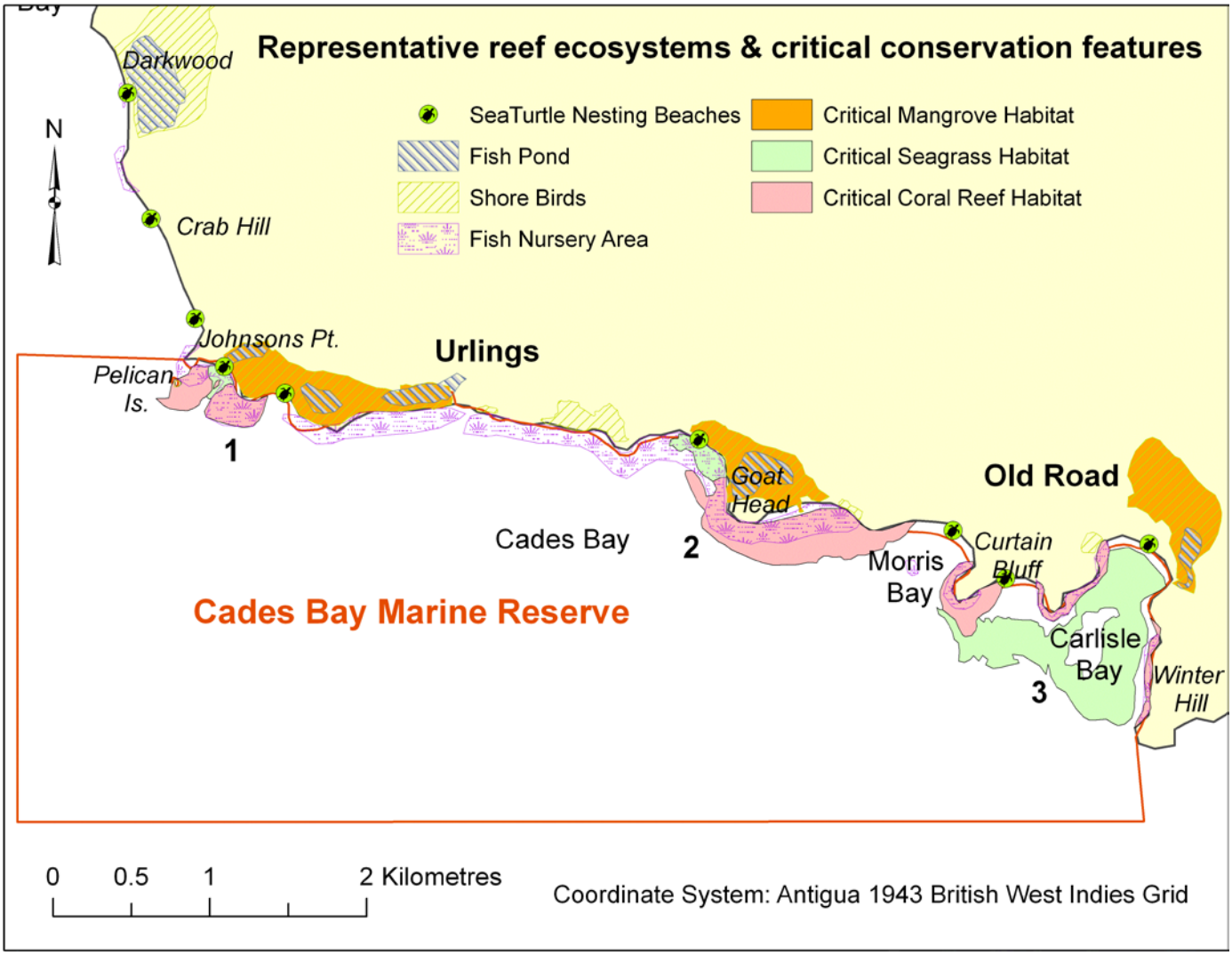


Figure 4. Map of the location of connected representative reef ecosystem habitat as well as other conservation features of interest in the SWW. Marine resource users

Based on personal observation and key informant interviews, a wide variety of stakeholders were observed using the coastal and marine areas and associated marine resources of the SWW. Marine resource users that currently use the some portion of the SWW project area on a regular basis are listing in Table 7 and include: five day tour operators, five dive shop operators, 100 fishers using four landing sites, six hotels, eight bars/restaurants, two charter yacht companies and one water-sports operator.

Table 7. Identified Marine Stakeholders that are Currently Using the SWW Marine Area

Stakeholder type	Company name
Day tour	Adventure Antigua
	South Coast Horizon
	Treasure Island Cruises
	Tropical Adventures
	Wadadli Cats
Dive shop	Curtain Bluff Hotel
	Indigo Dive
	Jolly Dive
	Sandals
	Soul Immersion
Hotel	Carlisle Bay Hotel
	Coco Bay Hotel
	Coco Rose Guest House
	Coco's Hotel
	Curtain Bluff Hotel
	Ocean View Apartments
Restaurant / bar	Darkwood
	Dennis
	Gibson's
	OJ's
	Sheer Rocks
	Sunset Horizon
	The Nest
	Turners Beach
Yacht company	Horizon Yacht Charters
	Sunsail
Water sport operator	Island Watersports

5.1. SPACE-USE PATTERNS

A number of coastal and marine-based activities (i.e. space-uses) important for both the communities of the SWW as well as the Antiguan tourism product presently occur in the SWW (Figure 5). There are four identified fish landing sites, only one of which (Urlings) has a boat ramp and facilities (e.g. gas, water, ice, market) for fishers. There are eight identified vending sites with approximately 23 vendors operating within the SWW. Five vending sites are located on the beach selling handicraft to tourists and three vending sites sell shells, fruits and vegetables on the roadside. There are eight day–anchorages, with Carlisle Bay being

commonly used for an overnight anchorage. There are three identified motorized water sport areas (Valley Church, Morris and Carlisle Bay). Most snorkelling is reported to occur just east of the cut in Cades Reef whereas the majority of SCUBA diving occurs just offshore of Cades Reef (in approximately 60-80 feet of water) as well as in a few other dive sites (Figure 5). The sailing lane depicted is the main channel used by yachts and boats passing through the SWW marine area.

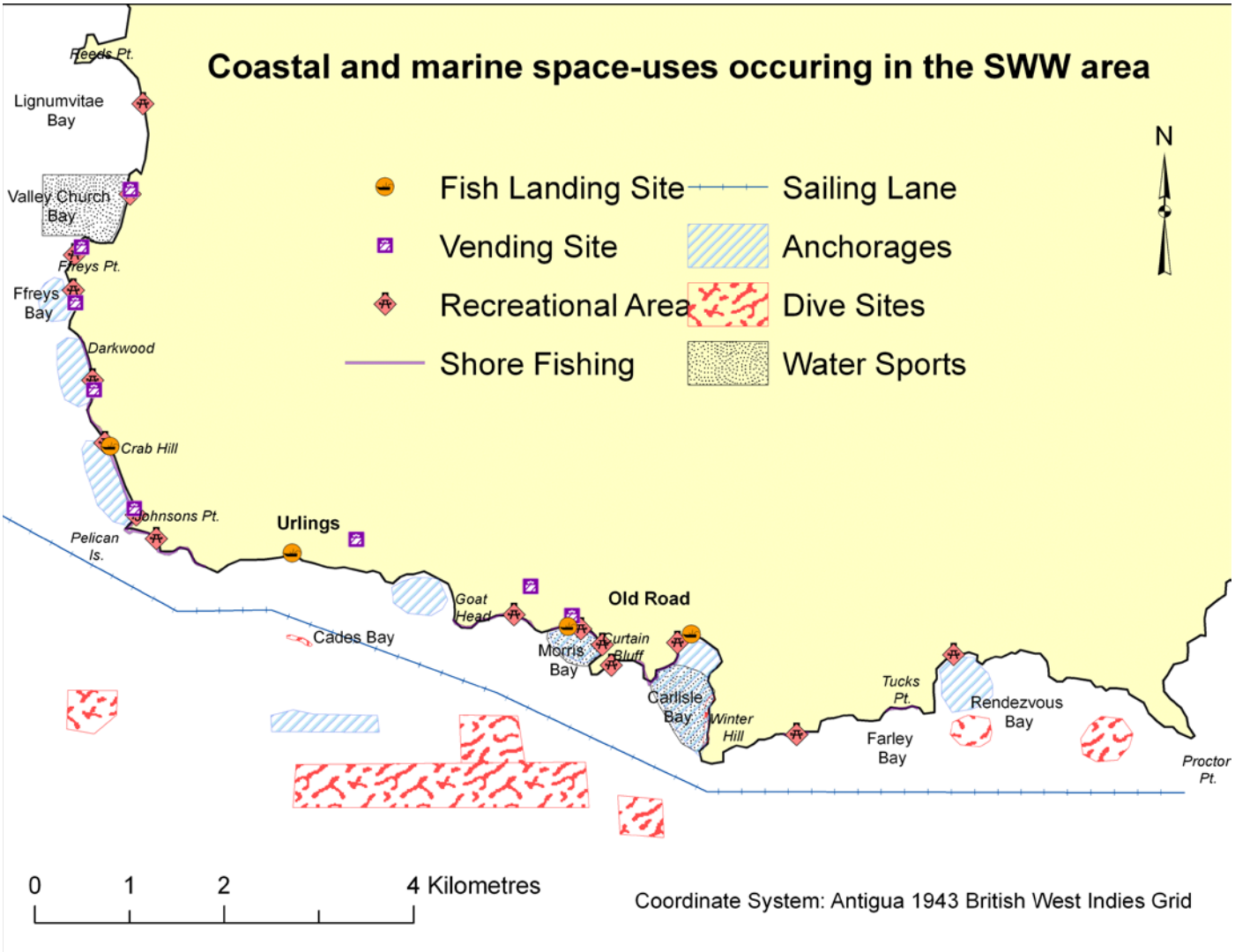


Figure 5. Map of the various marine and coastal uses of the SWW demonstration area.

Figure 6 is a map that highlights areas of importance for the Antiguan tourism product. The majority of coastal tourism activities occur on four beaches (e.g. Valley Church, Ffreys, Darkwood and Turners); both in terms of number of tourists as well as existing beach infrastructure (i.e. bathrooms, showers and chairs for rent), restaurants, bars and beach vendors. Interestingly, all of these beaches are also of conservation importance for sea turtle

nesting and shore bird roosting sites. Thus there be may be potential for ecotourism development in these areas, similar to the on-going EAG initiative in Hawksbill Bay.

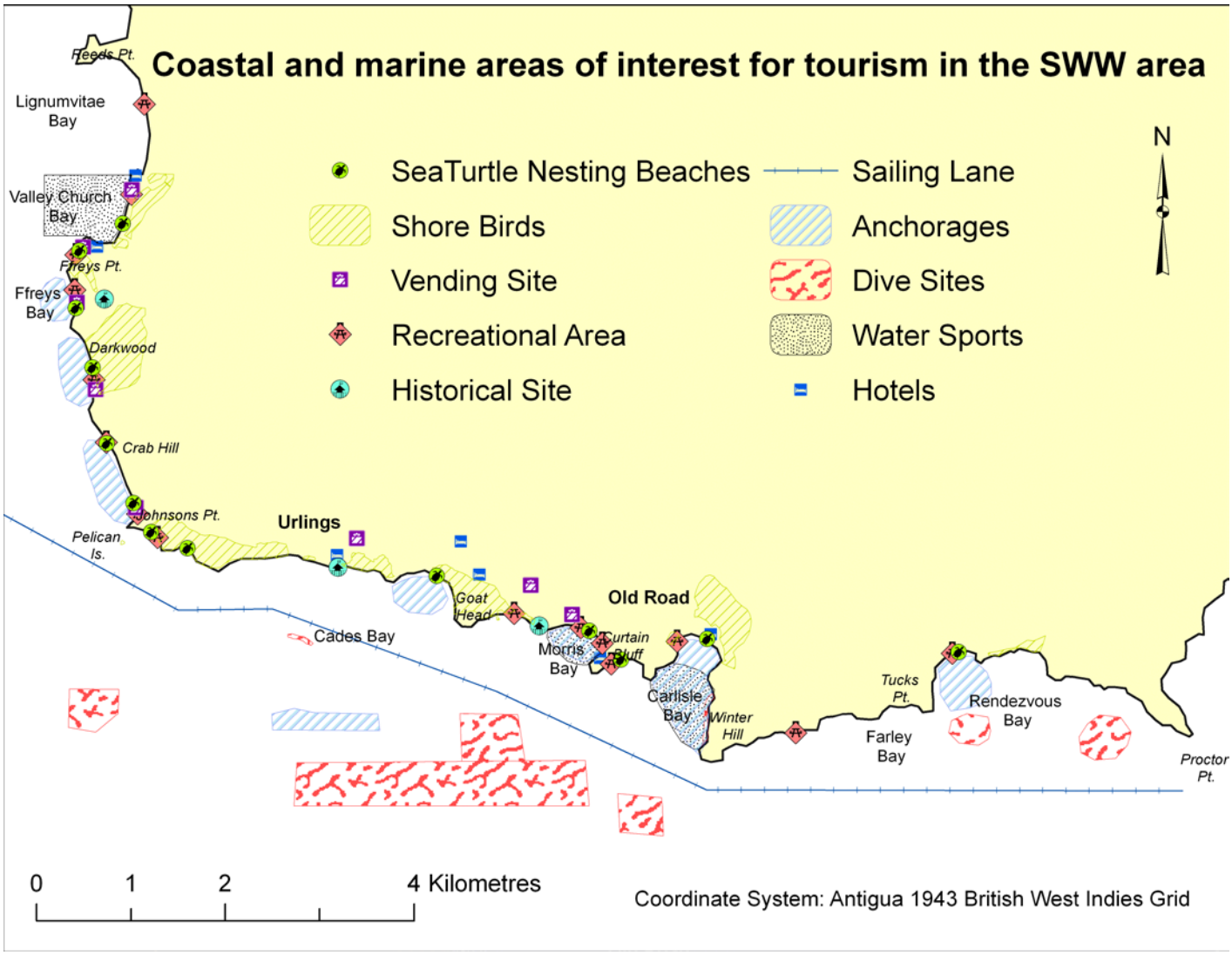


Figure 6. Map showing the areas of interest for tourism-related activities in the SWW project area.

5.2. THREATS

Stakeholders were asked to identify areas of perceived threat (e.g. dumping/pollution, beach erosion, sand-mining, mangrove cutting, sedimentation plumes) in the coastal and marine area of the SWW (Figure 7). The largest identified threat to the marine and coastal environment was an increase in coastal sedimentation plumes. Two areas (Old Road and Lignumvitae Bay) were reported to have large plumes particularly after a heavy rain event. Based on feedback obtained from the community meeting, stakeholders perceive that the removal of mangrove forests, the destruction of low-lying marsh grasslands and the filling in of

coastal 'settling' ponds are causative factors for the increasing coastal erosion and sedimentation occurring with in the SWW area. Not only have community members noted an increase in the amount of marine sedimentation plumes, but the loss of these habitats also threatens bird feeding, nesting and loafing sites used by shore birds including the West Indian whistling duck. This concern is also illustrated by the presence of a growing number of artificial coastal protection structures along the coastline of the SWW area. Therefore the prevention of further wetland loss and the importance of mitigation measures such as coastal re-vegetation should be a management priority to counteract these identified threats and rehabilitate the coastal and marine environment. Illegal dumping is reported to occur in two mangrove areas near Urlings and Goat Hill. An environmental education campaign of the importance of wetland areas is another management strategy to combat these issues. There is one desalination outfall pipe located just north of Ffreys Point but it was not operational during the field survey. A total of 5 artificial structures or breakwaters were mapped in the SWW coastal and marine area. Although historically there were reports of mangrove cutting and sand mining, they were not reported by the community to presently occur within the SWW.

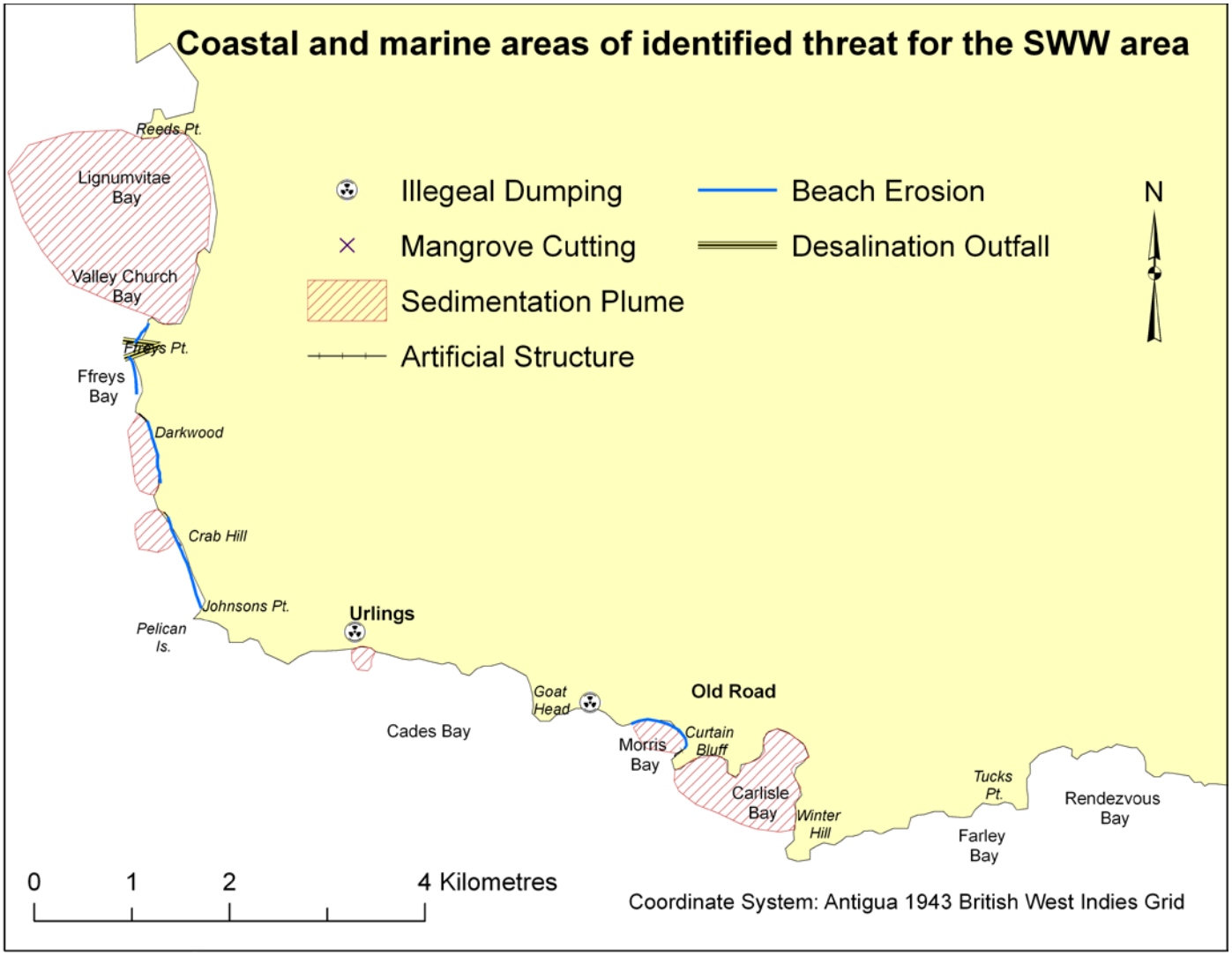


Figure 7. Map of coastal and marine areas of identified threat in the SWW project area.

6.0. RECOMMENDATIONS

The following are a variety of management recommendations based on the results of this study and addressed by topic.

6.1. GIS

The power of GIS to capture, store and integrate both quantitative and qualitative information from a variety of sources and scales in order to query, analyse and display spatial information is widely recognised as a useful tool for decision support and implementing an ecosystem-based management approach (as is intended for this ridge to reef demonstration project). The usefulness of stakeholder collaboration was thought to be instrumental in that it allowed for an efficient and comprehensive collection of existing marine resource and space-use information and GIS datasets. Local knowledge was used to map coastal and marine resources, marine habitats, human activities and to identify issues or threat in the SWW. The use of stakeholder engagement aided the building of a partnership approach within the project between the consultants, government agencies and SWW communities.

Unfortunately, the full EIMAS database was not released during the first field visit, and the complete EIMAS was only received after mapping was completed. Despite this, based on the portion of the EIMAS received, the review of existing GIS data was a challenge due to an absence of metadata in almost all cases. Time was spent communicating with the data providers and creators wherever possible, in an attempt to determine the accuracy, scale and methods applied to each available GIS dataset. Besides the imagery and mapping datasets, there were only three pre-existing GIS shapefiles found to be of relevance for the marine and coastal mapping of this project included within the geodatabase (Table 1). Most of the pre-existing GIS datasets consisted only of spatial data with little or no associated attributes. In addition, the methods for pre-existing datasets were largely un-documented and could not be suitably established resulting in unknown accuracy estimation.

The production of the SWW GIS data as an ArcGIS personal geodatabase was found to be advantageous in that it easily provided for an increase in quality assurance and control. The use of a geodatabase ensures that the same spatial reference (coordinate system) is applied to all imported feature classes. The use of subtypes and domains ensured uniformity in the ascribed attribute values applied to the various feature classes. Moreover, the use of feature datasets aided the organization of individual feature classes into similar themes so that information could be easily located and accessed. For these reasons, it is *recommended that the EIMAS is imported into the provided SWW geodatabase*.

6.2. EXISTING DATA AND INFORMATION

- GIS, mapping, remote sensing and literature resources should be compiled, organised and integrated amongst agencies and made easily available to authorized users via an accessible inter-governmental geodatabase server (a website or central terminal). Existing survey data collected by the various agencies should also be converted into spatial data (GIS format) for increased usability. Information should be freely shared between government agencies to allow for easy access to a wider range of existing information and allow for informed and holistic management and decision-making.
- Standard operating procedures should be developed to allow for uniform, integrated and effective data management, sharing, access and maintenance. To this end, a national data format should be clearly defined to guide the production of subsequent GIS products in a standard format. For example, the application of a uniform resolution of map scales and imagery pixel resolution across developed data products would result in greater usability of data amongst projects and agencies. Detailed metadata requirements should also be developed alongside data automation guidelines and upheld in order to maintain data integrity and quality assurance for the EIMAS.
- Marine and coastal resources should be included in aerial surveys and investigations (such as Environmental Impact Assessments) extending to the limits of the territorial sea or 30 meters in depth for all coastal development projects in order to fill this identified data gap.
- A national standard for marine habitat and land cover classes should be developed for habitat mapping to ensure data produced is applicable to a wide range of management, planning and decision-making purposes.
- Mangrove and wetland areas should be redigitized and forest stand cover recalculated *based on the 2010 imagery*.
- Local knowledge and community involvement should continually be solicited to fill existing information gaps, better guide management priorities and aid good governance. Furthermore, *including stakeholders in data collection initiatives* serves to increase stakeholder understanding and involvement in management decisions.
- GIS capacity within the various government agencies is limited. In order to build capacity and allow for an integrated management and decision-making environment, it is recommended that at least one to two persons (data entry and data managers) are trained not only in the use of GIS but also the practical application required to allow for data conversion and importation of existing data into GIS and a centralised geodatabase. Practical GIS training should also include instruction on the applied use of data for analyses as well as skills required to develop scenarios to better inform decision-making for planning and management.

6.3. CONSERVATION

The SWW area contains a large amount of representative reef ecosystem habitat and other critical conservation features making the area important for biological conservation. Conservation recommendations resulting from this project include:

- Management of coastal mangroves should be assessed. Currently mangrove management is split between Forestry Department and Fisheries Division and the respective role of each agency is unclear. Issues identified such as the removal of mangrove forests and the filling in of settling ponds and marshy grasslands should be prohibited due to their importance in the prevention of coastal erosion and the reduction of sedimentation plumes at sea as well as their importance for shore birds. There are nine IBAs in the SWW all of which are located in mangrove/wetland areas in which special protection should be established. Moreover, an education campaign aimed at the importance of wetland and the consequences of habitat destruction and illegal dumping known to occur in mangrove areas may also be of use.
- As a number of sea turtle nesting sites and popular tourism beaches are found to co-occur. In addition, a number of community members complained about hotel lighting on beachfront areas and the impact on successful sea turtle nesting. Therefore education and incentives for hotels on 'green' practices could be explored to mitigate these impacts.
- Likewise, fishers complained about the impact of tourism and sunscreen oils in particular affecting the water quality around Cades Reef. As this is a highly used tourism area, the carrying capacity of the CBMR and the number of boats/persons using the reef should be determined. Additionally, environmentally friendly sunscreens are available and the day tour companies could be required to provide eco-friendly sunscreen for their guests when swimming in the area.
- To reduce marine pollution and human health impacts, yachts and day tour operators could be required to use holding tanks, especially within the boundaries of the CBMR.

6.4. MANAGEMENT

- There is a need for integrated inter-agency management with wide stakeholder participation to allow for integrated ecosystem approach to land-sea management of the natural resources of Antigua. To this end, a marine space-use plan should be developed in tandem with the on-going national land-use planning initiatives to allow for effective, integrated, ecosystem-based management and provide for sustainable development in the country of Antigua and Barbuda.
- Although there is legislation drafted for the CBMR, there a lack of enforcement of its' regulations. There are no marine park marker buoys in the water demarcating the area or informational signs with regulations and boundaries. These factors may explain in part

why there is a general lack of public awareness of the existence of the CBMR as a marine park. Cades Bay Marine Reserve (CBMR) management plan is out of date (1992) and requires updating based on current information to allow for effective management implementation.

- There appears to be a good working relationship between local fishers and the Fisheries Division. Despite this, the communities report a disconnect between government agencies and what is happening on the ground. This government-community partnership should be strengthened, particularly in the collection of local knowledge and collaborative research initiatives, to aid good governance and better guide management and decision-making in accordance with community concerns and needs.

APPENDIX I: GROUND-TRUTHING

Field survey maps, representing the outline of the digitised habitat polygons and corresponding location of marine habitat survey sites (centroid of each identified habitat polygon) overlain on satellite imagery.

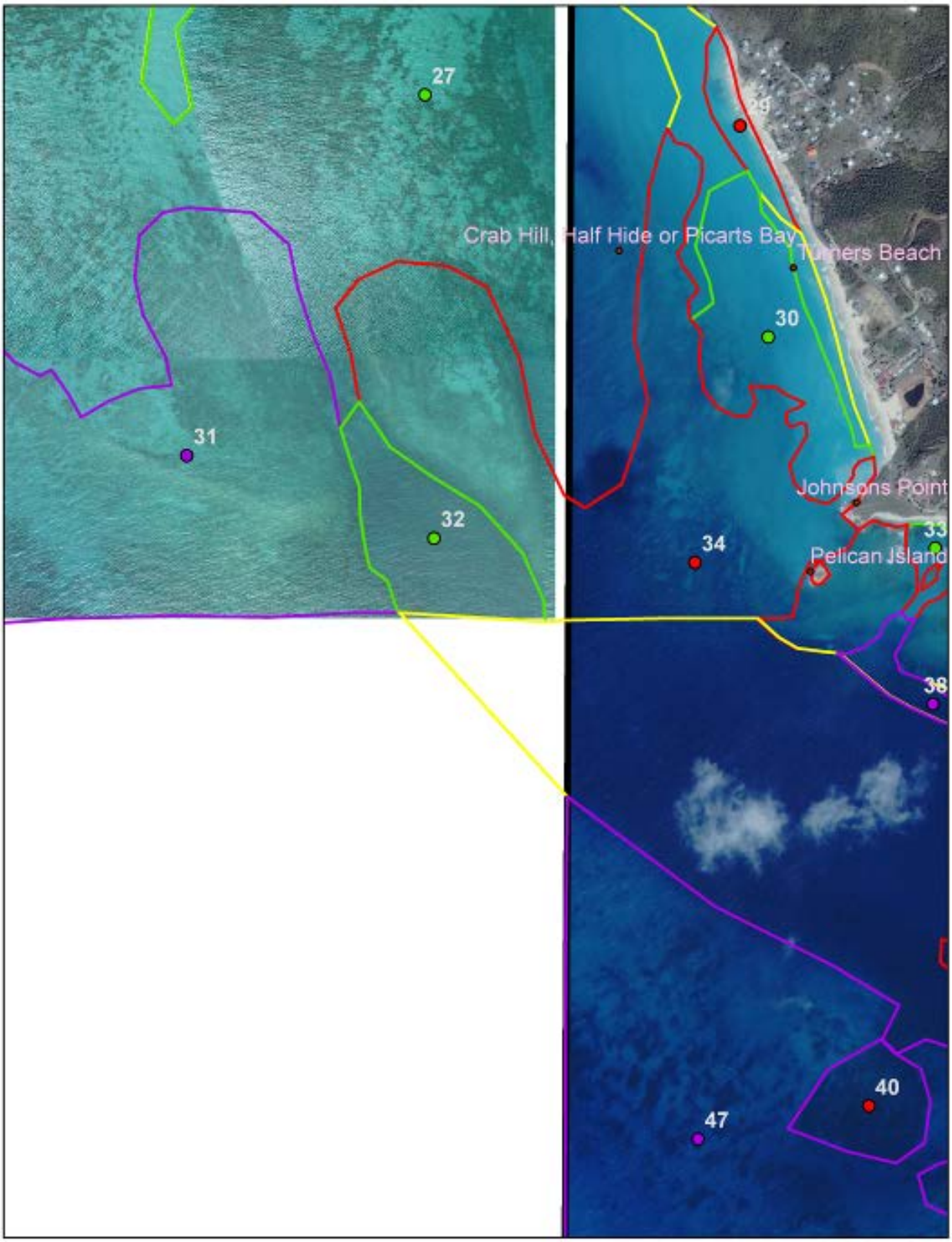
Legend. **red = coral**;

green = seagrass;

purple = mixed live bottom,

brown = hard bottom,

YELLOW = SAND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Crab Hill, Half Hide or Picarts Bay
Turners Beach
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32
Johnsons Point
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34
Pelican Island
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40
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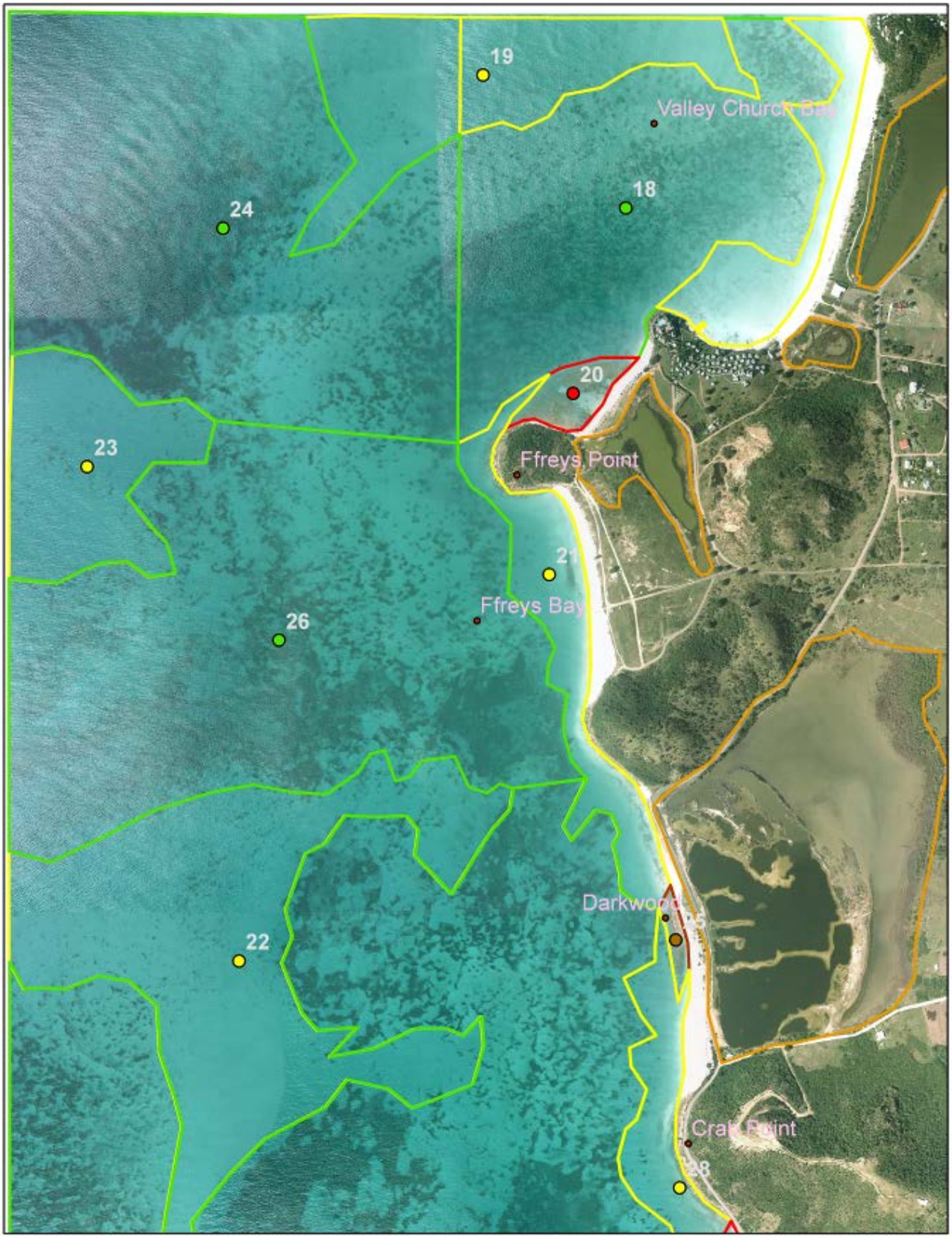
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Ffreys Point
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Ffreys Bay
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Darkwood
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Crab Point
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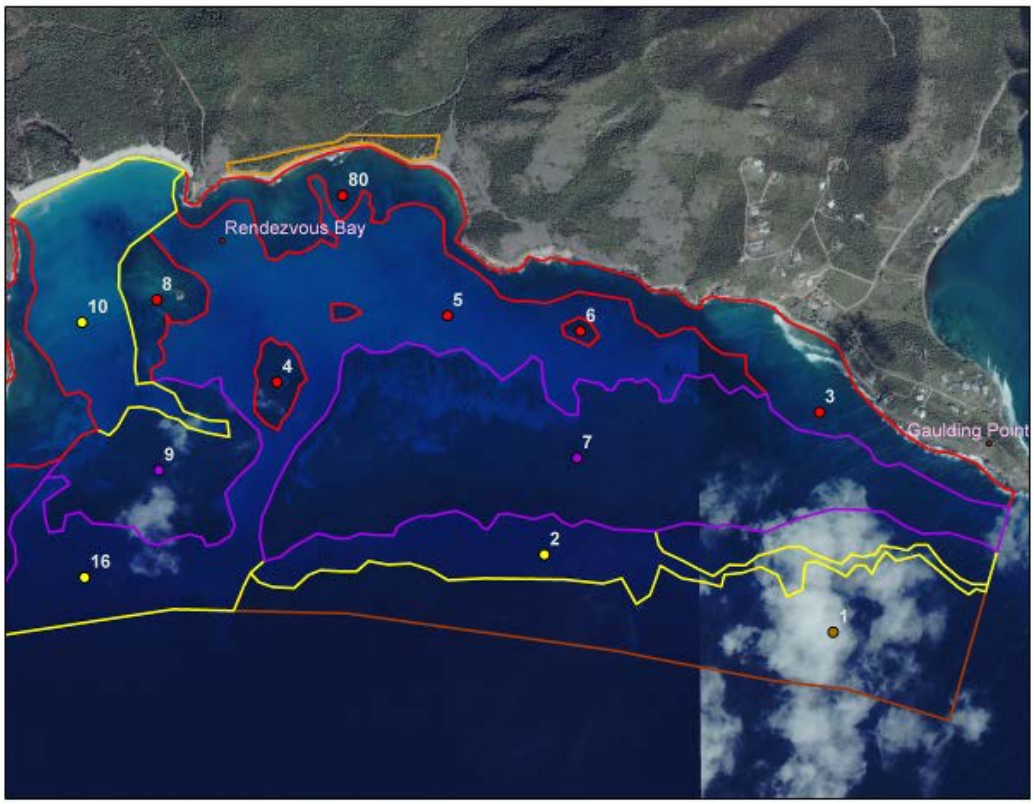
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Gaulding Point
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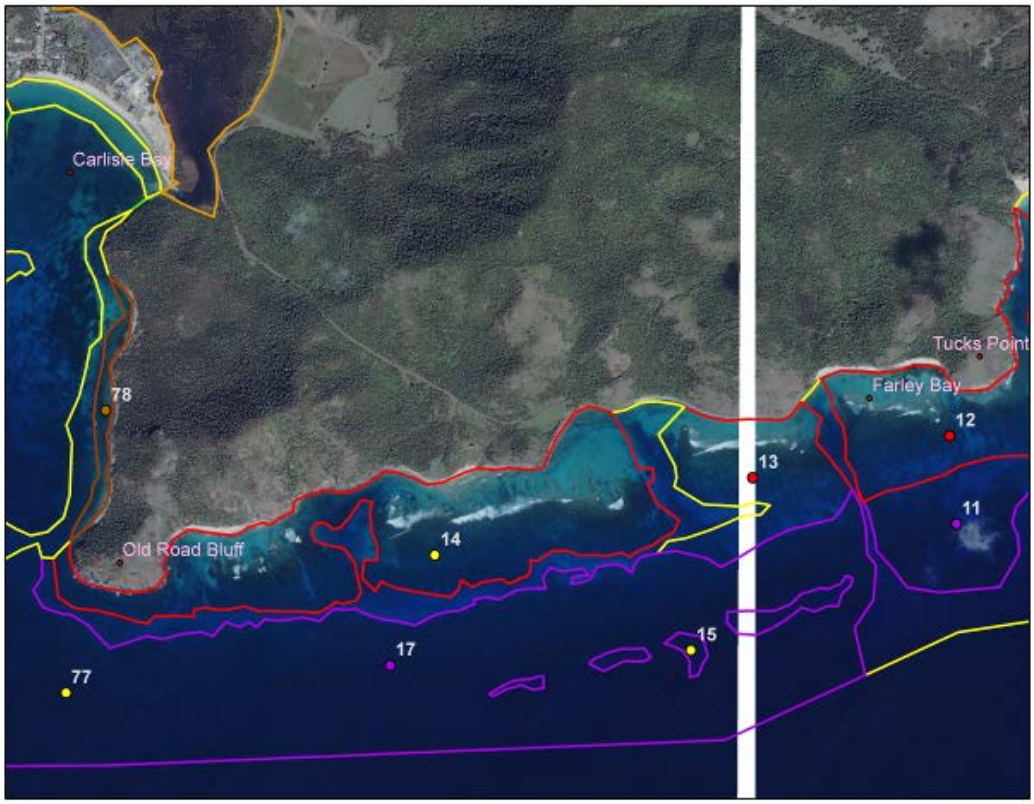
Carlisle Bay
Tucks Point
Farley Bay
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Old Road Bluff
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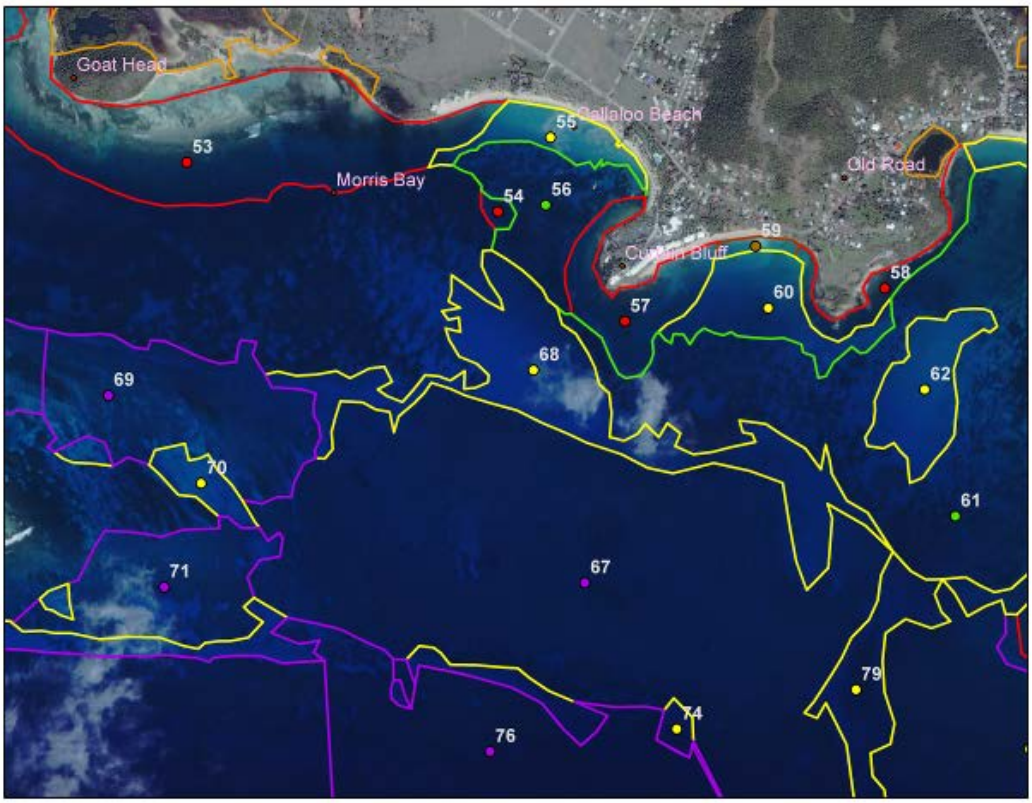
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Ballaloo Beach
Morris Bay
Old Road
Curtain Bluff
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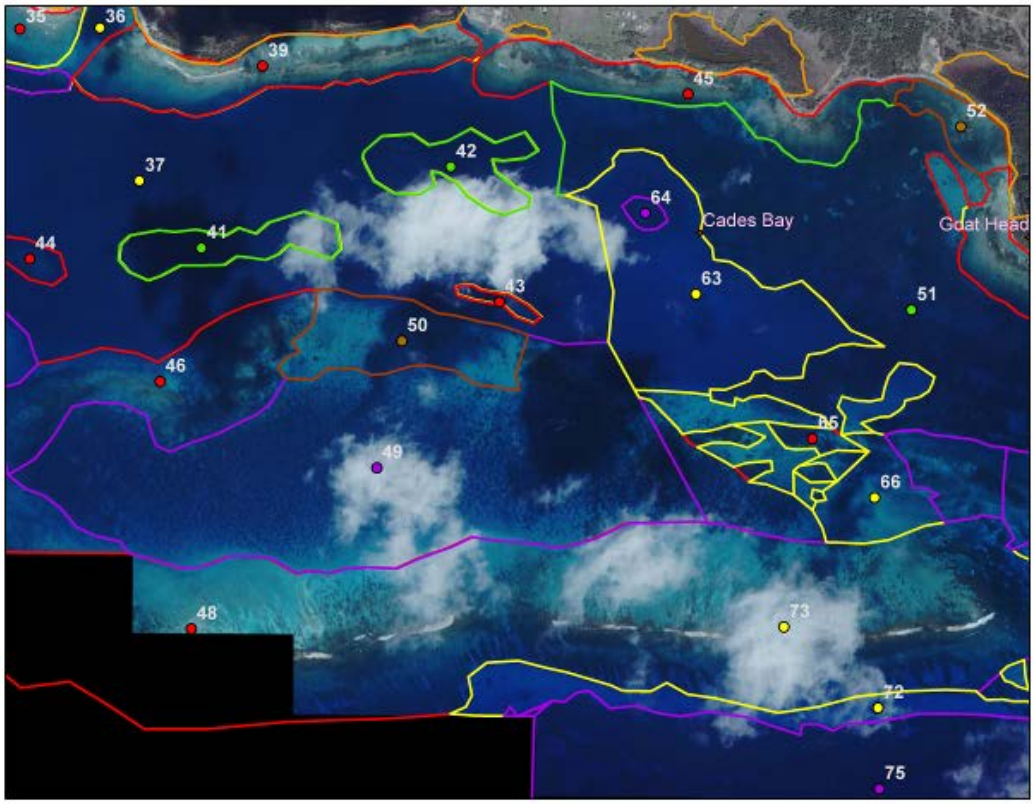
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Cades Bay
Goat Head
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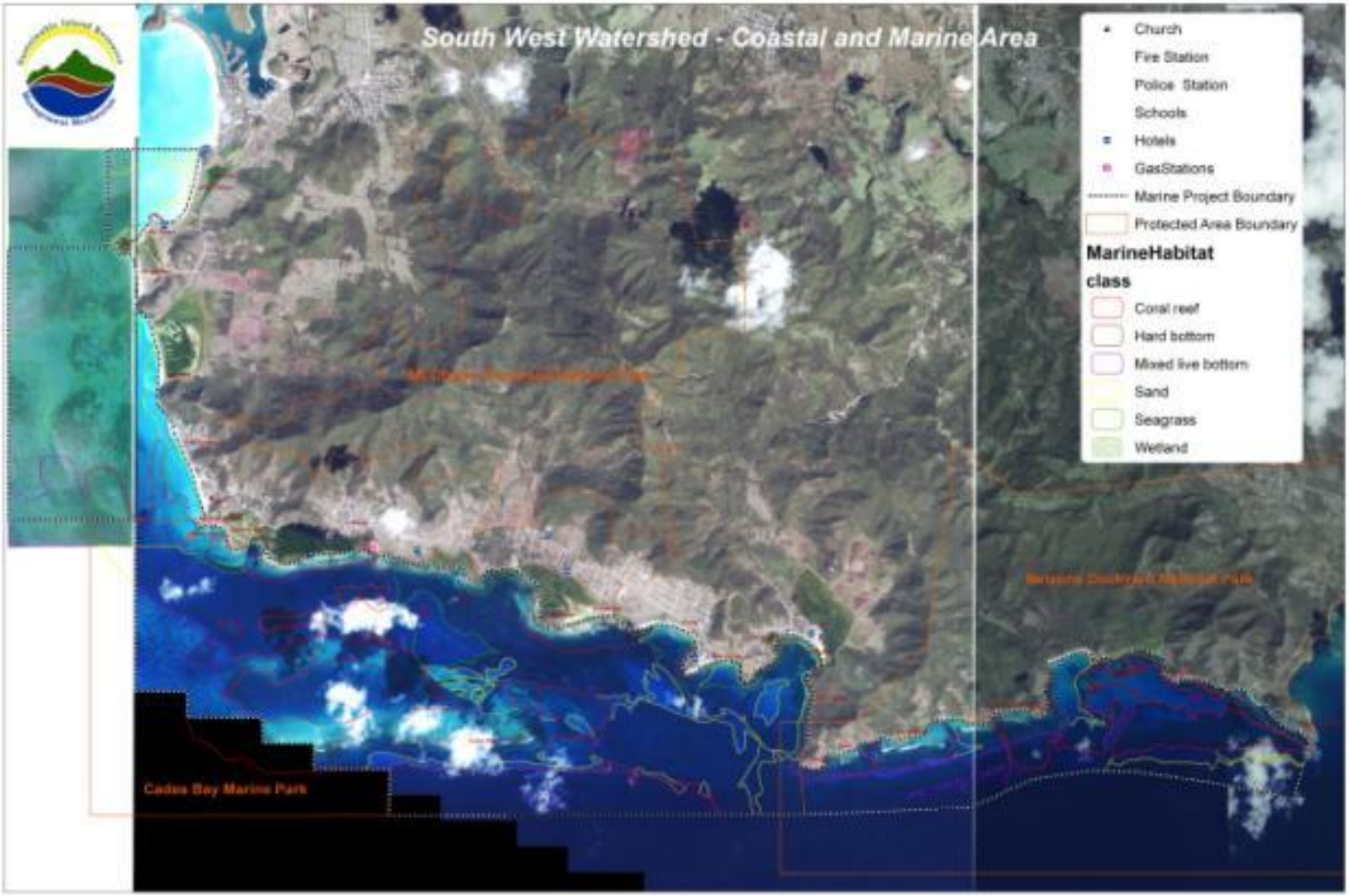
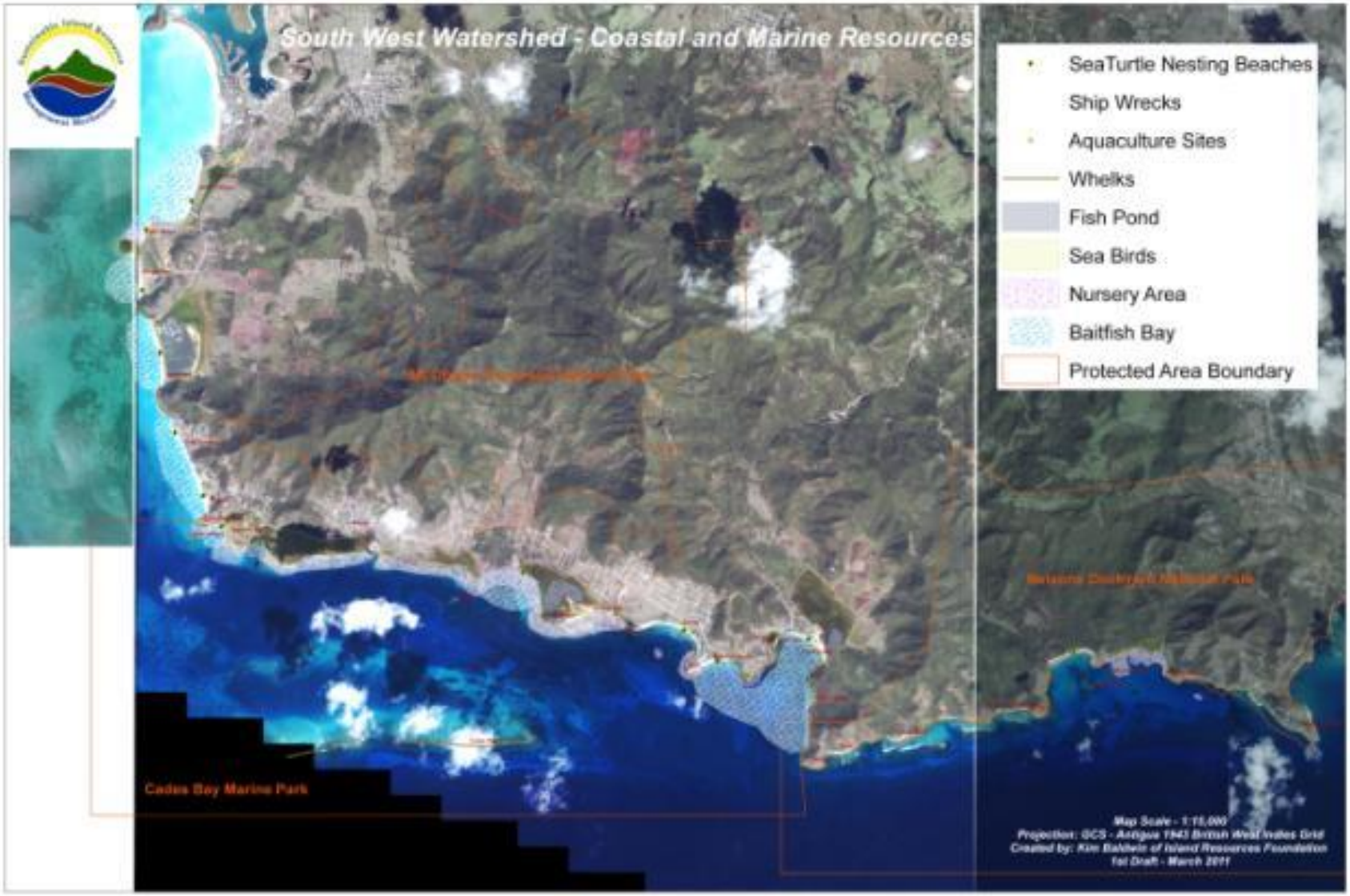
APPENDIX II. COASTAL AND MARINE INFRASTRUCTURE AND HABITAT MAP



APPENDIX III. COASTAL AND MARINE RESOURCES MAP



APPENDIX IV. COASTAL AND MARINE USES AND THREATS MAP