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Resources, Methods, and Effort Associated with ESI Mapping of the Bahamian Archipelago for Great Exuma, Bahamas

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ABSTRACT

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With the expanding exploration and transportation of petroleum products through Bahamian waters, a growing gap in coastal protection is an Environmental Sensitivity Index (ESI) mapping dataset of the entire archipelago. The resources required for coastal classification, ranking, and GIS mapping for one island, Great Exuma, are documented as a cost-effective methodology to protect all Bahamian shorelines. The ESI mapping follows international conventions for oil spill response planning, but because of the lack of a national coastal management structure, a relational database was developed to bring together field photographs, geology, and wildlife occurrence information to initiate the mapping process. The final product for Great Exuma was 13 ESI maps for one island environs, each map covering about 120 square km. The ESI mapping requires three types of expertise: (1) GIS (ESRI ArcMap 10.2) and relational database (Microsoft Access) expertise; (2) coastal ecology and geomorphology expertise; and (3) local resource management and natural history expertise. After initial field work of 14 days on the island, the GIS and coastal classification datasets required about 5 weeks for compilation. The datasets are dynamic and can be updated as new information becomes available. The ESI maps and coastal classification database are easily shared and revised moving forward. The process could be facilitated by the participation of citizen scientists to contribute photographs and local reports on status and changes to coastal resources. The overall ESI mapping product can provide a valuable management tool not only for oil spill response but for better integrated coastal zone management.

ADDITIONAL INDEX WORDS: *Oil spill response, island ecology, coastal classification, coastal ranking.*

INTRODUCTION

Environmental Sensitivity Index (ESI) maps provide a concise summary of coastal resources that may be at risk if an oil spill occurs nearby. Procedures for the construction of ESI maps do not exist for the Commonwealth of The Bahamas, thus the U.S. National Oceanographic and Atmospheric Administration (NOAA) Office of Response and Restoration guidelines offer valuable insight into the ESI map construction process (see NOAA, Office of Response and Restoration [2014] for guidelines and conventions). When an oil spill occurs, ESI maps can help responders meet one of the main response objectives: reducing the environmental consequences of the spill and the cleanup efforts (Spencer, 2003). Additionally, ESI maps can be used by planners before a spill happens to identify vulnerable locations, to establish protection priorities, and to identify cleanup strategies (Proffitt and Roscigno, 1996; UNEP, 1983). A main objective of oil spill responses globally, after protecting human life, is to reduce the environmental consequences of both spills and cleanup efforts. To do this, governments need to work together with nongovernment organizations to produce ESI maps, which identify vulnerable coastal locations as well as biological and human-use resources. These valuable maps help to establish protection priorities and to identify cleanup strategies. ESI map information is contained within spatial datasets in a GIS for rapid update and dissemination (Murday and Baca, 1990).

ESI maps combine information on species distribution, ecosystem ecology, oceanography, and resource use that is routinely used by government agencies, nongovernment conservation organizations, and key stakeholders such as fishermen or resort owners. ESI maps were first developed as a concept for oil spill response planning in 1979. In the Gulf of Mexico, the *Ixtoc 1* exploratory oil well blew out, spilling 140 million gallons of crude oil that threatened the coast of Texas. During the 2 months in which the United States had to prepare for oils slicks from the well to reach the Texas coast, NOAA created the first ESI maps with contractors to prioritize areas for environmental cleanup. Since that time, ESI atlases have been prepared for countries throughout the world using standard guidelines and methods (Francis, 1991).

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ESI maps were initially hand drawn over topographic maps. Areas along the shore were "ranked" in terms of their vulnerability in the event of a spill. The concept was to quickly pull together expert information and existing data onto one map for oil spill response planning. The information required cut across the portfolio of a single agency or organization and immediately mandated collaboration. Scientists, coastal managers, clean-up contractors, and oil companies used the maps for both oil spill preparedness and response activities. Scientists could now collect more detailed information on seasonality and breeding activities that could affect protection priorities; however, the advancement of GIS technology had the most profound impact on the production and distribution of the ESI maps (Jensen, Hall, and Michel, 1998). The *Exxon Valdez* oil spill in 1989 had a significant impact on the demand for ESI maps. Two key changes occurred. For the first time, the general public became involved both by their concern over the damage oil caused and by supporting volunteers for wildlife rescues. Second, this public awareness brought ESI maps to a wider audience that supported key laws and funding initiatives that mandated oil spill prevention and response strategies.

Advances in database technology made it practical to collect more information about species vulnerable to oil spills, and new ESI maps with their associated datasets will likely be accessed on tablet technology for rapid field responses. There are two central purposes for ESI maps in The Bahamas. First, oil spill response teams need to know which species occur and where they occur. Second, ESI maps assume legal implications because the Government of The Bahamas (GoB) is obligated by international treaty and laws to know about and to document the occurrence of key protected or exploited species (Antoine, 2008; Getter, Scott, and Michel, 1981; International Maritime Organization, 2010). The GoB is ultimately responsible for the assessment of preimpact (*e.g.,* baseline) conditions and the knowledge of which species could be impacted by an oil spill at a specific location as part of determining damages and restoration costs. All of this requires considerable resources and expertise.

Both of these purposes require organized, current, and accurate information on the marine and coastal resources of The Bahamas and their related stakeholders. This is no easy task for over 100,000 square km of shallow banks and over 7500 km of shorelines throughout the archipelago. Today, The Bahamas is at risk for oil spill impacts from transportation of diesel for power generation between islands, transportation, and storage of petroleum products moving through The Bahamas and drilling in adjacent areas of the United States and Cuba (BORCO, 2014; Buchan, 2000; Federal Information & News Dispatch, 2011).

This paper presents conventions used in ESI map development for the islands of The Bahamas through the mapping of the island Great Exuma. The development of mapping conventions that were compatible with international ESI standards is a critical step in oil spill response planning. The Great Exuma ESI maps integrate information from scientific reports, interpreted images, and field surveys. The methods and resources used to cover this island are outlined as a methodology to apply to the entire archipelago.

METHODS

The island of Great Exuma is used to illustrate the challenges of collecting information, classifying the coastal environment, and building the spatial datasets for ESI mapping. Great Exuma is the largest island in the Exuma island chain, with nearly 8000 residents living on the island in six major settlements (Government of The Bahamas, Department of Statistics, 2011). The island has approximately 290 km of shoreline, with the western shore dominated by mangrove wetlands (Figure 1). Individual ESI maps were formatted to cover approximately 120 square km, and 13 separate maps were constructed to cover the entire island of Great Exuma from The Ferry to Barraterre (Figure 2). The ecology and environmental quality of the island is critical for the tourism-based economy (Lowe and Sealey, 2003; Sealey, 2004). The extreme oligotrophic (low nutrient) conditions of the marine near shore systems were maintained by a complex filtering of freshwater run-off through ephemeral and coastal wetlands. There is a limited dataset for the state of the coast, records of coastal alterations, and coastal classification for the largest islands in The Bahamas (Sealey, McDonough, and Lunz, 2014). The existing coastal database was expanded for Great Exuma to include a more detailed coastal classification based on relief, substrate, and geomorphology.

The classification of marine and estuarine natural communities was facilitated by using the United States Classification of Estuarine and Marine Communities (CMECS) (Marine Classification Working Group, 2012). Existing data layers on coverage of submerged aquatic vegetation (seagrass), hard bottom, and coral reefs were reinterpreted and classified using the Coastal and Marine Ecological Classification Standard. The CMECS classification is compatible with existing upland and wetland classification standards; coastal wetlands were mapped using the Classification of Wetlands and Deepwater Habitat for the United States (Cowardin *et al*., 1979). These classification documents allowed for a transparent process of habitat characterization and description and allowed the comparison to ESI maps from the Florida Keys to determine detail and scale of coastal ranking needed. Information specific to Great Exuma was collected in a bibliographic database (EndNote, 2014[1]) to build a relational database dataset on the classification, distribution of key wildlife species, and human-altered structures such as piers, jetties, and seawalls around Exuma.

There are five key areas for ESI map development: (1) GIS base maps in ESRI ArcMap 10.2 that provide accurate shorelines and coastal wetland locations; (2) an inventory of biological resources that occur in the area, as well as details about critical habitats; (3) a coastal natural community classification that incorporates geomorphology and elevation; (4) knowledge of rare and protected species that occur in the area of interest; and (5) geo-referenced datasets on the history of the coastal zone, including prior preimpact assessments, user groups, stakeholders, and land managers. Key features of the final ESI Maps critical to oil spill response planning are as

[1] EndNote is the industry standard software tool for publishing and managing bibliographies, citations, and references on the Windows and Macintosh desktop.

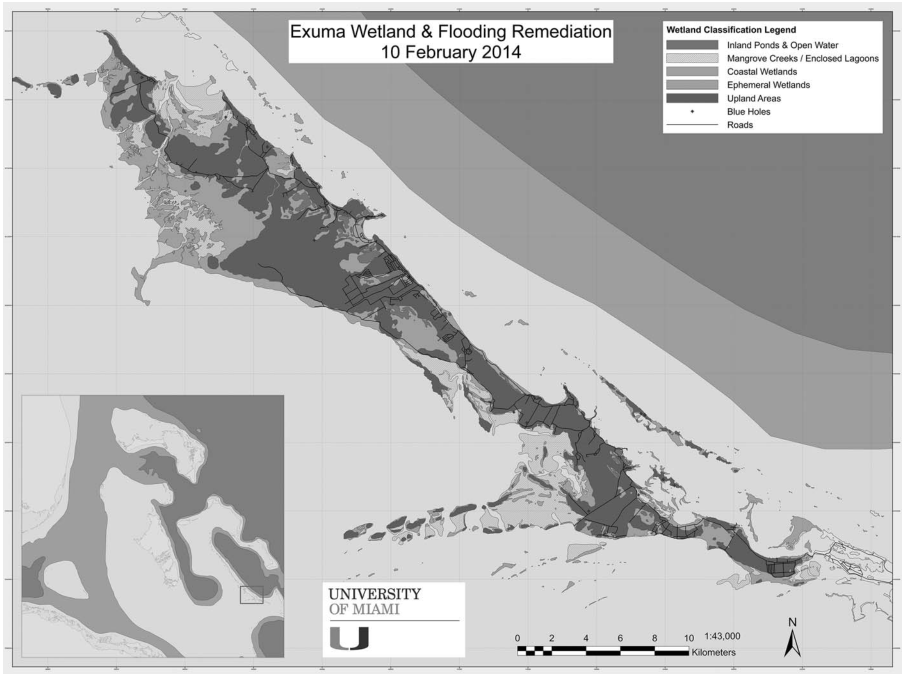


Figure 1. Wetland map of Great Exuma illustrating the extent of mangrove wetlands around the island. Much of the island is very low elevation and tidally floods. Coastal wetland maps are an essential part of creating ESI maps. Wetlands are identified by a combination of aerial photo interpretation and field surveys.

follows: (1) shoreline classification and ranking for sensitivity to oil spills; (2) marine benthic habitats such as sand, seagrass, or reefs; (3) mangroves; and (4) sensitive wildlife occurrences. Spatial datasets were organized into themes to assess the quality and scope of information. These spatial datasets were imported into ESRI ArcMap 10.2. Through a combination of analysis of aerial and satellite photography (Green and Edwards, 2000), knowledge of the natural history and

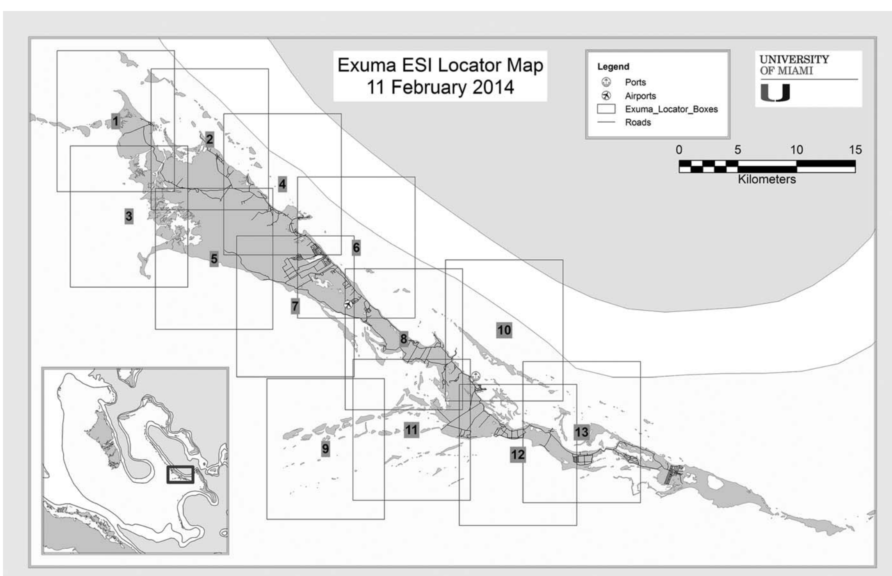


Figure 2. Map of Great Exuma illustrating the location of the 13 ESI maps to cover the entire island. About 10% overlap is put into the ESI maps to allow clear coverage of areas that fall near the map boundaries. ESI Map 10 for George Town is highlighted as the example map; this ESI map is found in detail in Supplementary Appendix A.

Table 1. *Coastal classification for ranking the shorelines on Great Exuma. Shorelines are represented by color-coded polygons to represent areas of increasing vulnerability to oiling impacts. The lower ranks are less impacted; the highest numbers ("10") represent mangroves and coastal wetlands most severely impacted by oil spill events.*

Ranking Number	Category	Coast Classifications	Modifiers, Examples
1A	Exposed, impermeable, high relief	Rocky headland; high relief rocky shore	Exposed to prevailing winds and frontal systems
1B	Exposed, impermeable, man-made, high relief	Exposed, solid, vertical, man-made structures	Sea walls, harbours, piers, pilings, bulkheads
2A	Exposed, rocky, natural, impermeable, low relief	Rocky headland; low relief rocky shore	Exposed to prevailing winds and frontal systems
3A	Semi-permeable fine sand to mud	Linear beach; pocket or curved beach; beach with exposed beach rock	Protected, usually within embayment or bay
4A	Medium permeability, sandy beach; oolite banks	Oolitic bank; linear beach; pocket or curved beach; beach with exposed beach rock; man-made dredge spoils or berms	Exposed at low tides; exposed to prevailing winds and frontal systems
5A	Medium to high permeability	Gravel beach with exposed beach	Exposed to prevailing winds and frontal systems
5B	Medium to high permeability, low relief	Gravel, pocket, or curved beach	Exposed to prevailing winds and frontal systems
6C	Riprap	Human-placed boulders and riprap	All coastal types, usually highly altered
10A	Vegetated emergent wetlands	Salt meadows; coastal, herbaceous wetlands	Mixed scrubland
10D	Vegetated emergent wetlands–mangroves	Scrub-shrub wetland; forested wetland	Mangrove scrubland; mangrove shrub thicket; mangrove forest

geomorphology of the area (from Rankey, Riegl, and Steffen, 2006), and topographic information, boundaries were determined for different shoreline types in the mapped areas. The coastal classification for the ESI mapping is presented in Table 1. Collected information was compiled in an EndNote bibliographic dataset, linked to specific GIS data layers, and linked with relational database data files that included photos and other wildlife habitat information. This information was translated into GIS layers by the creation of layers that included the benthic marine habitats (Table 2) and the location of critical wildlife, as indicated by standard symbols (Table 3). Wildlife occurrences are defined by international convention as outlined in Table 4; wildlife occurrences were compiled through literature reviews, online databases (*e.g.,* eBird, 2014), and field reports (Birdlife International, 2010).

Geological maps of Great Exuma were used to complete the coastal ranking according to oil spill vulnerability. Geologic attributes of the classified areas, such as shape of the shoreline (*e.g.,* pocket beaches and high relief cliffs) and makeup of the shoreline substrate (*i.e*. sandy *vs*. rocky shoreline), were used in the determination of priority response areas. Mangrove shorelines were identified as the most vulnerable coastal environments to oil spills (Hoff *et al*., 2010). Field logs from field work on Great Exuma, which catalogued vegetation structure, shoreline profile, and wildlife information, were used to create a database that contained relevant information for coastal classification. Included with the information are ground-level photographs that depict the shoreline profile. A template was developed for the ESI maps that included a standard 1:43,000 scale and legend elements. A locator map was developed first with an approximate 10% overlap between maps. The creation process of the locator map included the determination of the areas that would be covered by each ESI map. Gathered information was transcribed into GIS layers that represented the shoreline classification, benthic information, and wildlife occurrences of the entire mapped area. In

Table 2. *Marine benthic habitats mapped for near-shore environments of Great Exuma. The habitat categories are consistent with those used by other marine conservation initiatives in The Bahamas (The Nature Conservancy and the Marine Spatial Ecology Laboratory, University of Exeter, UK). These general categories of habitats were used as proxies for the location of key wildlife such as corals and fishes. Benthic community classifications followed guidelines provided in the* USA Classification of Marine and Estuarine Communities *(Coastal and Marine Ecological Classification Standard, 2014).*

Benthic Habitat Classification	Description
Coral reefs: patch reefs	Near-shore patch reefs are small but abundant in Elizabeth Harbour, occurring at 1 m to 6 m depths. Near-shore patch reefs tend to be adjacent to seagrass beds, averaging 20 m to 30 m in diam and roughly circular in shape, but may be quite variable in size.
Coral reefs: near-shore fringing reefs	Fringing reefs are a reef complex that modify the effects of waves, reducing their energy and providing relatively quiet water conditions in the lee of the reefs where lagoon and shore communities can develop. Fringing reefs are represented by ridges parallel to shore and with spur-and-groove development on the seaward side.
Low relief reefs and hard bottom	Low relief hard bottom is the dominant, shallow water (<20 m) reefal community type. The substratum consists of exposed, lithified sand-rock and is not of reefal origin, is dominated by algae, and is also referred to as "hard-bar" or windward hard bottom (Sluka *et al*., 1996). Variations in relief are principally attributable to the presence of isolated coral heads (<0.5 m). This is the primary fisheries habitat.
Sandy bottom	Unconsolidated bottom consisting of sands and muds, usually with low organic content, and can be dominated by calcareous green algal genera such as *Halimeda*, *Avrainvillea*, and *Udotea*.
Sparse seagrass	Submerged aquatic vegetation in the form of seagrasses, canopy coverage less than 30% of areal area, or small isolated patches of seagrass.
Dense seagrass	Submerged aquatic vegetation in the form of seagrasses, canopy coverage greater than 30% of areal area; usually dominated by turtle grass, *Thalassia testudinum*.

Table 3. *Subset of standard ESI symbols used for mapping of Great Exuma. These symbols can also be annotated with the specific species that occurs in a given area.*

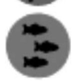
Category/Subcategory	Symbol	Locations Shown on Maps
Dolphin		Concentration areas based on Bahamas Marine Mammal Survey information.
Whale		Migratory or other concentration areas based on Bahamas Marine Mammal Survey information.
Gull/Tern		Nesting sites; other concentration areas. Based on reports of all seabird colonies and nesting sites from Bahamas National Trust.
Raptor		Nesting sites; migratory/feeding concentration areas. Mostly for Osprey.
Shorebird		Nesting sites; migratory, wintering, and roosting concentration areas. Based on Bahamas National Trust seasonal reports of sightings.
Wading bird		Rookeries; feeding and roosting concentration areas. Poorly documented, reported anecdotally.
Other reptiles/amphibians		Locations of threatened, endangered, or rare Bahamian Iguana based on reports and records from The Bahamas National Trust.
Turtle		Nesting beaches; concentration of juveniles. Limited nesting records mean that all beaches in The Bahamas can be nesting beaches.
Estuarine nursery fish		Spawning, nursery, and other concentration areas. Known areas for juvenile groupers, bonefish, or small-tooth sawfish.
Estuarine, marine, or pelagic fish		Spawning or other concentration areas; locations of threatened, endangered, or rare species. Especially important for bonefish, permit and tarpon in mangrove creeks, and lagoons.
Conch		Harvest areas; high concentrations, locations of threatened, endangered, or rare species.

Table 4. *Biological resources, notable wildlife, and general guidelines for ESI mapping of Great Exuma, Bahamas based on international conventions (see* National Oceanic and Atmospheric Administration, NOAA Technical Memorandum NOS ORCA 115, Environmental Sensitivity Index Guidelines, Version 2.0, October 1997*).*

Data Element	Sub-Element	Areas/Sites to Be Mapped	Description
Marine mammals	Dolphins; whales	Migratory or other concentration areas	Restricted to water. No restrictions to offshore or inshore extent; both resident and migratory
Birds	Pelagic birds; raptors; shorebirds; wading birds	Rookeries, roosting, nesting sites; migratory, feeding, and wintering concentrations	Pelagic birds occur in offshore waters and on islands or cliffs; raptors can be mapped along coastal shorelines, in wetlands, and across sheltered waters and islands; shorebirds and wading birds are typically restricted to 75 m on either side of the shoreline along open coasts.
Reptiles and amphibians	Turtles; rock iguanas	Nesting beaches; concentration areas, also juvenile turtle habitats and concentrations	Sea turtle nesting areas generally occur along sand beaches. Important foraging or nursery areas can be shown where specifically indicated by resource experts.
Fish	Estuarine nursery fish; marine benthic fish	Spawning, nursery, and other known concentration areas (*e.g.,* reefs or other critical habitats)	General distributions are usually defined by habitat type or salinity zone. Includes groupers, snappers, grunts, and some information on sharks.
Invertebrates	Gastropods (conch, top shells); lobsters	Nursery spawning and harvest areas; high concentrations, threatened, endangered, or rare occurrences	General distributions are usually defined by bathymetric contours or marine/intertidal habitat. There may also be special concentration areas defined by fishing concentrations.
Marine habitats (details in Table 2)	Algae; coral reefs; hard-bottom reefs	Algal beds of flats, important species; Living, reef-building coral areas; hard substrates that provide habitats	Generally restricted to shallow water of the banks and mapped from satellite images, aerial photographs, and field surveys.

Table 5. *Summary of time and effort required to assemble all 13 ESI maps and coastal characterization database for the entire island of Great Exuma. Great Exuma covers approximately 290 km of shoreline (160 square km island). The entire island (not the entire Exuma archipelago) would include coastlines on Great Exuma and Stocking Island, including the resources in Elizabeth Harbour*.

Task	Expertise, Resources Needed	Time Required (Person Days)
Development of base map layers for Great Exuma: wetlands and shorelines	Expertise: GIS; coastal ecology and geomorphology; local natural history resources: GIS; satellite and aerial images; topographical information	6
Collection and compilation of wildlife occurrences, species of concern; critical wildlife habitat GIS layers	Expertise: GIS; coastal ecology; local natural history and resource management resources: GIS; publications by wildlife experts; field reports	5
Classification and ranking of the coastal environment	Expertise: coastal ecology and geomorphology; local natural history resources: satellite and aerial images; field reports	9
Database creation and data input	Expertise: relational database; GIS resources: GIS: field reports	3
Construction of ESI map sets	Expertise: GIS resources: GIS workstation	12
Review and quality control of map products	Expertise: coastal ecology and geomorphology; Local resource management and natural history.	3
Complete ESI mapping of Great Exuma	All expertise listed above	40 days = 8 weeks

most occasions, the coastal classification information was hand drawn on a satellite photograph. The photograph was then scanned and geo-referenced in the GIS program, which provided an easy method of transcription of information from the hand-drawn map to the GIS ESI map layer. Later, details such as wildlife occurrence points or indications of other important features such as marinas were added to the map. Once the data layers for all of the mapped area were completed, the map template was used to create the individual ESI maps, which are outlined by the locator map.

Three approaches were taken to quality control the final ESI maps. First, the linked relational database was reviewed by two or more experts to examine the photos and to confirm the coastal classification as well as shoreline characteristics. Second, the final ESI map product was circulated to stakeholders, local managers, and government agencies. The location of wildlife or critical habitats could then be reviewed by people with current local knowledge. Last, the final Great Exuma ESI atlas was sent to ornithological experts for review of critical bird habitats and locations.

RESULTS

The final ESI mapping product for the George Town environs is reviewed in detail in Figure 3 (entire map in Supplementary Appendix A). This map illustrates the standard template for ESI maps, including a 1-km grid over the map, a legend indicating the coastal vulnerability ranking, and benthic habitats. The back of the map includes a specific species list for Great Exuma of birds, marine mammals, and marine reptiles (sea turtles). Hard copies of the ESI atlases can be produced easily from the pdf files as needed for oil spill response planning; however, the linked relational database (Figure 4) and GIS format is ideal for future ESI map accessibility on a tablet device.

The entire project required about 40 work days (Table 5) to complete all 13 maps for the entire island, with associated ground points referenced in the relational database. Once the database was set up, the elements could be updated and improved with more information. Elements of the database could be separated and used for other coastal management projects, such the coastal wetland GIS layers. This time is exclusive of the literature reviews and research on occurrences and status of wildlife, as well as background information on coastal geomorphology used in coastal classification (Supplementary Appendix B).

DISCUSSION

The GoB has the ultimate responsibility to establish the ESI guidelines; however, private corporations, nongovernmental organizations, and stakeholders' groups can take on the expense of compiling ESI data and creating the maps by established guidelines. The consequences of a large oil spill are severe and long term for small island countries (Keller, 2005; Zieman *et al*., 1984); therefore, a great deal of attention has been placed on public outreach and educational material concerning types of oils spills, impacts of oil spills on marine resources, as well as what the oil spill response process involves. The Bahamas has the benefit of using these guidelines to modify the standards to meet the needs of a large, ecologically fragile archipelago.

The GoB experienced the first real need for ESI maps during the 2010 Deep Water Horizon Oil Spill. The Incident Commander, Captain Stephen Russell of the National Emergency Management Agency, and the Deputy Incident Commander, Commander Patrick McNeil of the Port Department, requested the assistance of experts from The Bahamas National Trust, The Nature Conservancy, and the University of Miami to assist in the preimpact assessment of the islands in the Western Bahamas (NODC, 2012; Tiercelin and Ramos, 2010). The risk of an oil spill was exacerbated by the lack of ESI maps, and make-shift maps were improvised in Google Earth. This single incident highlighted both the necessity and cost of ESI maps for remote islands that were most at risk for oil spills from events outside of The Bahamas. Since 2010, the proposed exploratory drilling by Bahamas Petroleum Company has motivated and funded the development of an ESI mapping method and framework.[2] This methodology has been developed with input and review by both the non-government and government agencies responsible for marine resource protection and spatial data standards (Bahamas National Geographic Information Systems, BNGIS).

ESI maps have proven to have a long-term use, and the spatial datasets are excellent tools for studying shoreline change and its effects on the distribution and concentration of

[2] See Oilbarrel (2014) for an overview.

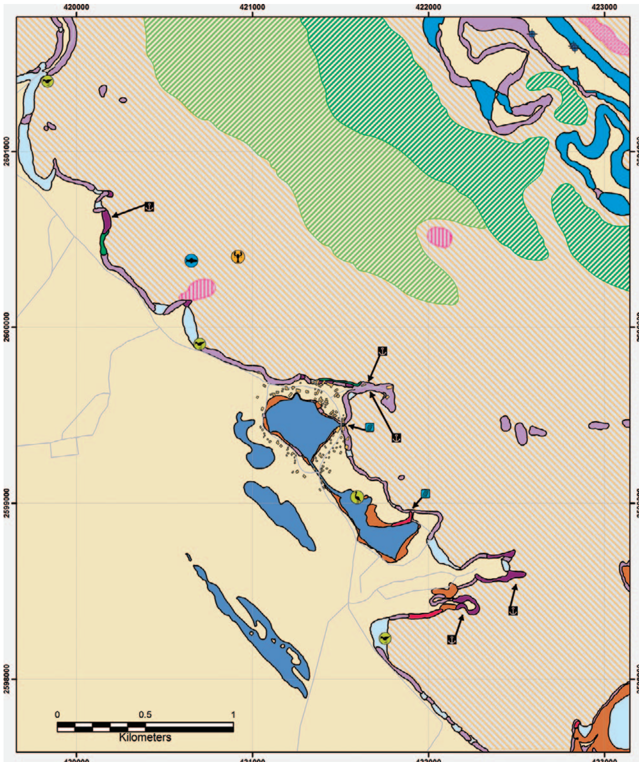


Figure 3. Detail of ESI Exuma Map 10 illustrating the coastal ranking for the George Town and Stocking Island environs. The coastal classifications are shown as narrow polygons following the shoreline. Wildlife occurrences are indicated, along with the location of marina and inlets. Additional information on occurrence of rare or endangered wildlife, and changes to the coastline or new infrastructure such as marinas can easily be added and tracked.

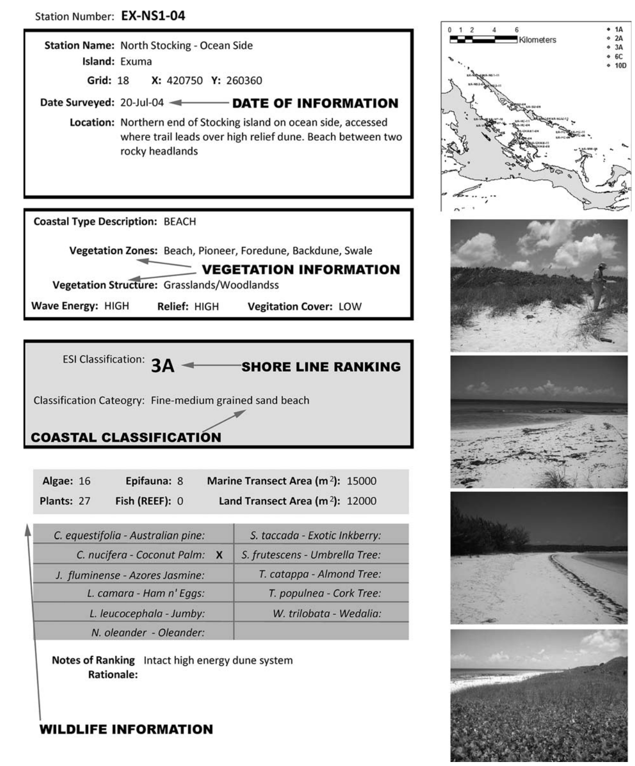


Figure 4. Microsoft Access table illustrating coastal classification and ranking information from one site on Stocking Island (ES-NS1-04) used to develop ESI maps. The coastal database that supplements the ESI mapping is supported in the relational database with hyperlinked site photos.

plants and animals living near the coast. Environmental sensitivity mapping could be a key management tool for natural resources not only for The GoB but also The Bahamas National Trust, which has responsibility for protected area design, implementation, and management. Both government and nongovernment groups have an interest in how ESI maps evolve in The Bahamas. One key challenge for starting the discussion of ESI mapping in The Bahamas is the lack of a biogeographic and ecological classification for the country. There are no national standards applied to terminology and classification of natural communities, critical species habitats, or biodiversity inventory.

The goal of ESI mapping is to integrate maps of a region with geographically referenced biological resources, human-use resources, and ESI-classified shorelines that are ranked based on their sensitivity to oiling. This can only be accomplished by an interagency team of professionals that not only understand GIS, but also have first-hand knowledge of the biological and human-use resources. Thus, the responsibility for ESI mapping is often multiagency, with one lead person or management committee. The ESI maps can be provided to the National Emergency Management Agency to serve as a quick reference for oil spill responders and coastal zone managers. A single map or an entire atlas of maps may be needed, depending on the size of the oil spill.

The ESI spatial dataset development and maintenance is a technical task that can be organized and run by resource management professionals. Because of the broad utility in ESI spatial datasets beyond just oil spill response planning, a team approach should be used to leverage resources and funding through private–public partnerships. A professional team will be able to identify less obvious sources of information, including local knowledge, on-line media, and archives. A significant problem with large ESI and coastal assessment datasets is keeping information current. An outdated ESI map poses potential problems because the information on the map can suggest emergency responses that are no longer appropriate. Communities and citizen scientists can contribute timely and critical information on the state of the coast (Hildebrand, 1997; Kawabe, 2004; Treby and Clarke, 2004). Preimpact assessments can be carried out as part of the requirements for research permits, or they can be completed by volunteers carrying out field expeditions and surveys. The information compiled in preimpact assessments is easily stored and retrieved in the relational database. At a minimum, the digital map should be revisited each year for populated islands because coastal alterations are occurring rapidly. If an ESI mapping team is working continuously, the ESI mapping process can be updated more frequently and can engage local communities to monitor the status of their local coasts.

CONCLUSIONS

Although ESI mapping represents a significant investment of time and resources, the ESI spatial database products can be used to update the status of endangered species, contribute information to Environmental Impact Assessments, and identify areas at risk of storm damage or flooding. The question is whether The GoB is comfortable with the risk of not having an ESI mapping program. With increased coastal alterations throughout The Bahamas, the GoB will be compelled to increase the regulatory environment for key industries such as ports and marinas, energy production, and resort developments. The lack of an appropriate ESI data map can expose the government as well as other stakeholders to potential legal or financial risks if information cannot be identified, located, or retrieved to meet mandatory legal or regulatory deadlines.

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