A NATURAL RESOURCE ASSESSMENT OF THE U.S. VIRGIN ISLANDS NATIONAL PARK AND VIRGIN ISLANDS CORAL REEF NATIONAL MONUMENT

by:

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ABSTRACT

The National Parks Conservation Association's (NPCA) State of the Parks Program was developed to identify natural and cultural resources in jeopardy across the United States National Parks System. This natural resources assessment has been prepared on behalf of NPCA and in accordance with the guidelines outlined in NPCA's *Natural Resources Assessment and Ratings Methodology* (NPCA 2006). It is intended to provide an ecosystem-level evaluation of the health of natural resources at Virgin Islands National Park and Virgin Islands Coral Reef National Monument. These protected areas are unique units within the National Parks System because of the diversity and complexity of habitats and organisms they contain, but outside pressures are threatening the integrity of some of the most critical systems within both the park and monument. Existing data from the National Park Service, other federal and territorial agencies, academic research studies, and peer-reviewed journals were used in conjunction with interviews of park staff and site visits to evaluate the health of the natural resources. The results of the assessment indicate that park and monument resources are vulnerable due to a combination of natural and anthropogenic stressors, including hurricanes, development, grazing of non-native animals, and visitor damage to sensitive systems such as coral reefs. Park staff have implemented numerous management initiatives to protect resources and mitigate threats to sensitive resources; however, the park and monument do not have sufficient funding or staff to enforce existing rules or to implement new programs that could help improve the state of vulnerable resources. This assessment concludes with management recommendations that would allow park managers to improve conditions and help ensure that the park's resources are present and healthy for future generations.

NATIONAL PARKS CONSERVATION ASSOCIATION
State of the Parks

Virgin Islands National Park & Virgin Islands Coral Reef National Monument

Final Report

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List of Acronyms

BRD	Biological Resources Division
CASTnet	Clean Air Status and Trends Network
DEP	Department of Environmental Protection
DFW	Division of Fish and Wildlife
EIS	Environmental Impact Statement
ESA	Endangered Species Act
EPA	Environmental Protection Agency
IMPROVE	Interagency Monitoring of Protected Visual Environments
I&M	Inventory and Monitoring Program
MAB	Man and the Biosphere
NAAQS	National Ambient Air Quality Standards
NADP/NTN	National Atmospheric Deposition/National Trends Network
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
NPCA	National Parks Conservation Association
SFCN	South Florida/Caribbean Vital Signs Network
STORET	Storage and Retrieval
UNESCO	United Nations Educational, Scientific, and Cultural Organization
USDOT	U.S. Department of Transportation
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey

List of Acronyms

USVI	U.S. Virgin Islands
VIERS	Virgin Islands Environmental Resources Station
VIRMC	Virgin Islands Resource Management Cooperative
WRD	Water Resources Division
WWF	World Wildlife Fund
ypb	years before present

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Cover photo by Kelly O'Rourke

I. INTRODUCTION

This report provides an ecosystem-based assessment of the natural resources at Virgin Islands National Park and Virgin Islands Coral Reef National Monument. It was prepared on behalf of the National Parks Conservation Association (NPCA), Center for State of the Parks, by Kimberly Collini and Kelly O'Rourke of Duke University's Nicholas School of the Environment and Earth Sciences, in accordance with the guidelines outlined in NPCA's *Natural Resources Assessment and Ratings Methodology* (NPCA 2006).

NPCA is a non-profit that advocates on behalf of U.S. national parks. In this context, 'parks' refer to any management unit that is under the jurisdiction of the National Park Service (NPS). This can include monuments, historic sites, battlefields, and national seashores, in addition to more traditional parks. In 2000, NPCA initiated the State of the Parks program, whose primary objectives are to identify features and systems in jeopardy across the National Parks System; create and enhance public and political understanding of park threats; track changes in flora, fauna, and cultural features over time; and solicit resources and support to remedy identified areas of degradation (NPCA 2006b).

The primary way that the Center achieves these objectives is through the publication of its State of the Parks assessment series. Initially, researchers are sent to a park to develop a comprehensive technical report document and calculate an overall park rating by using an existing assessment methodology. This information gets distilled into a publication that summarizes the status of the park's natural and cultural resources. It is then distributed to the park, local non-profits, the local community, and Congress in an attempt to leverage funding for critical needs identified during the assessment.

To date, NPCA has prepared 28 of these reports and another 30 are currently underway. The goal is to complete an assessment for each of the 390 units in the Park Service system. This is a very time and resource intensive objective, so NPCA has been trying to strategically choose parks that represent the range of park types, sizes, and locations within the NPS system so they can make some broad generalizations about how the park system as a whole is doing.

NPCA developed its own assessment methodology for its State of the Parks Program, which they based on The Nature Conservancy's (TNC) 5S model. They chose to adapt TNC's model because it represents an ecosystem-level approach that incorporates the impact of natural and anthropogenic threats to resources, as well as ongoing management strategies (NPCA 2006). From the basic 5S framework, NPCA developed guidelines for data collection and the actual rating of ecosystem elements.

In the initial research phase, background information such as park size, location, ecoregion classification, land use history, adjacent land uses, and information on existing monitoring and management structures is collected. The second part of the research involves collecting data on assessment criteria such as environmental and biotic measures of water, air and soil, which are designed to rate the overall health of park resources.

These assessment criteria are broken down into more than 120 discrete ratings elements, which are displayed in the final ratings worksheets in Appendix A. Each of these elements is rated on a 0-3 scale. A 0 indicates that a resource is severely or completely degraded with little or no hope of recovery. A 0 has yet to be given during any of NPCA's assessments. On the other end of the scale, a 3 indicates that a resource is pristine or of very high quality, with no known threats that could cause a future impact. Ratings of 1 and 2 represent an intermediate level of threat. An element would generally be rated a 2 if there is some degradation or threat, but the park can and is appropriately managing the threat. An element would receive a score of 1 if there is serious degradation or threat, and the park either can't or isn't appropriately managing the situation. All of the elements ratings are then rolled up into an overall natural resource score for the park. This overall park rating can indicate natural resources in need of attention, as well as being used for comparative purposes among all parks. The final ratings for this park can be seen in Appendix A, and are based on the findings discussed in Section III (Assessment Criteria).

The purpose of this technical report, in particular, is to describe existing natural resources and synthesize available information on the health of those resources at Virgin Islands National Park and Virgin Islands Coral Reef National Monument. Though Virgin Islands National Park and Virgin Islands Coral Reef National Monument are two separate units within the National Parks System, they have been described and evaluated together in this report because the units are geographically adjacent, share many of the same threats, and are managed by the same staff. No new data were collected to complete this assessment. In accordance with NPCA State of the Parks guidelines, existing information and data pertaining to the ecosystem elements outlined in the NPCA rating methodology were collected and analyzed. The primary sources of information used include: park management documents; NPS inventories; academic research studies; federal and territorial regulatory agency reports; and personal communications with park staff.

While a relatively large body of information is available on resources within Virgin Islands National Park, there were specific elements in the NPCA ratings framework that could not be evaluated because the necessary data do not exist. Information on the Virgin Islands Coral Reef National Monument was particularly lacking. In addition, some of the existing data on park resources were out of date or not applicable to this particular assessment framework (i.e., studies that were too species, time, or spatially specific to lead to overall conclusions about ecosystem conditions) and therefore could not be relied upon when making determinations regarding overall resource health. Throughout the report, areas that could not be properly evaluated because of a lack of data have been noted.

For consistency and comparability among parks, this report follows the outline specified in the NPCA *Natural Resources Assessment and Ratings Methodology* (NPCA 2006). Section II introduces Virgin Islands National Park and Coral Reef National Monument and their respective resources. It provides an overview of the biogeographic and physical setting, regional and historic context, unique resources and designations, and existing science and resource management programs. Section III addresses the health of park resources based on the NPCA natural resources assessment framework, and follows the outline of the ratings elements seen in Appendix A. Finally, Section IV provides conclusions and recommendations regarding management of the park's natural resources.

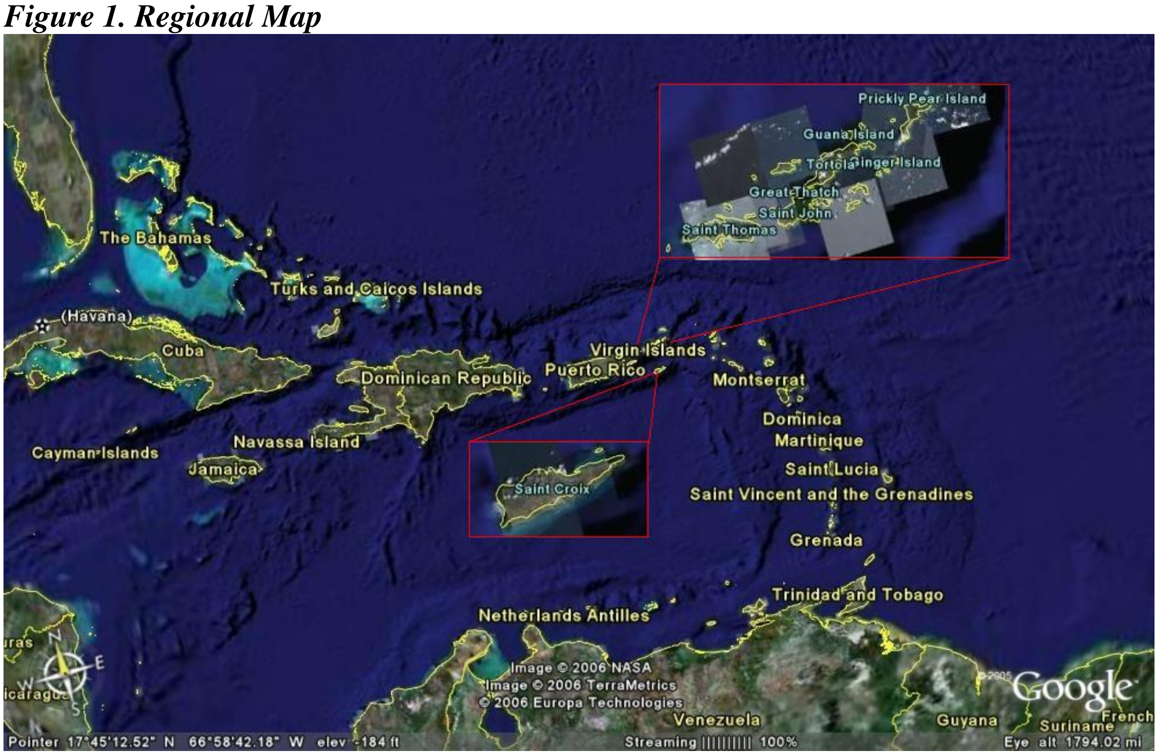
II. PARK RESOURCES AND CONTEXT

A. Biogeographic and Physical Setting

i. Park Location and Size

Virgin Islands National Park is located on the island of St. John, the smallest and least developed of the three inhabited U.S. Virgin Islands (Figure 1). St. Thomas and St. Croix, the other two inhabited U.S. Virgin Islands, are located approximately 4 miles west and 40 miles south of St. John, respectively (Boulon 1999). Together, the U.S. and British Virgin Islands constitute the eastern extent of the Greater Antilles, part of the Antilles Island Arc that separates the Caribbean Sea from the Atlantic Ocean (Rankin 2002; Gyory et al. 2005). St. John is approximately 70 miles east of Puerto Rico (Boulon 1999).

Figure 1. Regional Map



Source: Google Earth 2006 (created by K. Collini)

The park was established by Congress on December 1, 1956 (Boulon 1999). The enabling legislation formally established Virgin Islands National Park as a new NPS unit, defined the boundary, and described, as follows, the justification for a park designation:

> A portion of the Virgin Islands of the United States, containing outstanding scenic and other features of national significance, shall be established…and preserved by the Secretary of the Interior in its natural condition for the public benefit and inspiration…(70 Stat. 940).

The initial legislation included only terrestrial lands, but in 1962, Congress passed an amendment to include submerged lands containing "significant coral gardens, marine life and seascapes" (76 Stat. 746). The protection afforded by the amendment was not intended to limit customary uses of or access to offshore areas,

> ...for bathing and fishing (including setting out fishpots and landing of boats), subject to such regulations as the Secretary of the Interior may find reasonable and necessary for protection of natural conditions and prevention of damage to marine life and formations (76 Stat. 746).

A second amendment passed in 1978 added Hassel Island, located in St. Thomas' Charlotte Amalie Harbor, and adjacent submerged lands out to 91 meters (Boulon 1999). NPS owns and maintains nearly all of Hassel Island, but a small portion is owned by the territorial government of the U.S. Virgin Islands and private interests.

The enabling legislation and subsequent amendments protected 7,259 acres of terrestrial and shoreline habitat, along with 5,650 acres of adjacent submerged lands as Virgin Islands National Park (Figure 2) (Boulon 1999). Although the majority of the park's sites and facilities are located on St. John, the unit also includes just over 10 acres of land used for housing and administration on St. Thomas, as well as the NPS-owned terrestrial and submerged lands of Hassel Island (Boulon 1999).

Nearly 57 percent of the land area of St. John is owned and operated by the NPS (Boulon 1999). The island is approximately 9 miles long and 5 miles wide. The park includes most of the north shore of the island, as well as most of the central and southeast (south of Coral Bay) portions of the island. As seen in Figure 2, the submerged park lands extend outward from the terrestrial park lands at varying distances around the island. The town of Cruz Bay, located on the western tip of St. John, is the most developed portion of the island and is not within park boundaries. The town of Coral Bay and the East End, both on the eastern portion of the island, are also not within park boundaries.

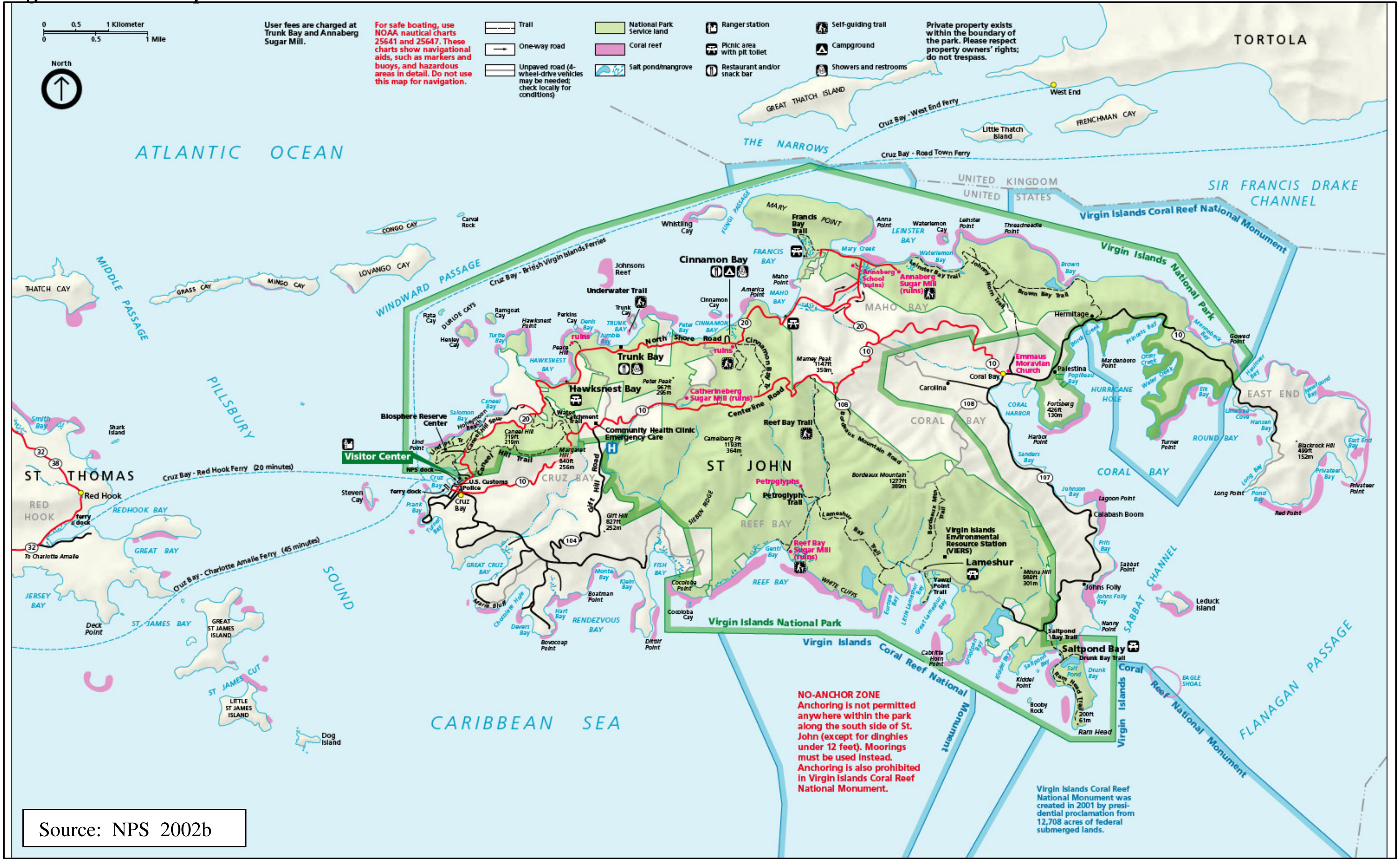
When the park was established in 1956 as a result of a land donation from Lawrence Rockefeller and the Jackson Hole Preserve Corporation to the federal government, the delineated boundary included 9,485 acres of land (Boulon 1999). However, more than 2,000 of those acres were owned by private interests and the Virgin Islands government. The NPS was not given eminent domain authority on St. John, and therefore must purchase or trade to acquire these private lands, known as "inholdings," that are scattered throughout the park. There are numerous large parcels or clusters of parcels throughout the park, and the trend has been to subdivide the parcels for development (NPS 2002).

In 2001, Virgin Island Coral Reef National Monument was established by presidential proclamation to protect an additional 12,708 acres of submerged lands around St. John (Figure 2). This designation includes two distinct areas south of the island, one just south of Reef Bay and Great Lameshur Bay out to the 3-mile territorial sea boundary and the other to the south and southeast of Ram Head Point out to the 3-mile territorial sea boundary. A third area included in the monument is located just north of Mary Point out to the boundary between U.S. and British waters. The fourth area of the monument is found north of Brown and Mennebeck Bays out to the boundary between U.S. and British waters. This area also includes a portion of Coral Bay and the mangrove forests found in Hurricane Hole on the eastern part of the island.

ii. Climate Regime

The dry tropical climate of Virgin Islands National Park is temperate year-round, with mild, dry winters and warm, humid summers. Rain generally falls in short showers lasting only a few minutes, though storms can be severe. High evapotranspiration rates, continuous trade winds, long hours of sunshine, and high ambient temperatures result in dry conditions across the island. Month-to-month precipitation averages vary considerably across years. Long-term records for Cruz Bay show that annual rainfalls of less than 35 inches occur nearly 30 percent of the time and greater than 59 inches, about 10 percent of the time (Boulon 1999). The southeastern end of the island receives the smallest amount of precipitation, approximately 35 to 40 inches per year, while Bordeaux Mountain and Maho and Cinnamon Bays receive the most, about 50 to 55 inches per

Figure 2. Park Map



Source: NPS 2002b

year (Boulon 1999). February and March are historically the driest months, and September and October are the wettest. Hurricane season extends from June through November. At least 12 major hurricanes and tropical storms have passed over or near St. John since the mid-20th century (USVI DFW 2005b). Hurricanes in the Caribbean generally pass from the southeast to the northwest, bringing heavy winds and rain that can damage both human and natural features (USVI DFW 2005b). The island also experienced seven moderate or severe droughts during the 1900s (Weaver unpublished).

iii. Geology and Land Forms

St John is located near the northeastern corner of the Caribbean plate (Rankin 2002). The oldest rocks on the island are extrusive keratophyres (fine-grained igneous rocks), basalt, and minor cherts of the Water Island Formation, which formed from volcanic flows on the ocean floor during the Early Cretaceous period (~100 million years ago). These volcanic rocks were eventually uplifted by regional tectonic stresses. Shallow water and subaerial volcanism during the Late Cretaceous age resulted in St. John's second period of rock development (Louisenhoj Formation). A limestone formation was deposited after the second volcanic period, but these rocks have limited exposure on the island.

At the end of the last glaciation, about 18,000 years before present (ypb), sea level began to rise (Goenaga and Boulon 1992). As a result, between about 8,000-9,000 ybp, Caribbean shelves flooded and reef construction began on the topographic high points of Pleistocene erosional surfaces. The oldest reefs around St. John (about 8,000-9,000 years old) occur along insular shelf edges (Goenaga and Boulon 1992). Reefs further inshore are younger, approximately 4,000-5,000 years old (Goenaga and Boulon 1992).

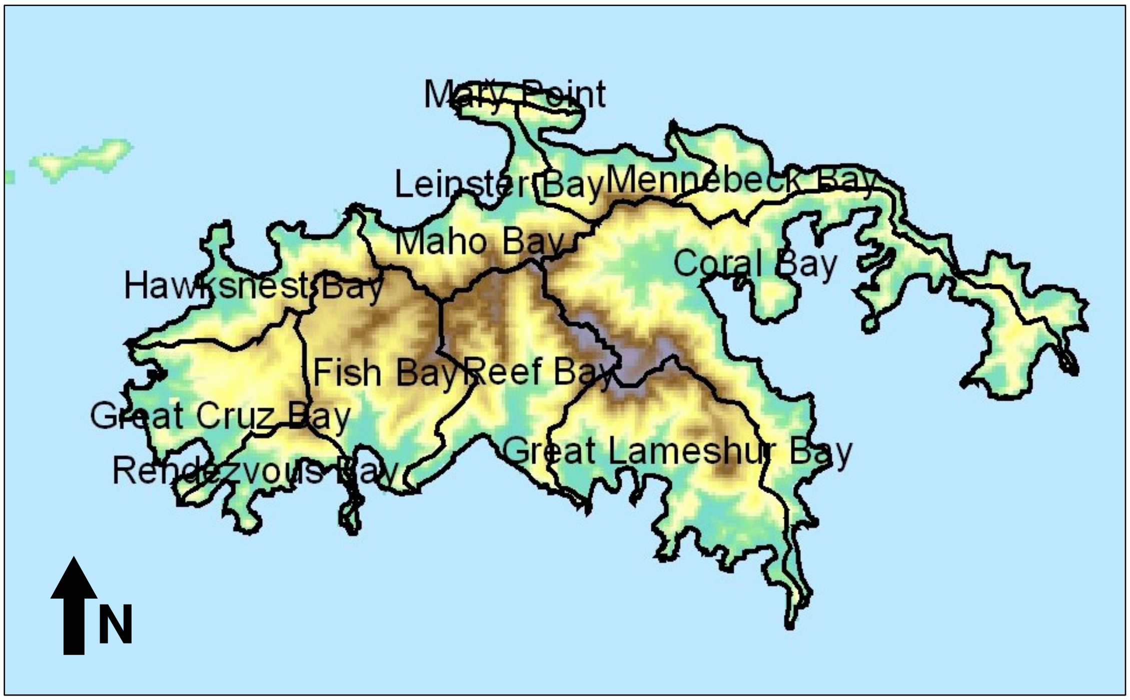
St. John is a mountainous island with very little flat land. Slopes exceeding 30 percent occur on over 80 percent of the land surface (Boulon 1999). A central ridge runs east to west along the length of St. John. At 1,270 feet, Bordeaux Mountain is the highest point on the island and within the park. Much of the shoreline is steep, with protruding rocky headlands and deep indentations containing bays rimmed with narrow, white carbonate sand beaches. St. John’s topography is a result of the folding, faulting, and uplifting characteristic of its volcanic origins. Consequently, nearly all of the soils on the island are volcanic. Limestone soils can be found in a small area in the center of the island near Mamey Peak. Generally, soils on the island and in the park are stony, well-drained, moderately permeable, moderately fertile, and dry. These types of soils can only hold a small amount of water. The depth of topsoil to bedrock varies but is usually less than 20 inches (Boulon 1999).

iv. Marine Resources and Hydrology

St. John, with nearly 50 miles of shoreline, is surrounded by the Atlantic Ocean to the north and Caribbean Sea to the south. Most of the shoreline remains in its natural state, although a few areas have been armored with rip-rap or bulkheads. Mangroves are found along portions of the shorelines in Cruz Bay, Mary’s Creek, Haulover Bay, Newfound Bay, Hurricane Hole, Coral Harbor, and Fish Bay (Boulon 1999).

The island is divided into 11 distinct watersheds (Figure 3). The central ridge running east to west divides the island into a northern portion, draining into the various bays along the north shore, and a southern portion, draining into the various bays of the south shore. There are no perennial streams on the island (Loftus 2003; Boulon 1999). Evidence from relict stream beds indicates that perennial watercourses did exist at some time in the past; however, historic forest and soil loss led to a drier climate and ultimately the elimination of persistent freshwater flows (Loftus 2003; Boulon 1999).

Figure 3. Watershed Map



Source: Adapted from "Watersheds of the USVI" Map (USVI DEP 2006)

Two intermittent streams, Guinea Gut and Fish Bay/Battery Gut, run along the south shore outside of park boundaries. Several other unnamed intermittent streams and watercourses run across the island and through the park, carrying stormwater runoff and sediment to the bays surrounding the island. The combination of steep slopes, small drainage areas, shallow soils, and occasional intense storms generally results in flashy runoff (Ramos-Scharrón 2004).

Groundwater is generally brackish and of minimal quantity and poor quality. The freshwater lens is less than 50 feet below the land surface (Boulon 1999).

Five salt ponds greater than 2 acres in size can be found on St. John. The largest salt pond is found on the southeast corner of the island, just behind Saltpond Bay and within park boundaries. Salt ponds are shallow, saline ponds usually found at the base of valley drainage systems. They form as reefs grow from two rocky points of a bay, eventually meeting in the middle and forming a berm created by wave-deposited coral rubble. The berm isolates the pond from the sea and usually becomes colonized by mangroves and other salt-tolerant vegetation. Salt ponds are very effective upland sediment traps, thus maintaining water quality in adjacent marine waters (Boulon 1999).

Drinking water on the island is supplied by rainfall (cisterns), saltwater conversion, and groundwater wells (U.S. DOI 1999).

v. Ecological and Habitat Classification

Regional Classification

Virgin Islands National Park is located within the Leeward Islands moist forest and Cayman Islands xeric scrub ecoregions (WWF 2001). The Leewards Islands moist forest ecoregion is characterized by rugged, volcanic mountains with moist forests primarily containing associations of *Miconia* and *Clusia* species. This ecoregion is found in the central portion of St. John and along the northwestern shoreline. The Cayman Islands xeric scrub ecoregion, characterized by evergreen thicket, palms, and cacti, is found along the remaining coastal portions of the island. The World Wildlife Fund (WWF) classifies both of these ecoregions as critical/endangered (WWF 2001).

Terrestrial Habitat – St. John

The vegetation of the U.S. Virgin Islands, including St. John, is considered sub-tropical due to the unique conditions created by climate, soil, wind, elevation, and aspect. Classification of the plant communities on these islands is complex because of the blending across environmental gradients, leading to subtle changes in species composition and abundance (Gibney et al. 2000). Past land use activities and fluctuation in the natural environment contribute to this complexity.

Environmental change in the Virgin Islands in the recent past has been dramatic. While the islands enjoy a warm and moist climate today, cooler climates existed prior to this period, some 15,000 to 20,000 years ago. Additionally, natural processes such as earthquakes, fires, landslides, and hurricanes have been critical in shaping the island environment. As a consequence, animal and plant communities have gradually evolved toward their present composition (Gibney et al. 2000).

The arrival of European settlers resulted in significant changes to the vegetation of St. John and the other U.S. Virgin Islands. Prior to colonization, natural changes in climate and catastrophic events like hurricanes had the greatest impact. With the arrival of settlers, agricultural and land clearing activities almost completely altered the landscape (Gibney et al. 2000).

In the terrestrial communities of St. John, a range of successional stages can be found, from recently disturbed to late secondary successional forest up to 100 years old (Boulon 1999). Eleven terrestrial and shoreline vegetative community types have been mapped and described, including: mangroves, salt flats, rock pavement/coastal hedge, basin moist forest, upland moist forest, gallery moist forest, dry thicket and scrub, thorn and cactus, dry evergreen forest, pasture, and disturbed (Boulon 1999; see Figure 4). About 63 percent of the island is classified as dry evergreen forest and 17 percent is classified as combined moist forest (basin, upland, and gallery) (Boulon 1999). The combined moist forest is characterized by the following species: partridgewood (*Andira inermis*), fourleaf buchenavia (*Buchenavia tetraphylla*), maricao (*Byrsonima spicata*), kapok tree (*Ceiba pentandra*), galen del monte (*Cestrum laurifolium*), smooth manjack (*Cordia laevigata*), ironwood (*Eugenia confusa*), Christmas cherry (*Eugenia pseudopsidium)*, Mata-de-mariposa (*Gonzalagunia hirsute*), West Indian locust (*Hymenaea courbaril*), Urban's holly (*Ilex urbaniana*), Spanish oak (*Inga laurina*), bulletwood (*Manilkara bidentata*), smooth johnnyberry (*Miconia laevigata*), red rodwood (*Myrcia citrifolia*), guavaberry (*Myrciaria floribunda*), yellow-cedar (*Palicourea croceoides*), wild coffee (*Psychotria* spp.), pitch apple (*Clusia rosea*), and copey vera (*Ternstroemia peduncularis*) (Acevedo-Rodríguez et al. 1996). The dry vegetation (dry evergreen forest, dry thicket and scrub, and thorn and cactus classifications) is characterized by torchwood (*Amyris elemifera*), white bully (*Sideroxylon salicifolium*), breakbill (*Sideroxylon obovatum*), seagrape (*Coccoloba uvifera*), maidenberry (*Crossopetalum rhacoma*), marbletree (*Cassine xylocarpa*), blacktorch (*Erithalis fruticosa*), braceletwood (*Jacquinia arborea*), *Jacquinia berterii*, and nosegay tree (*Plumeria alba*) (Acevedo-Rodríguez et al. 1996). Less than 6 percent of the island is classified as developed (Gibney et al. 2000).

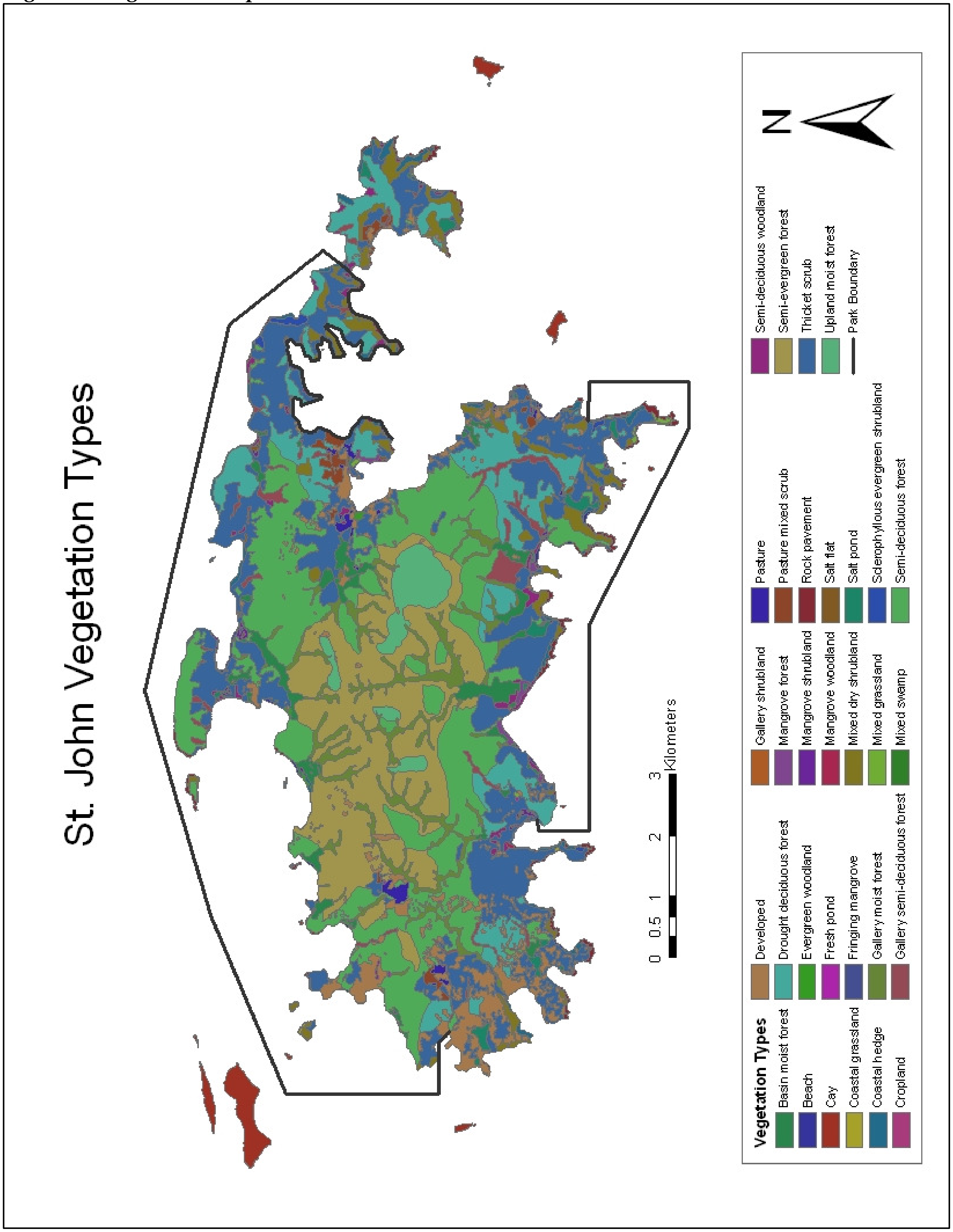
Each of the 11 terrestrial and shoreline vegetative community types is briefly described below:

- ***Mangroves:*** Mangroves are coastal, periodically flooded forests. Four species of mangroves are found on St. John: red mangrove (*Rhizophora mangle*), black mangrove (*Avicennia germinans*), white mangrove (*Laguncularia racemosa*), and buttonwood (*Conocarpus erectus*). They mostly occur along the coastal fringe, just seaward of terrestrial uplands. On St. John, mangroves occur on just over 2 percent of the shoreline (Boulon 1999). Hurricane Hole on the east end of the island may be the most pristine of the remnant mangrove habitats remaining in the U.S. Virgin Islands (over 50 percent of all mangroves in the U.S. Virgin Islands have been destroyed during the past 50 years) (Boulon 1999). Mangroves provide numerous ecological benefits including filtering sediment from upland runoff, thus maintaining water quality; producing and exporting nutrients used by other marine ecosystems; serving as nursery grounds for many species of coral reef fish; and serving as nesting or roosting sites for numerous bird species.

- ***Salt Flat:*** Salt flats are low-lying estuarine areas that are periodically submerged by tidal waters. Salt flats are muddy and non-vegetated. They serve as valuable feeding grounds for shorebirds (USVI DFW 2005).

- ***Rock Pavement/Coastal Hedge:*** Rock pavement includes coastal cliffs and rock outcrops with less than 10 percent vegetation cover. Coastal hedge communities are located on beach berms seaward of salt ponds and above rocky shorelines along eastern, southeastern, or northeastern coastal areas with exposure to prevailing winds. These communities, shaped by wind shear

Figure 4. Vegetation Map



Map created by K. Collini (2006)
Data source: Conservation Data Center, University of the Virgin Islands 2001

and salt spray, are composed of limited species within dense patch communities 1 to 3 meters in height (USVI DFW 2005).

- ***Basin Moist Forest:*** This community occurs in basins and lowland areas that collect runoff. Emergent species may reach 25 meters or more in height, with a continuous canopy at 15 to 18 meters, a mid-canopy layer at 5 to 10 meters, and a lower shrub layer. Herbs and vines are present, but epiphytes and ferns are rare (USVI DFW 2005).

- ***Upland moist forest:*** This forest type is restricted to the summits and upper north-facing slopes of tall mountains, where a continuous canopy is formed at a height of about 15 meters and a sub-canopy layer at about 5 to 10 meters. Emergent trees may exceed 25 meters in height. The abundance of shrubs, herbs, and epiphytes varies greatly, ranging from absent to very abundant, and is highest shortly after hurricane damage to the canopy (USVI DFW 2005).

- ***Gallery moist forest:*** Gallery moist forest is a riparian habitat occurring in ravines and guts that drain large upland watersheds. Those with the gentlest slopes support the tallest trees. Younger trees are more frequent and stratification is less pronounced than in upland moist forest. The abundance of shrubs, herbs, and epiphytes in the shrub layer is highly variable (USVI DFW 2005).

- ***Dry thicket and scrub:*** Thicket/scrub is a dense, thorny formation that often represents a transitional stage to taller woodland or dry forest. The vegetation is usually 3 to 4 meters high with occasional emergent trees, and is often dominated by one or two species of shrub (Gibney et al. 2000).

- ***Thorn and Cactus:*** This formation occurs on the driest parts of the island and contains a few thorny, woody species and cacti with a maximum height of 5 meters. In many areas, this formation has an open aspect (Acevedo-Rodríguez et al. 1996).
- ***Dry Evergreen Forest:*** This is a widespread formation characterized by dense growth, with a layer of trees reaching 10 meters in height, a layer of herbs and shrubs, and a few species of vines (Acevedo-Rodríguez et al. 1996).
- ***Pasture:*** Pasture is a grassland-dominated community with less than 10 percent shrub/tree cover. It is generally maintained by fire or grazing. Pastures and other types of grasslands in the U.S. Virgin Islands generally occur in areas of low rainfall and represent early stages of succession (Gibney et al. 2000).
- ***Disturbed:*** This classification includes the developed areas of St. John. Vegetation in this class primarily includes grass and ornamental plantings.

<u>Terrestrial Habitat – Hassell Island</u>

Hassel Island is a steep, rocky island located off the coast of St. Thomas in Charlotte Amalie Harbor. This 135-acre island, managed by NPS as part of Virgin Islands National Park, has a diverse variety of flora. Terrestrial communities on the island have been significantly impacted by human activity and are in various stages of recovery.

Five vegetation types have been identified on the island: fringing mangrove, basin moist forest, dry evergreen thicket, thorn and cactus, and coastal hedge/rock pavement (Boulon 1999). Habitat descriptions are similar to those provided above for St. John.

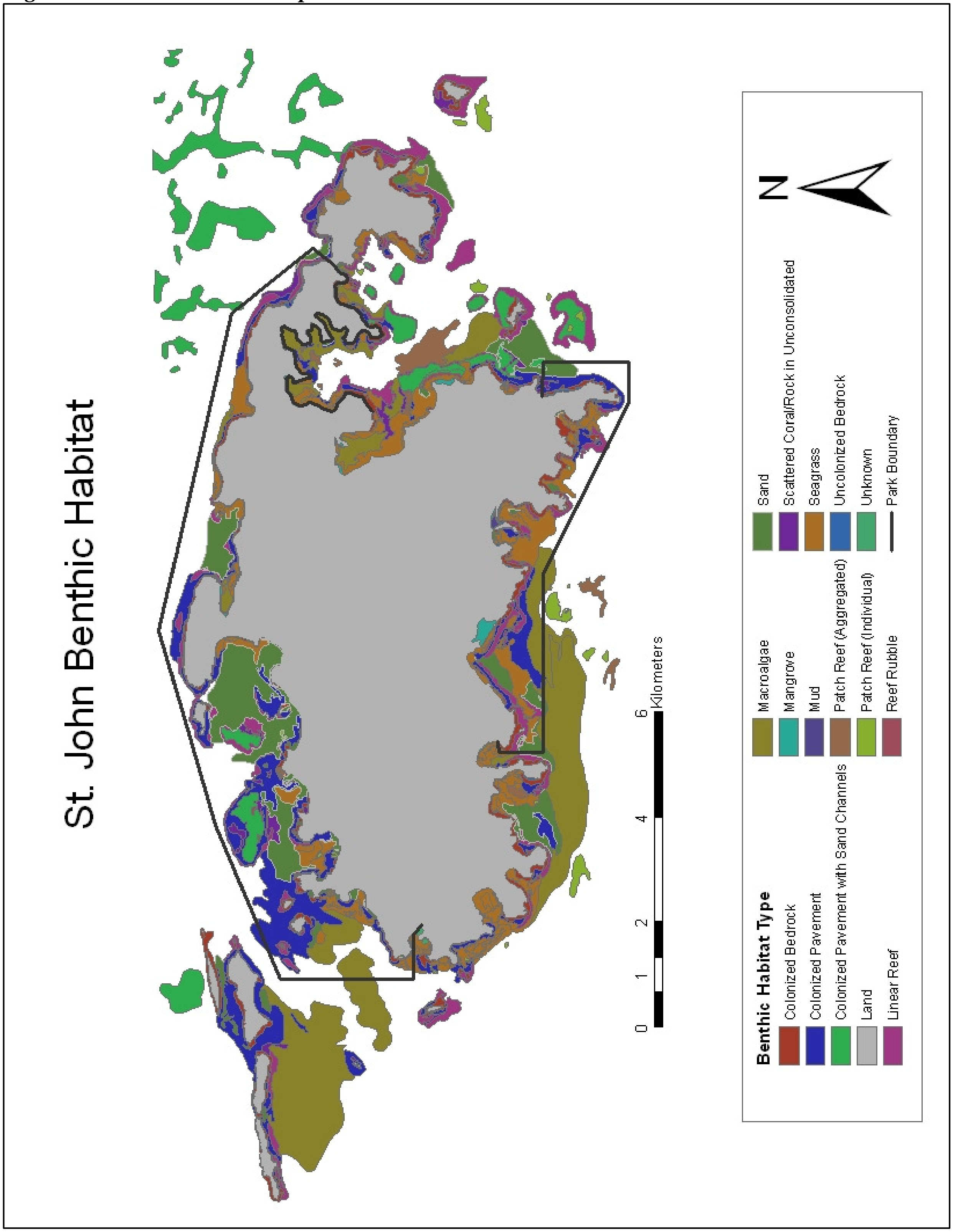
Marine Habitat Classification

St. John and other Caribbean islands located on the Puerto Rican Bank share similar confining physical and coastal characteristics, including limited coastline extension, a restricted shelf dimension, a permanent temperature gradient, oligotrophic waters, and a scarcity of upwelling zones (Devine 2000). Despite these limitations, the littoral zones around these islands are hotbeds of biodiversity and are responsible for coastal organic production. Consequently, the seagrass beds, coral reef, and hardbottom areas in and adjacent to Virgin Islands National Park and Virgin Islands Coral Reef National Monument are important marine habitat areas.

The National Oceanic and Atmospheric Administration (NOAA) recently developed and implemented a hierarchical classification scheme to define and delineate the marine habitats of the U.S. Virgin Islands using visual interpretation of orthorectified aerial photographs (Kendall et al. 2001). Figure 5 depicts the marine habitats found in the waters around St. John, and Table 1 presents the classification scheme with descriptions of habitat types. Since this classification scheme relies on visual interpretation of aerial photography, the maps and classifications below do not include the deep water areas within park and monument boundaries. The deeper submerged areas of the monument predominantly consist of deep algal plains with scattered areas of raised hardbottom (Presidential Proclamation Number 7399; 66 Federal Register 7364; January 22, 2001).

Algal plain communities are dominated by large red algae (*Laurencia, Gracilaria, Halymenia, Dasya, Chondria*, etc.) attached to shells or coral rubble (USVI DFW 2005b). The bottom area is covered by clumps of related algal species and sponges (USVI DFW 2005b). In the Virgin Islands much of the algal plain is covered with carbonate nodules formed by coralline algae called rhodoliths (*Lithothamnion* spp.) and encrusting foraminifera. This community is extremely productive under normal conditions but is sensitive to light reduction. Both the algal plains and raised hardbottom communities link the shallow water reef, seagrass, and mangrove habitats with the deep water shelf and shelf-edge communities of fish and invertebrates (USVI DFW 2005b).

Figure 5. Marine Habitat Map



Map created by K. Collini (2006)
Data source: NOAA Center for Coastal Monitoring and Assessment Biogeography 2001

Table 1. Marine Habitat Classification	
I. Unconsolidated Sediment	Unconsolidated sediment with less than 10 percent cover of submerged vegetation.
A. Sand	Coarse sediment typically found in areas exposed to currents or wave energy.
B. Mud	Fine sediment often associated with river discharge and buildup of organic material in areas sheltered from high-energy waves and currents.
II. Submerged Vegetation	Greater than 10 percent cover of submerged vegetation in unspecified substrate type (usually sand, mud, or hardbottom).
A. Seagrass	Habitat with 10 percent or more cover of *Thalassia testudinum, Syringodium filiforme, Halodule wrightii, Halophila baillonis*, or some combination thereof.
a. Continuous Seagrass	Seagrass covering 90 percent or more of the substrate. May include blowouts of less than 10 percent of the total area that are too small to be mapped independently. This includes continuous beds of any shoot density (may be a continuous sparse or dense bed).
b. Patchy Seagrass	Discontinuous seagrass with breaks in coverage that are too diffuse or irregular, or result in isolated patches of seagrass that are too small to be mapped as continuous seagrass.
B. Macroalgae	An area with 10 percent or greater coverage of any combination of numerous species of red, green, or brown macroalgae. Usually occurs in deeper waters on the bank/shelf zone.
a. Continuous Macroalgae	Macroalgae covering 90 percent or more of the substrate. May include blowouts of less than 10 percent of the total area that are too small to be mapped independently. This includes continuous beds of any shoot density (may be a continuous sparse or dense bed).
b. Patchy Macroalgae	Discontinuous macroalgae with breaks in coverage that are too diffuse or irregular, or result in isolated patches of macroalgae that are too small to be mapped as continuous macroalgae.
III. Coral Reef and Hardbottom	Hardened substrate of unspecified relief formed by the deposition of calcium carbonate by reef building corals and other organisms (relict or ongoing) or existing as exposed bedrock.
A. Coral Reef and Colonized Hardbottom	Substrates formed by the deposition of calcium carbonate by reef building corals and other organisms. Habitats within this category have some colonization by live coral, unlike the Uncolonized Hardbottom category.
a. Linear Reef	Linear coral formations that are oriented parallel to shore or the shelf edge. These features follow the contours of the shore/shelf edge. This category is used for such commonly used terms as fore reef, fringing reef, and shelf edge reef.
b. Spur and Groove	Habitat having alternating sand and coral formations that are oriented perpendicular to the shore or bank/shelf escarpment. The coral formations (spurs) of this feature typically have a high vertical relief compared to pavement with sand channels and are separated from each other by 1-5 meters of sand or bare hardbottom (grooves), although the height and width of these elements may vary considerably. This habitat type typically occurs in the fore reef or bank/shelf escarpment zone.
c. Patch Reef	Coral formations that are isolated from other coral reef formations by sand, seagrass, or other habitats and that have no organized structural axis relative to the contours of the shore or shelf edge. A surrounding halo of sand is often a distinguishing feature of this habitat type when it occurs adjacent to submerged vegetation

Table 1. Marine Habitat Classification	
d. Scattered Coral/Rock in Unconsolidated Sediment	Primarily sand or seagrass bottom with scattered rocks or small, isolated coral heads that are too small to be delineated individually (i.e., smaller than individual patch reef).
e. Colonized Pavement	Flat, low-relief, solid carbonate rock with coverage of macroalgae, hard coral, gorgonians, and other sessile invertebrates that are dense enough to partially obscure the underlying carbonate rock.
f. Colonized Bedrock	Exposed bedrock contiguous with the shoreline that has coverage of macroalgae, hard coral, gorgonians, and other sessile invertebrates that partially obscures the underlying rock.
g. Pavement with Sand Channels	Habitat having alternating sand and colonized pavement formations that are oriented perpendicular to the shore or bank/shelf escarpment. The sand channels of this feature have low vertical relief compared to spur and groove formations. This habitat type occurs in areas exposed to moderate wave surge such as that found in the bank/shelf zone.
B. Uncolonized Hardbottom	Hard substrate composed of relict deposits of calcium carbonate or exposed bedrock.
a. Reef Rubble	Dead, unstable coral rubble often colonized with filamentous or other macroalgae. This habitat often occurs landward of well developed reef formations in the reef crest or back reef zone.
b. Uncolonized Pavement	Flat, low relief, solid carbonate rock that is often covered by a thin sand veneer. The pavement's surface often has sparse coverage of macroalgae, hard coral, gorgonians, and other sessile invertebrates that does not obscure the underlying carbonate rock.
c. Uncolonized Bedrock	Exposed bedrock contiguous with the shoreline that has sparse coverage of macroalgae, hard coral, gorgonians and other sessile invertebrates that does not obscure the underlying rock.
d. Uncolonized Pavement with Sand Channels	Habitat having alternating sand and uncolonized pavement formations that are oriented perpendicular to the shore or bank/shelf escarpment. The sand channels of this feature have low vertical relief compared to spur and groove formations. This habitat type occurs in areas exposed to moderate wave surge such as that found in the bank/shelf zone.
IV. Land	Terrestrial features above the spring high tide line.
V. Mangroves	Emergent habitat composed of red, black, or white mangroves, or some combination thereof. Mangroves are generally found in areas sheltered from high-energy waves. Mangroves must be part of an open tidal system to be mapped. This habitat type is found only in the shoreline/intertidal, back reef, or barrier reef crest zone.
VI. Artificial	Man-made habitats such as submerged wrecks, large piers, submerged portions of rip-rap jetties, and the shoreline of islands created from dredge spoil.
VII. Unknown	Bottom type unknown due to turbidity, cloud cover, water depth, or other interference

Source: Kendall et al. 2001

B. Regional and Historic Context

i. Land Use History

Prior to European contact, two prehistoric Indian groups, the Arawaks (also known as the Tainos) and the Caribs, inhabited and explored the Virgin Islands (Boulon 1999). It is believed that the small populations of Indians that settled St. John were largely confined to the coast and had little impact on vegetation (MacDonald et al. 1997). By the time Christopher Columbus arrived in the Virgin Islands in 1493, the island was likely uninhabited (Weaver unpublished). No lasting settlements were in place on the island until the 1700s.

Beginning in 1718, St. Thomas and St. John were colonized by the Danish West India and Guinea Company. Land was cleared and cultivated using slave labor, and a plantation system began to develop on the islands. By 1728, much of the natural vegetation on the islands was disturbed by the island's 800 inhabitants and approximately 90 plantations existed on the island (Weaver unpublished). During this time, a number of non-indigenous plants were introduced on St. John, including sweet lime (*Citrus limetioides*), bay rum (*Pimenta racemosa*), mango (*Mangifera indica*), sugar apple (*Annona squamosa*), soursop (*Annona muricata*), and genip (*Meliococca bijugatus*) (Boulon, pers. comm, 2006b).

In 1734, development of the plantation system was slowed and nearly stopped by a slave uprising, but when the Danish West Indies became a crown colony in 1755, development again accelerated. By 1780, the majority of St. John was under cultivation. It is estimated that approximately 90 percent of the island was cleared for cultivation during the 1700s (Ramos-Scharron 2004). With the exception of most xeric communities, all native vegetation was affected by the activities of this era (Boulon, pers. comm, 2006b). It is also likely that clearing activities resulted in sedimentation of nearshore waters. Cores taken from large coral colonies off of St. John suggest that reefs have been gradually declining since the late-1700s (Rogers 1998)

The primary crops under cultivation during the 18th century included cotton, tobacco and dye woods such as indigo. Over time, production switched primarily to sugar. The rugged terrain, thin rocky soil, and labor-intensive economies were challenging, but as long as sugar prices remained high and African slaves were easily available, agricultural development on St. John remained financially viable (Boulon 1999).

Things began to change when Denmark abolished the slave trade in 1792. By the 1800s, sugar prices dropped, and the plantation economy became marginal. By the mid-1800s, technological innovations in other regions and the increased production of the European sugar beet caused some St. John plantations to fold. In 1848, when slavery was abolished in the Danish West Indies, the plantation system suffered another setback. The breaking point for most remaining plantations occurred in 1867 when a major hurricane and an earthquake resulted in tracts of cultivated land being abandoned or converted. Island population declined, and land reverted to natural vegetation, primarily the native communities described above (Terrestrial Habitat – St. John). Only a few plantations lasted into the 20th century (Boulon 1999). Between 1900 and 1950, the population of St. John remained at about 800 inhabitants (Weaver unpublished). During this time period, bay rum production was the island's primary industry. Subsistence agriculture included tainas, okra, cassavas, yams, sweet potatoes, bananas, and papayas.

In 1917, the Danish West Indies were ceded to the United States. The territory of the U.S. Virgin Islands was created in 1931 and is currently administered by an elected governor and legislature. Oversight authority for the territory rests with the U.S. Department of the Interior (Boulon 1999).

Virgin Islands National Park was established on St. John in 1956 as a result of a land donation from Lawrence Rockefeller and the Jackson Hole Preserve Corporation to the federal government. Beginning in 1952, Rockefeller began the purchase of approximately 55 percent of the island with the intent of preserving the majority as parkland and developing a restored sugar plantation/resort on a portion of Caneel Bay (Towle 2003; Weaver unpublished). The Caneel Bay area, which remained deeded to Rockefeller at the time of the original land donation, is outside of park boundaries and is currently maintained as an exclusive resort.

After the park was established, NPS undertook the task of undoing the effects of almost 250 years of cultivation. This caused conflicts with some local islanders because access to economic resources in the park (e.g., grazing land, flora and fauna) was restricted, severely limiting traditional uses of the environment (Boulon 1999).

In 2001, President Clinton designated 12,708 acres of submerged land within 3 miles of the Virgin Islands National Park as a Coral Reef National Monument. This newly protected area is a no take zone except for bait fish harvesting at Hurricane Hole and blue runner harvesting (rod and line) (NPS 2004b). This no take area provides an opportunity for park managers to monitor changes in the monument compared to other marine areas in the park where fishing is allowed and to look for trends in anthropogenic effects on marine resources. This designation has also allowed further protection for coastal habitats, such as mangroves, in areas that are now under continuous protection from the terrestrial parklands into the submerged monument lands.

The present economy of the U.S. Virgin Islands is based on tourism, with the majority of visitors originating from the United States (64 percent), Europe (10 percent) and Canada (7 percent) (Boulon 1999). Beginning in the 1950s, St. Thomas became a popular destination for Caribbean cruise ships that would send passengers to St. John for day trips. Local people have had to adapt to new development designed to feed, house, and entertain the tourists (Boulon 1999). The island, which once harbored fewer than 800 people living mostly in two-room wooden cottages without indoor plumbing, electricity or telephones, has undergone a dramatic transformation. A permanent population of approximately 4,200 persons with a median household income of $32,482 is now sustained on the island (Israel 2004). The majority of residents live in Cruz Bay.

ii. Adjacent Land Use

Park lands account for over 50 percent of the island of St. John. Approximately 5 percent of the island is owned by the Virgin Islands government, and the remaining portion of the island is private land that is currently undeveloped or used for residential or light commercial activity (Boulon, pers. comm, 2006b). Over the last 40 years, there has been rapidly increasing development of residences and tourism-related businesses (e.g., hotels, rental properties, shopping, restaurants) on privately held lands (MacDonald et al. 1997). Development of inholdings (private lands within park boundaries) is a particular concern for park managers (Boulon 1999). Over 2,000 acres of private inholdings exist within park boundaries. The trend in recent years has been to subdivide and develop these parcels. For example, there were 261 parcels in 1991 and approximately 322 parcels in 1992 (NPS 2002). NPS works with non-profit organizations such as the Trust for Public Lands and Friends of Virgin Islands National Park to acquire inholdings, but high real estate prices make this difficult (NPS 2002). Impacts associated with the development of inholdings include fragmentation of communities, clearing of native vegetation, and planting of non-native ornamentals.

Numerous paved and unpaved roads run through and adjacent to park lands. NPS maintains roads on its property (USDOT 2004). Roads have the potential to act as dispersal barriers, and unpaved roads are a significant source of sediment loading to the marine environment (Ramos-Scharron 2004).

Activities in surrounding waters also impact park resources. Commercial and recreational fishing, cruise ship traffic, and development on nearby islands impact marine populations, water quality, and coral reef health.

C. Unique Park Resources and Designations

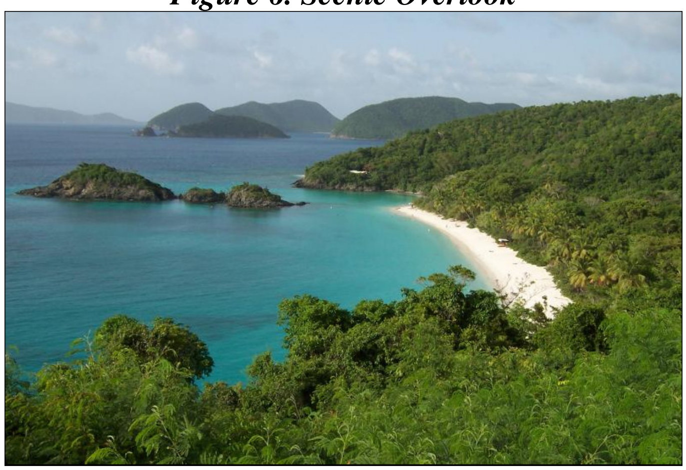
The U.S. Virgin Islands National Park and Coral Reef National Monument contain several resources significant to NPS's natural resource management goals of preserving "…topographic features, geologic features, paleontologic resources, and aesthetic values, such as scenic vistas, sound, and clear night skies" (NPCA 2006).

i. Aesthetic Resources

Scenic Vistas

Scenery can be considered the most significant feature of the park (Boulon 1999). Visitors travel to St. John to experience a tropical park with palm tree-lined beaches, sparkling blue water, lush green vegetation, and abundant and unique wildlife. The winding roads throughout Virgin Islands National Park are dotted with scenic overlooks for visitors to pull off and take in the natural beauty of this protected area (Figure 6).

Figure 6. Scenic Overlook



Source: http://www.pbase.com/robertablake/image/46329582

Unfortunately, this view is becoming diminished in places due to the development of private property that exists within park boundaries (Boulon 1999). Large corridors have been bulldozed for electrical lines and new road development (Figure 7), interrupting the natural viewshed (Boulon, 1999). Actions need to be taken to ensure that future road and power line construction be placed in less visible areas and occurs along existing corridors if possible.

Figure 7. Road Construction

Source: Rogers 1997

Air quality and visibility are considered to be excellent in the park, which is designated as a Class I area under the Clean Air Act (greatest level of regulatory protection). Although Virgin Islands National Park is not located near any major industrial areas, visibility can be affected during certain events and times of year. Volcanic activity on the nearby island of Montserrat has impaired the visibility in the park as ash travels towards the Virgin Islands. The particles from these eruptions are usually coated with sulfur dioxide, which can cause acid rain events (Boulon 1999).

Another event that has caused visibility impairments in the park is the transport of dust particles from North African deserts to the Caribbean during summer months (Perry et al. 1997). The Interagency Monitoring of Protected Visual Environments (IMPROVE) fine aerosol monitoring network has stated that the Virgin Islands monitoring site is the dustiest of all the IMPROVE sites throughout the United States (Boulon 1999). In addition to impacting visibility, this dust could be harmful to the natural resources within the park in several ways. The dust may be significant enough to alter the chemistry of St.

John's soils, and may affect the amount of solar radiation reaching the earth's surface (Boulon 1999). There is also research being conducted on the possibility of these dust particles carrying fungal spores or bacteria that could be contributing to some of the marine diseases damaging coral reefs within the park (Boulon 1999).

Research has shown that the number of bacteria and fungi in Virgin Islands air samples is two to threefold greater when African dust is present in the area (Garrison et al. 2003). Several types of coral disease are caused by common terrestrial fungi that are small enough to be carried by winds and dispersed over large distances (Garrison et al. 2003). Experiments have been conducted on fungus that affect sea fan species and results show that African dust storms may be a source of Caribbean sea fan pathogens (Garrison et al. 2003). Another common coral disease affecting primarily stony corals is black band disease (Garrison et al. 2003). Iron, which is commonly present on African dust particles, is believed to trigger the biomass buildup of the black band microbe to the point where it is able to kill the coral (Garrison et al. 2003). White plague disease is caused by a bacteria pathogen but has been observed in Caribbean coral reefs that are far from human development. The African dust hypothesis has recently been suggested as a cause for this disease (Garrison et al. 2003). Although these dust events have occurred for hundreds of years, it is the recent industrial development and use of toxins that are contributing to the dangers associated with African dust transport to the Caribbean. Toxins and chemicals used as pesticides in Africa that travel on dust particles to the Caribbean can indirectly affect corals by limiting growth rates and reproductive capabilities (Garrison et al. 2003).

Sound and Dark Night Skies

Dark night skies can be affected in the Virgin Islands National Park by several sources. Lights from neighboring islands in the British Virgin Islands, from St. Thomas, and from private property and the main harbor of Cruz Bay on St. John are visible from park land at night. St. Thomas is the most visible at night, due to the amount of development that has occurred on that island. Soundscapes can also be impaired at times by road traffic such as taxis and construction trucks that travel through the park, as well as passenger ferries to St. Thomas and the British Virgin Islands.

ii. Unique Features and Special Designations

Virgin Islands National Park was established to protect the significant natural features present in the upland and marine areas of St. John. Coral reefs and seagrass beds provide essential habitat for endangered sea turtles, many fish species, conchs, lobsters, and other commercially and economically important species (Rogers 1997). The park also contains some of the last remaining native tropical dry forest in the Caribbean (Rogers 1997). These dry tropical forests, which were once common in the region, are under great stress from development, and Virgin Islands National Park is the only area where these forests are protected in the United States (Rogers 1997).

The Virgin Islands National Park is also located within the Leeward Islands moist forest and Caymen Islands xeric scrub ecoregions (WWF 2001). Both of these ecoregions are classified by the World Wildlife Fund (WWF) as critical/endangered (WWF 2001).

Biosphere Reserve

Virgin Islands National Park was designated as a Biosphere Reserve in 1976 by the United Nations Educational, Scientific, and Cultural Organization (UNESCO) through its Man and the Biosphere (MAB) program. The park was one of the first protected areas to receive this designation in the United States. The reserve is recognized as internationally significant because it represents the Lesser Antillean biogeographic region and contains a national park that is under long-term protection (Boulon 1999). It is also one of 30 out of over 311 international biosphere reserves that contain marine and terrestrial ecosystems (Rogers 1997).

Coral Reef National Monument

In 2001, President Clinton designated 12,708 acres of submerged land within 3 miles of the Virgin Islands National Park as a Coral Reef National Monument. This newly protected area is a no take zone except for bait fish harvesting at Hurricane Hole and blue runner harvesting (rod and line) (NPS 2004b). This no take area provides an opportunity for park managers to monitor changes in the monument compared to other marine areas in the park where fishing is allowed and to look for trends in anthropogenic effects on marine resources. This designation has also allowed further protection for coastal habitats, such as mangroves, in areas that are now under continuous protection from the terrestrial parklands into the submerged monument lands.

Endangered and Threatened Species

Virgin Islands National Park provides very important habitat for many federally listed threatened and endangered species (Table 2). Five species of whales, as well as several porpoise species, also migrate through park waters (Boulon 1999). The West Indian manatee has recently been recorded in nearby Tortolla, British Virgin Islands and has been recorded as rare around St. John (Boulon 1999). Several bird species migrate though and nest on St. John, including the federally endangered brown pelican, the roseate and least terns (summer nesters), and piping plover (rare summer migrant) (Boulon 1999). As mentioned before, St. John contains some of the last intact tropical dry forests in the Caribbean, which provide habitat for wintering warblers and may even be the only considerable wintering area for migratory warblers throughout the entire NPS protected areas system (Rogers 1997).

Several listed reptiles are also found in the park. The hawksbill sea turtle commonly nests on St. John beaches, and the green sea turtle feeds in nearshore seagrass beds. Green and leatherback sea turtles occasionally nest on St. John (Rogers 1997). The federally endangered Virgin Islands boa has never been observed on St. John, but is very likely to occur because it has been observed on nearby St. Thomas.

In the summer of 2006, two coral species were listed as federally threatened species under the Endangered Species Act (ESA). Staghorn coral (*Acropora cervicornis)* and elkhorn coral (*A. palmata)* are the first coral species to be listed under the ESA and this listing is considered very significant for coral reef conservation (NOAA News Online 2006). Elkhorn coral is one of the primary reef building corals and usually creates shallow reefs responsible for breaking ocean waves and diminishing coastal erosion

(Rogers 1998). There has been a significant decline in this important species due to damage from hurricanes and boat groundings, and a federal listing is an important step towards protecting the species from further loss (NPS 2006).

Table 2. Federally Listed Threatened and Endangered Species		
COMMON NAME	**SCIENTIFIC NAME**	**STATUS**
Brown pelican	*Pelecanus occidentalis*	Endangered
Kirtland's warbler	*Dendroica kirtlandii*	Endangered
Peregrine falcon	*Falco peregrinus*	Endangered
Piping plover	*Charadrius melodus*	Threatened
Roseate tern	*Sterna dougailii*	Threatened
Green sea turtle	*Chelonia mydas*	Endangered
Hawksbill sea turtle	*Eretmochelys imbricata*	Endangered
Leatherback sea turtle	*Dermochelys coriacea*	Endangered
Elkhorn coral	*Acropora palmata*	Threatened
Staghorn coral	*Acropora cervicornis*	Threatened
Humpback whale	*Megaptera novaeangliae*	Endangered
West Indian manatee	*Trichechus manatus*	Endangered
Thomas' lidflower	*Calyptranthes thomasiana*	Endangered
St. Thomas prickly-ash	*Zanthoxylum thomasianum*	Endangered

Source: NPSpecies Database 2005

D. Park Science and Resource Management

i. Management Plans

The Virgin Islands National Park natural resource staff has compiled several management plans addressing natural resource protection throughout the park. The most significant management plan is the Resource Management Plan. This was compiled in 1999 by the chief resource manager R.H. Boulon, Jr., as well as other natural resource staff. This document provides general information on the status of natural resources throughout the park, as well as highlights the main threats to the area.

The most recent General Management Plan was completed in 1983, and a revised draft is expected in 2008. The park does have a Fire Management Plan (year of draft is unknown), but does not recommend any prescribed burns or understory clearing to manage fires in the park. The only fire management concern is during the 4^{th} of July near Hassel Island for fireworks-related fires.

An Integrated Pest Management Plan is being compiled and will be a helpful addition to the existing Environmental Assessments related to exotic and invasive species in the park. Other management plans that are important for the management of natural resources in the park, but not yet completed, are Vegetation and Habitat Management Plans. Park staff also plan to develop a separate Resource Management Plan for Virgin Islands Coral Reef National Monument, as there are currently no separate management documents for that unit (Boulon, pers. comm., 2006).

Management Initiatives

Non-native Animal Reduction Plans

At this time, Environmental Assessments have been completed to address the negative impacts on park resources incurred from the non-native wild hog, goat, sheep, rat, cat, and mongoose populations. These Environmental Assessments outline several management alternatives as well as the recommended alternative for each problem species. The preferred alternative for all of the above animals is sustained reduction of the populations. This will include fencing, trapping, rodenticide application, and other cultural practices within Virgin Islands National Park (NPS 2002, 2003, 2004).

Mooring Buoy and Marker Buoy Installation

Damage to coral reef and seagrass habitats from improper boat anchoring and groundings has also been addressed by park staff. A survey of boats anchoring in park waters was conducted in 1987 from January to March. This study found that the average length of boats was 45 feet and that 46 percent of them had anchored in coral or seagrass (Allen 1992). Researchers found that the bottom was “severely disrupted” 23 percent of the time (Allen 1992). This study was only conducted on smaller boats, ignoring the damage caused by the increasing number of larger 150-225 foot long “mini-cruise” boats that are able to enter shallow, environmentally sensitive areas within park boundaries (Allen 1992). Park managers have taken steps to minimize this damage, including anchoring restrictions in park waters, education and outreach, and implementing a mooring buoy system in several north shore bays.

A mooring system has been developed and implemented in the park to reduce direct damage from boat anchors to these sensitive habitats. The mooring buoys are designed to hold boats up to 55 feet, which has been estimated to include 82 percent of boaters in the park (Boulon 1999). Private donations as well as funding from the Regional office have allowed the installation of 208 mooring buoys in the park in the fall of 1999 (Boulon 1999). Currently there are 215 moorings in the Virgin Islands National Park and 17 moorings (not counting storm moorings) in the Coral Reef National Monument (Boulon, pers. comm., 2006b). Although educational brochures have been handed out, there is a lack of staff available to monitor and collect user fees for existing moorings. Park staff have also deployed strings of marker buoys around shallow coral and rocky areas that are susceptible to boat groundings, as well as in beach areas to separate swimmers and boaters (Boulon 1999).

ii. Research and Monitoring

The NPS Inventory and Monitoring Program (I&M) is responsible for collecting basic resource data for about 270 parks considered to contain significant natural resources. The parks are designated into 32 different Vital Signs Networks based on geography and natural resource characteristics (NPS 2005). Virgin Islands National Park is part of the South Florida/Caribbean Vital Signs Network (SFCN), which has the responsibility of selecting 'vital signs' and developing monitoring programs to report the status of these 'vital signs' to assist in adaptive management of park resources (SFCN IMP 2006). Three Vital Signs Indicator Development Workshops were held in 2006 with scientists, agency staff, NPS staff, and non-NPS natural resource managers to prioritize a list of 62 indicators in each park (SFCN IMP 2006). The SCFN will design a monitoring program based on the ranking of these indicators and will produce a "*Vital Signs Monitoring Plan*" by December 2007 (SFCN IMP 2006). Table 3 displays the indicators sorted by and importance, and estimated levels of existing monitoring.

The SCFN program focuses on coral reefs, seagrass beds, dry forest ecosystems, reef fish, turtles, birds, water quality, and the effects of natural and anthropogenic stressors on these resources (Rogers 1997). The existing monitoring program focuses on the effects of development and increased visitation on terrestrial and marine ecosystems; effects of hurricanes, droughts, and other natural stresses on marine and terrestrial resources; effects of fishing on fish populations and reef systems; effects of soil erosion

Table 3. SFCN Vital Signs Indicators

A: Importance to Park (park superintendants rated top 32 indicators): - =Not applicable to park management; L= Low importance to park managers; H= High importance to park management

B: Esttimated Level of existing monitoring: o =No monitoring occuring but within indicator geographic scope; \ =Some monitoring occuring, but either protocol or sampling scope would need change; X =Lots of monitoring occuring, little change presumed needed to level of effort, protocol, or scope.

Priority Rank	Indicator	Importance to Park	Existing Monitoring
1	Coral Communities	H	\
2	Exploited Fish Assemblage-Grouper, Snapper (parrotfish, surgeonfish in USVI)-population structure, status and trends	H	\
3	Hydrology = water storage, flow, timing, and duration.	L	o
4	Seagrass and other SAV cover and community composition	H	\
5	Water Quality-Nutrients characteristics of the marine water bodies	H	X
6	Invasive exotic plants	H	\
7	Freshwater Inputs to Estuaries	-	
8	Marine Invertebrates-Rare, threatened, and endangered species - *Acropora, Diadema, Antipathes*	H	\
9	Shape, orientation, location, and coverage of vegetation community types	H	o
10	Wading birds- Regional South Florida - Systematic Reconnaissance Flights	-	
11	Spatial and Temporal Salinity Patterns	L	o
12	Surface Water Quality-physiochemical surface water characteristics at specific locations	L	o
13	Exploited Inverts (Lobster, Conch, Crabs, Shrimp, Stone Crab, Blue Crab, Clams, Oysters, Sponges, Whelks).	H	\
14	Land Development inside/outside the park (within 5 mile radius for USVI parks)	H	\
15	Marine Fish Communities - Coastal Shelf/Deep oceanic Stratus, structure, trends	H	X
16	Colonial Nesting Birds (e.g. Least terns, pelicans, boobies, roseatte terns, egrets, storks, herons)	H	X
17	Invasive exotic fauna	H	o
18	Nutrient Loading and Sediment Loading	H	\
19	Visitor Use (Both commercial and individual/personal use)	H	\
20	Early detection, status, and trends of non-indigenous aquatic species.	L	o
21	Marine Fish Communities - Bays/Mangroves - Status, structure, trends	H	o

Table 3. SFCN Vital Signs Indicators

A: Importance to Park (park superintendants rated top 32 indicators): - =Not applicable to park management; L= Low importance to park managers; H= High importance to park management

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Priority Rank	Indicator	Importance to Park	Existing Monitoring
22	Location of critical ecotones - field plots/transects	H	\
23	Periphyton	-	
24	Freshwater fish and large macro-invertebrates in wet prairies and marshes	L	o
25	Contaminants in water column, organisms, and sediments.	H	o
26	Long-term, within community vegetation shifts using permanent plots	H	X
27	Sea Turtles	H	X
28	American crocodile (*Crocodylus acutus)*	-	
29	American alligator (*Alligator mississippiensis)*	-	
30	Benthic community spatial & temporal changes in extent and distribution-remote sensing	H	\
31	Land Birds-residential and migratory	H	\
32	Amphibians-South Florida and USVI	H	o
33	Ecotone shifts along wetland boundaries - Mangrove to marsh to cypress- Aerial photography		
34	Sediment elevation in mangroves and mud banks (Fl Bay) Salt Ponds (USVI) and Mangrove fringes		o
35	Marine Vertebrates-Rare, threatened, and endangered species		\
36	Physical drivers of mangrove-marsh ecotone		
37	Fire Return Interval Departure		
38	Goliath Grouper (Red Hind in VI)- population structure, status, and trends		\
39	Critically Imperiled and Rare Plants		o
40	Pink Shrimp population structure, status and trends		o
41	Aquatic invertebrates in wet prairies and marshes		
42	Land birds - Mangrove-population abundance and distribution		o
43	Bonnethead, Lemon, Bull, Nurse Sharks- population structure, status and trends		
44	Florida panther		

Table 3. SFCN Vital Signs Indicators

A: Importance to Park (park superintendants rated top 32 indicators): - =Not applicable to park management; L= Low importance to park managers; H= High importance to park management

B: Esttimated Level of existing monitoring: o =No monitoring occuring but within indicator geographic scope; \ =Some monitoring occuring, but either protocol or sampling scope would need change; X =Lots of monitoring occuring, little change presumed needed to level of effort, protocol, or scope.

Priority Rank	Indicator	Importance to Park	Existing Monitoring
45	Gray Snapper (Schoolmaster in VI)- popultaion structure, status and trends		\
46	Position and Spatial Extent of Mud Banks, Buttonwood Embankment and Berms		
47	Oyster population structure, status and trends		
48	Spotted Sea Trout- population structure, status and trends		
49	Landbirds - Pine Rockland- population abundance and distribution		
50	Phytoplankton composition and biomass		
51	Spatial and temporal changes in extent and distribution of substrate type (marl vs. peat)		
52	Snook- population structure, status and trends		
53	Infaunal benthic community structure and abundance for animals		
54	Pig Frog (*Rana grylio)*		
55	Landbirds- Cavity nesting pine rockland birds-Demographics (Fecundity and Survival)		
56	Sawfish- population structure, status and trends		
57	Reptiles – USVI		o
58	Long-term sediment elevation changes in cypress strands and domes		
59	Florida Box Turtle (*Terrapene Carolina bauri)*		
60	Bats- USVI		o
61	Butterflies		o
62	Island Insects		

on coastal and marine ecosystems; and the status of rare, endangered, and endemic species (Rogers 1997).

Virgin Islands National Park is also part of several air quality monitoring initiatives, including, the IMPROVE program, which focuses on visibility; the Clean Air Status and Trends Network (CASTnet), which focuses on dry deposition monitoring; and the National Atmospheric Deposition/National Trends Network (NADP/NTN), which focuses on wet deposition air quality monitoring (NPS 2005).

In 1984, Virgin Islands National Park initiated a series of interdisciplinary research projects conducted by members of the Virgin Islands Resource Management Cooperative (VIRMC) (Rogers 1997). The VIRMC consisted of the NPS and fifteen other members from territorial and federal agencies, private researchers, and educational institutions (Boulon 1999). The data generated from the projects were compiled in a synthesis report in 1998 by Rogers and Teytaud and provide a summary of the marine and terrestrial ecology of the island through the late 1980s (Rogers 1997). In addition, hundreds of academic and government-sponsored studies focusing on fisheries health, hurricane and dust events, and coral reef health have been conducted in the park, but an updated ecosystem summary report is needed (Rogers 1997). There was a park marine biologist on staff from 1970-74 and from 1981-88. Since 1996, research biologists have been stationed at the Biological Resources Division (BRD) of the U.S. Geological Survey (USGS) and work out of the Biosphere Reserve Building located in the park. These researchers are responsible for developing protocols for research on the natural resources within the park (Boulon 1999). Some biologists have also developed protocols for the SFCN program responsible for conducting inventories of species within Virgin Islands

National Park (Rogers 1997). A list of current research permits can be obtained from the director of natural resources of the park, but is too long to include in this document. The ongoing research projects within the park cover a very wide range of scientific topics. Examples include research on coral diseases, sedimentation rates, fisheries population biology, and watershed delineation.

iii. Education and Outreach

The Virgin Islands National Park Visitors Center is located in Cruz Bay, St John. The center contains exhibits, brochures, maps, park videos, and books describing the history and natural ecology of the park. Many programs are organized and run by park interpretive staff such as hikes, historical tours, snorkel trips, evening campground programs, and cultural craft demonstrations. Trunk Bay has a 225-yard, self-guided underwater snorkeling trail marked with underwater signs identifying coral reef organisms.

The Development Concept Plan of 1983 called for the installation of information, orientation, and interpretation kiosks at the main beaches, the public ferry docks, and visitor contact areas (Boulon 1999). The purpose of this plan was to improve interpretive trails and exhibits. A number of these planned developments have been completed, including installation of kiosks; upgrading of toilet facilities; maintenance area improvements; and improvements to handicapped accessibility, trails, and off-road parking (Boulon 1999). Although this is an important contribution to the visitor experience, many of the interpretive signs are faded and in need of replacement. These interpretive signs display crucial information to visitors on proper interaction with resources such as coral reefs and other animals and should be updated and replaced as necessary.

There are also several centers on St. John that focus on environmental education. The Virgin Islands Environmental Resources Station (VIERS) is a non-profit organization located in Lameshur Bay on the south shore of St. John. VIERS serves the local community and visiting groups through on-site, year-round environmental education programs and activities. VIERS staff conduct guided trail hikes, seashore explorations, mangrove walks, plant and wildlife identification excursions, and snorkeling outings to identify marine life to visitors of all ages to discover the local environment (VIERS 2006).

The Friends of the Park organization is another non-profit organization that contributes to the protection the park's natural resources. They hold a seminar series throughout the year to inform the local community about park-specific issues and are a source of advocacy and fundraising for the park. Members and volunteers work with park staff to meet existing needs, as well as initiate programs to address new and potential park resource issues.

Many other volunteers work throughout the park such as the Student Conservation Association, local school programs, local church groups, and individuals from the community. Various types of volunteer projects are conducted by these groups such as vegetation clearing, NPS document scanning, beach and trail litter removal, mooring buoy line cleaning, and sea turtle nest monitoring (Boulon, pers. comm., 2006).

III. ASSESSMENT CRITERIA

A. Ecosystem Measures

i. Ecosystem Extent and Function

Development, increased visitation, and natural disturbances have resulted in ecosystem-wide impacts to terrestrial and marine resources at Virgin Islands National Park and Virgin Islands Coral Reef National Monument.

In the terrestrial environment, the most immediate threats to forest health and regeneration in all community types are land development and the impacts of growing populations of non-indigenous mammals, such as goats and donkeys (Acevedo-Rodríguez et al. 1996). A discussion of the extent and impact of non-indigenous animal populations is provided in Section III.A.ii. (Species Composition and Condition). Visitor impacts to terrestrial systems are minor in comparison to the effects of visitors on marine systems. The creation of social trails and the illegal removal of plant material to create vistas and for crafts and home gardens are the primary visitor threats to forests (Boulon, pers. comm, 2006).

Clearing of St. John's steep hillsides on slopes approaching and exceeding 30 degrees, has resulted in elimination of native species; spread of exotic plants such as Brazilian pepper (*Schinus terebinthifolius*), tan tan (*Leucaena leucocephala*), and limeberry (*Triphasia trifolia*); increased soil erosion; loss of sparse topsoil; and fragmentation of the forest and "viewshed" (Boulon 1999). All forest communities are at risk from clearing and development activities (Boulon, pers. comm, 2006b) The potential re-opening and paving of old Danish cart roads is also a threat to forest communities. The opening of these roads would result in the removal of vegetation, spread of exotic plant species, and increased erosion to nearshore waters (Boulon 1999).

Intact forests are important habitat for migratory birds. Development of private lands within the park and construction of roads through watersheds that are now largely undisturbed could have drastic consequences for the birds that winter in the Virgin Islands. Forest fragmentation associated with development of inholdings has been suggested as a possible reason for the reduction in over-wintering warblers within the park (USDOT 2004).

Because the park is located on an island, issues associated with species isolation and dispersal and/or recolonization barriers could potentially impact native communities in the park. However, no research or studies are available to determine if these processes have had an effect or pose a future threat to any communities.

Natural disturbances, particularly hurricanes, have had an impact on both terrestrial and marine systems, although the impacts have been more significant and long-lasting in the marine environment. Terrestrial floral and faunal communities have developed in the presence of hurricanes and have evolved efficient recovery mechanisms. Hurricanes generally result in the toppling of trees and stripping of leaves, but even the damage from Hurricane Hugo (1989), one of the most powerful hurricanes to hit St. John in recent times, did not cause widespread damage to terrestrial vegetation (Boulon 1999). Recovery of forests and associated animal populations from Hugo and subsequent hurricanes was relatively rapid (Boulon 1999).

In contrast to their impacts on the terrestrial environment, hurricanes have had severe and enduring impacts on mangroves, coral reefs, and seagrass beds in and around the park (Boulon 1999). Mangroves at Lameshur Bay study plots have exhibited heavy mortality due to a combination of drought and hurricane stress (Boulon 1999). A series of hurricanes in the 1990s closed off the inlet of the tidal lagoon at Lameshur Bay and resulted in a massive die-off. In addition, mangroves lack the ability to bud epicormically and therefore die when they are defoliated or lose branches due to wind or wave damage. Recovery of these systems depends on restoration of the site hydrology and forest composition through growth of seedlings. A restoration project conducted jointly by Virgin Islands National Park and University of the Virgin Islands at the Lameshur site has had mixed success. Red mangrove seedlings planted in August 2003 had a 48 percent survival rate (UVI 2006). However, black and white mangrove seedlings, as well as uprooted and transplanted red mangroves planted during February 2003, had very low survival rates and in some plantings, all individuals of these species died (UVI 2006). Studies conducted by researchers from the University of the Virgin Islands on the Lameshur mangrove restoration speculate that planting season and physical environmental properties (e.g., salinity) contributed to the high mortality rates (UVI 2006).

Coral reefs have also suffered significant damage due to physical hurricane effects. At long-term monitoring sites around St. John, coral cover dropped to 8-18 percent (from around 30 percent) following Hurricane Hugo (Edmunds 1991; Rogers et al. 1991; Rogers 1992). The dominant coral species, star coral, declined about 35 percent in Lameshur Bay after Hugo (Rogers 1998). Studies have shown that no substantial recovery in total coral cover has occurred to date, although coral recruitment is occurring (Rogers and Beets 2001). Decreases in the amount of living star coral are of particular concern because it is one of the major reef-building species in the Caribbean (Rogers 1998).

Additionally, since hurricanes have reduced the spatial relief of affected reef areas around St John, it is likely that herbivore habitat and consequently herbivore abundance and grazing rates have decreased (Rogers and Beets 2001). This situation, combined with the availability of new substrate, facilitates extensive algal growth and negatively impacts the reef system (Rogers 1998; Rogers and Beets 2001).

During Hurricane Hugo, gorgonian corals and sponges were torn apart and ripped off the sea floor. Many collected in sand channels and other depressions on the reefs, and later washed up on the beaches. In Lameshur Bay study plots, the number of species and the size of colonies of gorgonians and sponges increased between 1991 and 1992 (Gladfelter 1993). Although there was a slight decrease in the number of sponge colonies during this time, the number of gorgonian colonies increased (Rogers and Beets 2001). These results may indicate ongoing recovery of the sponge and gorgonian communities from Hurricane Hugo.

In September 1995, two hurricanes (Luis and Marilyn) hit the U.S. Virgin Islands within a 10-day period. Reefs off the south side of St. John suffered severe damage. Although damage was visible at Lameshur Bay, the percentage of live coral cover along the permanent study transects did not decrease, perhaps because of the uneven nature of hurricane damage or because so little coral remained to be damaged (Rogers 1998). In some bays on the north shore of St. John, coral colonies suffered extensive physical damage from boats that had broken loose and dragged across the reef. Large coral colonies, some perhaps more than 100 years old, were split into pieces by boat keels (Rogers 1998).

Hurricanes in 1989, 1995, and 1999 also caused major ‘blow-outs’ (scoured depressions) in the seagrass beds within Virgin Islands National Park (Rogers and Beets 2001). Long-term monitoring of Great Lameshur Bay seagrass communities has demonstrated that hurricanes produce fluctuations in both seagrass density and community structure (Boulon 1999). Following Hurricane Hugo, park managers did not see significant seagrass recovery for five years. Hurricanes in 1995 and 1996 again reduced seagrass densities.

Visitor disturbance is also a problem for both coral reefs and seagrass beds. Reef destruction from anchors and boat groundings has been severe (Rogers and Beets 2001). In 1998, a single anchor drop from a cruise ship resulted in the destruction of almost 300 square meters of reef. Monitoring at this site has revealed no significant recovery of hard coral (Rogers and Beets 2001). In 1987, a survey of 186 boats revealed that 32 percent were anchored in seagrass beds and 14 percent in coral communities. About 40 percent of the anchors in coral and 58 percent in seagrass beds caused damage (Rogers 1998). Small boats continue to run aground on reefs within Virgin Islands National Park. The installation of mooring buoys and size limits on vessels allowed in park waters have resulted in less pressure on these reefs, but in some areas there is little coral left to protect (Rogers 1998). According to park staff, boats tied to mangroves were also a significant problem in the past, particularly during hurricanes. Mooring buoys have helped to alleviate this stress to mangrove systems (Boulon, pers. comm., 2006).

Although hurricanes and visitor impacts have caused severe damage to reef systems around St. John, one of the most serious causes of reef loss and degradation is disease. Diseases have caused extensive coral mortality on reefs in and around the park and monument. Thirteen coral species have exhibited disease in Newfound, Mennebeck, Haulover, Great Lameshur, and several other bays (Rogers and Beets 2001). There is little or no development in the watersheds of these bays, and no clear link to any known pollution. Plague type II is currently the most severe disease observed around St John (Rogers and Beets 2001). Black band disease, which primarily infects major reef-building corals like boulder star coral (*Montastraea annularis*) and symmetrical brain coral (*Diploria strigosa*), has been documented in park waters, but is not as prevalent or damaging as white band disease or plague type II.

In the mid-1970s to mid-1980s, white band disease killed large stands of elkhorn coral in the Caribbean, including the waters off St. John. In 1984, Beets et al. (1986) found the disease at seven sites off the north shore of the island, although it was not prevalent. The branching acroporid species, elkhorn coral (*Acropora palmata*) and staghorn coral (*Acropora cervicornis*), are the most vulnerable to white band disease, which has yet to be correlated with pollution or any other human activity (Rogers and Beets 2001; Rogers 1998). It generally kills the colonies it infects, although occasionally patches survive. To date, no pathogen has been conclusively linked to the disease (Rogers and Beets 2001).

In July 1997, conspicuous white patches of necrotic tissue began to appear on corals in several bays around St John. Analysis of the diseased tissue confirmed the presence of *Sphingamonas*, the pathogen associated with plague type II (Rogers and

Beets 2001). In some of the affected areas, the disease killed entire colonies. Algae began to grow on infected portions of the reef within a few weeks, and no recovery of diseased portions has been noted on individual colonies monitored around the island (Rogers and Beets 2001). Monthly surveys have documented new incidence of disease (bare white patches of skeleton) on Tektite reef every month since December 1997 (Rogers and Beets 2001). The frequency of disease at survey sites ranges from 3 to 58 percent. While the loss of coral to disease each month is small, the cumulative effects have led to a significant decline in the percentage of total live coral cover (Rogers and Beets 2001).

Coral bleaching is also a concern in park and monument waters. Bleaching occurs when symbiotic algae (zooxanthellae) that live inside coral tissue are lost, leaving the tissue transparent and revealing the white coral skeleton underneath. Bleaching occurs as a response to elevated water temperature and/or ultraviolet radiation (Rogers and Beets 2001), and has been linked to global climate change (Graham et al. 2006). Colonies in park waters bleached in 1987, 1990, 1998, and 2005. In most cases, bleaching results in partial mortality or complete recovery, rather than death, of entire coral colonies (Rogers and Beets 2001). In 2005, the most severe bleaching event recorded to date in the U.S. Virgin Islands resulted in 90 percent of coral cover bleached at six long-term monitoring sites located within Virgin Islands National Park and Buck Island Reef National Monument (St. Croix) (NPS 2006). Many corals began to recover from the bleaching episode, but were then afflicted by disease. Tektite reef experienced a 40 percent loss of live coral cover and Haulover reef more than 20 percent as a result of the 2005 bleaching/disease event (NPS 2006). Of the over 460 elkhorn colonies that are being monitored at four reefs in Virgin Islands National Park, about 45 percent bleached, 13 percent died partially, and 8 percent died completely (NPS 2006).

Recent analyses of coral cover show very high rates of cover loss due to the most recent episode of bleaching and disease. Preliminary calculations of coral loss between September 2005 and July 2006 show an average cover loss at all sites of 48.7 percent (Boulon, pers. comm, 2006b). Of the four reefs sampled, Tektite reef experienced the greatest cover loss at 54.3 percent (Boulon, pers. comm, 2006b). Further data and information on the causes and extent of this recent disease episode are not yet available, but the findings are currently being prepared for publication (Boulon, pers. comm, 2006b).

Finally, development on St. John also impacts the benthic communities in park waters. Runoff from land development activities on St John is one of the biggest threats to water quality and habitat in shallow nearshore areas. The island is very steep and usually receives brief but intense precipitation. Additionally, there are a number of unpaved roads across the island. These characteristics result in erosion and sedimentation that can smother coral colonies and reduce the amount of light available for photosynthesis (Rogers and Beets 2001). Data from 30 sites around St. John demonstrate that bays with developed watersheds have higher turbidity and light extinction coefficients and lower light transmission than bays associated with less disturbed watersheds (Rogers and Beets 2001). Additionally, data on coral growth rates in Hawksnest Bay have shown short-term declines associated with increased runoff from upland development (Rogers and Beets 2001). Extensive bulldozing and clearing of vegetation in the upper Hawksnest Bay watershed threaten the recovery of elkhorn coral on nearshore fringing reefs. In general, the effects of hurricanes, disease, and damage from boats appear to have caused more reef degradation around St John than sedimentation; however, it is believed that chronic sedimentation has significant effects on reef communities (Rogers 1998).

The cumulative and potentially synergistic effect of the abovementioned stressors on coral communities is difficult if not impossible to quantify, but it is clear that coral reefs in and near the park and monument are in a seriously degraded state and are acutely susceptible to both controllable and uncontrollable threats.

ii. Species Composition and Condition

This section will describe the flora and fauna found within Virgin Islands National Park and Virgin Islands Coral Reef National Monument, and the threats/stressors affecting these resources.

Floral Composition

The existing floral composition of St. John consists of 747 species of vascular plants (native and naturalized), of which 642 (86 percent of the total flora) are native to the island (Acevedo-Rodríguez et al. 1996). There are 117 families of vascular plants represented on St. John (12 of which are introduced), with a total of 469 genera (55 of which are introduced). Nearly every species on St. John (99.7 percent) is also found on other Virgin Islands, with the exception of two endemic flowering plants, *Eugenia earhartii* in the Myrtle family and *Machaonia woodburyana* in the Coffee family (Acevedo-Rodríguez et al. 1996).

Historic destruction of the natural vegetation on St. John has been extensive, encompassing nearly 90 percent of the island (Acevedo-Rodríguez et al. 1996). The first 130 years of colonization were particularly harsh on the vegetative communities of St. John due to extensive clearing for agriculture. As a result, some native and endemic plant species have become extinct or nearly extinct with their populations reduced to a few individuals. Examples include marron bacoba (*Solanum conocarpum*), pepino (*S. mucronatum*), cowhage cherry (*Malpighia infestissima*), Woodbury's stingingbush (*M. woodburyana*), and woolly nipple cactus (*Mammillaria nivosa*) (Acevedo-Rodríguez et al. 1996). Additionally, the introduction of aggressive exotic plants such as Brazilian pepper, tan tan, and limeberry may have contributed to the demise of some of St. John's native plants.

The present vegetation of St. John shows differing degrees of regeneration, ranging from recently disturbed to late secondary successional forests (Acevedo-Rodríguez et al. 1996). Existing vegetative cover contains numerous introduced plants that have become established in dense stands or more commonly intermixed with native species. Introduced invasive species can be found in most communities across the island, particularly near historic structures and in recently disturbed, open areas such as roadsides or construction sites (Acevedo-Rodríguez et al. 1996; Boulon, pers. comm, 2006b). NPS is currently considering invasive species management options for Virgin Islands National Park and the other parks in the SFCN. A Draft Environmental Impact Statement (EIS), released in September 2006, evaluates the potential environmental consequences of the proposed options (NPS 2006b).

Two federally endangered species of plants occur in the park, St. Thomas prickly-ash (*Zanthoxylum thomasianum*) and Thomas' lidflower (*Calyptranthes thomasiana)* (NPSpecies Database 2005). Recent surveys of both species show them to be stable within the park (Boulon, pers. comm., 2006b).

<u>Threats to Species Composition – Flora</u>

Altered and degraded forest systems are recovering from the clear-cutting of the plantation days. Most species are still present, but composition and forest structure do not yet resemble pre-plantation descriptions of the forests (Boulon 1999). Ecological succession to dominant communities is being monitored.

As discussed above (under Ecosystem Extent and Function), vegetative communities in the park are threatened by development of inholdings and adjacent land, as well as grazing and rooting activities of feral animals.

Development activities have impacted species composition by removing native plants to clear land for construction and facilitating the spread of exotic plants. Harmful exotic plants can have profound environmental consequences ranging from wholesale ecosystem changes and extinction of indigenous or native species (especially on islands) to more subtle ecological changes and increased biological sameness (monospecific forests). To date, no known extinctions as a result of invasive plants have occurred on St. John (Boulon, pers. comm, 2006b)

Numerous non-indigenous animal species are found within Virgin Islands National Park. A complete list is provided in Appendix B. The species that have the most significant impacts on natural communities and processes are the domestic cat, Norway and black rat, West Indian mongoose, domestic goat, domestic sheep, wild hog, and donkey (NPS 2002; 2003; 2004). Table 4 provides an overview of the origin, distribution, relevant behavioral characteristics, and impacts of each of these species. A more detailed discussion on the impacts of non-indigenous species to floral composition is presented below.

Non-native goats and sheep are selective browsers, preferentially eating certain plants and leaving others (NPS 2004). Goats and sheep tend to graze small shrubs and grasses very close to the ground, and often tear the roots from the substrate, preventing regeneration and accelerating topsoil loss and erosion (NPS 2004). Goat and sheep herds are capable of denuding large areas of land of all vegetation, including trees (through bark stripping) and cacti (NPS 2004). The most fragile forest community on the island is the dry forest, which predominates, in the southeastern portion of the island. These communities may have the smallest possibility for recovery, and both their species composition and total individual numbers are low. In addition, the steep semi-barren cliffs that dominate this area are preferred habitat for the goat. Precious topsoil that is lost during grazing activities can degrade the coral reefs found in submerged areas below the cliffs (NPS 2004).

Direct impacts to threatened and endangered plant species include herbivory and trampling, crushing, and uprooting of vegetation by non-native goats, sheep, donkeys, and wild hogs (NPS 2003; 2004). These non-native species consume the two federally listed plant species found on St. John, the prickly-ash (*Zanthoxyllum thomasianum*) and St. Thomas lidflower (*Calyptranthes thomasiana*). Marron bacora (*Solanum conocarpum)*, a rare plant found only on St. John, is also consumed by goats, sheep, and wild hog. Marron bacora was proposed for listing under the ESA in 1998, but in 2006 the U.S. Fish and Wildlife Service (USFWS) announced its decision that the plant did not warrant protection under the law (USFWS 2006).

Goats, sheep, and wild hogs also forage on seedlings of three mangrove species, which are protected under Virgin Islands law (NPS 2003; 2004). Their trampling and grazing disturbs soil surface layers and contribute to erosion and sedimentation in mangrove habitats found in Cruz Bay, Mary's Creek, Haulover Bay, Newfound Bay, Hurricane Hole, Coral Harbor, and Fish Bay (NPS 2003; 2004).

Herbivory and direct disturbance to vegetation (trampling, crushing, and uprooting) by goats, sheep, wild hogs, and donkeys negatively affect territorially protected plant species such as *Cyposelia humifusa*, Urban's holly (*Ilex urbanii*), Central American oak (*Ilex sideroxyloides*), pinion (*Tillandsia lineatispica*), wooly nipple (*Mammilaria nivosa*), *Croton fishlockii*, Egger's cockspur (*Erythrina eggersii*), Egger's galactia (*Galacteria eggersii*), cowage cherry (*Malpighia woodburyana*), *Malpighia linearis*, *Byrsonima* sp., *Psidium* sp., *Eugenia* sp., *Schoepfia schreberi*, Christmas orchid *(Encyclia ciliare*), yellow dancing lady (*Tolumnia prionochila*), white dancing lady (*Tolumnia variegatum*), *Ponthieva racemosa, Prescottia oligantha*, *Prescottia stachyoides*, *Tetramicra canaliculata,* myrtle-leaved peperomia (*Peperomia myrtifolia*), *Machaonia woodburyana*, bulletwood (*Manilkara bidentata*), and *Solanum mucronatum* (NPS 2003; 2004). Because the rarity of these listed plant species is defined by their limited numbers, even relatively small impacts can have a large detrimental effect (NPS 2003; 2004). Individual plants lost through predation, trampling, or uprooting cannot contribute offspring to the succeeding generation. This results in a loss to the next

Table 4. Summary of Significant Impacts of Non-indigenous Animals					
Common Name	**Scientific Name**	**Introduced When/By?**	**Distribution**	**Characteristics**	**Impacts**
Norway or brown rat	*Rattus norvegicus*	1700s or earlier by European explorers	Found across St. John – can live in a variety of habitats; largest populations near Cinnamon and Trunk Bays	Eats almost anything; has no natural predators on the island; high reproductive rates	Affects the distribution and abundance of native and non-native species through predation and competition
Black, roof, or tree rat	*Rattus rattus*	Existed on St. John since earliest records; possibly introduced by Taino Indians from South America	Found across St. John – can live in a variety of habitats; largest populations near Cinnamon and Trunk Bay	Eats almost anything; has no natural predators on the island; high reproductive rates	Affects the distribution and abundance of native and non-native species through predation and competition
Domestic cat	*Felis domesticus*	Date unknown; Europeans	Found across St. John; largest populations near Cinnamon and Trunk Bays	Feeding by humans increases population; hunts for food and fun; wildlife predation by cats is most pronounced in island settings (actual islands or islands of habitat)	High predation on reptiles and ground/shrub-nesting birds; vectors for parasites and disease

Table 4. Summary of Significant Impacts of Non-indigenous Animals

Common Name	Scientific Name	Introduced When/By?	Distribution	Characteristics	Impacts
West Indian mongoose	*Herpestes auropunctatus*	1880s by European planters as a biological control to reduce tree rat population	Scattered across St. John; estimated population of 330-400, concentrated in heavily populated or used areas of north shore	No biological predators; populations can grow very quickly if food is available	Impacts to reptile and bird populations (eat eggs), as well as the endangered Hawksbill sea turtle (eat eggs and emergent hatchlings); carry rabies
Domestic goat	*Capra hirus*	1718 by Danes	Population estimated at 600-1000 animals impacting 95% of park, including most sensitive and rare forest habitat types	Selective browsers; prefer shrubs and grasses near ground; often tear root structure during feeding, preventing regeneration	Selectively graze dry tropical forest (most sensitive on St. John) - this community is rare, has few individuals, and low possibility of recovery; grazing in certain areas erodes topsoil, which can enter marine systems and degrade reefs; capable of denuding large areas of vegetation; disperse seeds of exotic grasses and weeds on coats and through feces; trample vegetation creating bare areas suitable for the establishment of non-native plant species

Table 4. Summary of Significant Impacts of Non-indigenous Animals					
Common Name	**Scientific Name**	**Introduced When/By?**	**Distribution**	**Characteristics**	**Impacts**
Domestic sheep	*Ovis aries*	1718 by Danes	Across island in all habitat types; less common than domestic goat (estimated population of 50 individuals)	Selective browsers; prefer shrubs and grasses near ground; often tear root structure during feeding, preventing regeneration	Selectively graze dry tropical forest (most sensitive on St. John) - this community is rare, has few individuals, and low possibility of recovery; grazing in certain areas erodes topsoil, which can enter marine systems and degrade reefs; capable of denuding large areas of vegetation; disperse seeds of exotic grasses and weeds on coats and through feces; trample vegetation creating bare areas suitable for the establishment of non-native plant species
Wild hog	*Sus scrofa*	1718 by Danes	Found in 4 watersheds (Reef, Lameshur, Cinnamon, and Maho); all habitat types; populations oscillate widely between climatic episodes (200-300 estimated during drought conditions; 800 during normal rainfall)	Successful because they have no natural predators on the island, have high reproductive rates, and are opportunistic omnivores	Rooting behavior disrupts natural communities, individual species populations, forest succession patterns, and forest nutrient cycles; rooting causes soil erosion; negatively impact fauna through predation, habitat alteration, and competition for food; carry infectious and parasitic diseases

Table 4. Summary of Significant Impacts of Non-indigenous Animals					
Common Name	**Scientific Name**	**Introduced When/By?**	**Distribution**	**Characteristics**	**Impacts**
Donkey	*Equus asinus*	Introduced by Europeans during the plantation era for transportation and to operate sugar mills	Across island; researchers have estimated that population could reach 2000-3000 by 2015 unless population controls are implemented	Herbivorous; no current program to control population but donkey exclusion fences have been used in some areas of the park to limit damage to native communties	Selectively graze certain species such as black mangrove saplings; direct disturbance (e.g., trampling and uprooting) could impact rare and/or protected plant species

Sources: NPS 2002, 2003, 2004; Boulon 1999; USVI DFW 2005 generation of both absolute numbers and potential genetic diversity. A decrease in genetic diversity can lead to an overall decrease in evolutionary fitness for a species. Decreased population numbers lead to increased potential for extirpation from continued predation or from large random disturbance events such as hurricanes or drought. Local extirpation of certain plants is possible if a population is exposed to damaging hog rooting (NPS 2003).

Indirect effects to listed threatened and endangered plant species by non-native goats and sheep include alterations in listed plant micro-habitats, soil erosion, and facilitation of the spread of invasive, nonnative plants into the habitats of listed plant species (NPS 2004). Disturbances caused by goats and sheep in and around listed plant occurrences can lead to increased erosion. This increased erosion can expose the roots of listed plant species inhibiting water and nutrient uptake or in severe cases completely uproot individual plants. Disturbances caused by goat and sheep foraging and grazing can also facilitate the spread of invasive, non-native plant species within listed plant occurrences (NPS 2004). Invasive, non-native plant species can out-compete native plant species, including listed plants, for available nutrients and water. This can lead to the local extirpation of listed plant occurrences.

Goats and sheep excrete excess nutrients and waste in the form of urine and feces (NPS 2004). Nitrogenous organic compounds in urine can chemically burn (over-fertilize) individual threatened and endangered listed plants and alter the micro-habitat around the point of urination. Goat and sheep feces can cover individual listed plants blocking their access to sunlight and reducing the plant's vigor and health (NPS 2004).

When searching for food and shelter, goats, sheep, and wild hogs create winding trails through plant communities (NPS 2003; 2004). These paths compact the soil and contribute to increased water runoff, erosion, and nutrient loading to nearby marine resources. These paths can also serve as routes for the spread of invasive, non-native plant species. Hogs rooting on maintained park trails have caused extensive damage, exacerbated erosion, and affected visitor safety. In one case, hog rooting caused $50,000 worth of damage to the Reef Bay Trail (NPS 2003).

The effects of wild hogs on park resources result from their movements, habitat utilization, and food habits (NPS 2003). Of greatest concern are the destructive effects hogs have on natural ecosystems and native components of those ecosystems. Hog rooting behavior profoundly disrupts natural communities, individual species populations, forest successional patterns, and forest nutrient cycles (NPS 2003). Rooting adjacent to water bodies often results in high rates of soil erosion, which severely affects aquatic habitats (NPS 2003).

Hog rooting in dry evergreen woodlands, dry evergreen scrub, thorn and cactus scrub, moist forest formations, early successional vegetation, and coastal wetlands may reduce understory cover by as much as 95 percent of normal ground density, resulting in changes in forest structure and composition (NPS 2003).

Disturbances caused by hog rooting and movement through island vegetation may facilitate the spread of non-native, invasive plant species, which have adaptive mechanisms that allow them to avoid being grazed or to better survive the impacts of grazing (NPS 2003). These non-native plant species have expanded in the presence of goats and hogs on St. John at the expense of the island's native flora (NPS 2003). The presence of hogs likely benefits these undesirable species because exotic plants are widely dispersed through their feces.

Wild hogs are opportunistic omnivores and will eat almost any plant species (NPS 2003). They do so by uprooting and denuding large areas of vegetation. After eating most of the uprooted vegetation, the hog often continues to dig with its large and powerful snout. The associated digging activities in search of roots causes disturbance to the soil. This can result in increased soil erosion and changes in the forest understory layer by killing tree seedlings and trampling herbaceous plants (NPS 2003). Longer-term changes could result in the overstory layer if tree recruitment is affected by the removal of young trees (NPS 2003).

Faunal Composition

The only native mammal of St. John is the bat, of which six species occur on the island: the red fig-eating bat (*Stenoderma rufum*), greater bulldog bat (*Noctilio leporinus*), Jamaican fruit-eating bat (*Artibeus jamaicensis*), Antillean fruit-eating bat (*Brachyphylla cavernarum*), velvety free-tailed bat (*Molossus molossus*), and Brazilian free-tailed bat (*Tadarida brasiliensis*) (Boulon 1999; USVI DFW 2005). The rare frugivorous red fig-eating bat is endemic to the U.S. Virgin Islands, and the only known population of insectivorous Brazilian free-tailed bat throughout the U.S. Virgin Islands is on St. John (USVI DFW 2005). The red fig-eating bat, greater bulldog bat, and Antillean fruit-eating bat are protected under the Virgin Islands Endangered and Indigenous Species Act of 1990 (Act No. 5665). Bats occupy most terrestrial environments and roost in a variety of places including trees, caves, and human-built structures. Beacause they are important pollinators of many native floral species of St. John, as well as important seed dispersal agents for fruit-bearing trees and shrubs, they are regarded as keystone species by park managers (Boulon, pers. comm, 2006). The primary threats to bat populations include loss, fragmentation, and degradation of habitat and direct take by humans (USVI DFW 2005). SFCN I&M is coordinating a study on the bat populations of St. John that is expected to be complete by 2007.

Numerous exotic mammals are also found within the park, including white-tail deer, donkeys, pigs, goats, cows, wild pigs, West Indian mongoose, rats, and cats. A complete list of introduced species can be found in Appendix B.

Bird species are abundant and varied throughout the U.S. Virgin Islands. An inventory of birds found in Virgin Islands National Park and Virgin Islands Coral Reef National Monument is not currently available, but in 2005 the U.S. Virgin Islands Division of Fish and Wildlife (USVI DFW) published the *Comprehensive Wildlife Conservation Strategy for the U.S. Virgin Islands*, which includes information on bird species found in the region (USVI DFW 2005). Because of the transient nature of birds and the close proximity of the three main U.S. Virgin Islands and associated cays, it can be assumed that many of the bird species discussed in the strategy would likely be found within the park and monument.

Thirty-nine species of seabirds have been recorded in the U.S. Virgin Islands (USVI DFW 2005). Boobies (family Sulidae), pelicans (Pelecanidae), and frigatebirds (Fregatidae) are present year-round, although seasonal in their nesting activities (USVI DFW 2005). In contrast, most petrels, shearwaters (Procellariidae), storm-petrels (Hydrobatidae), tropicbirds (Phaethontidae), jaegers, gulls, and terns (Laridae) are present only during migratory or breeding seasons (USVI DFW 2005). Little is known about the offshore distribution of many of these species. Most seabirds nest on cays and are piscivorous. The brown pelican (*Pelecanus occidentalis*) is federally listed as endangered and the roseate tern (*Sterna dougailii*) is federally listed as threatened under the ESA. Threats to seabird populations include predation by introduced species such as rats, human disturbance, and declining availability of fish as a food resource due to overfishing and marine habitat degradation (USVI DFW 2005).

Twenty-three species of waterfowl (family Anatidae); 23 species of marshbirds, including grebes (Podicipedidae), waders (Ardeidae, Threskiornithidae, and Poenicopteridae), and rails, gallinules, and coots (Rallidae); and 37 species of shorebirds (families Charadriidae, Haematopidae, Recurvirostridae, and Scolopacidae) are found in the U.S. Virgin Islands (USVI DFW 2005). The major threats to waterfowl, marshbird, and shorebird populations are habitat destruction (particularly coastal salt ponds and lagoons), beach development, human recreational use of beaches, and predation by mongoose and other non-indigenous species (USVI DFW 2005). The federally endangered piping plover (*Charadrius melodus*) occurs on St. John as a non-breeding vagrant during winter (USVI DFW 2005).

At least 59 species of Nearctic landbird migrants have been recorded in the U.S. Virgin Islands, including five raptors (families Accipitridae and Falconidae), one cuckoo (Cuculidae), two nightjars (Caprimulgidae), one swift (Apodidae), one kingfisher (Alcedinidae), one woodpecker (Picidae), one flycatcher (Tyrannidae), three vireos (Vireonidae), six swallows (Hirundinidae), two thrushes (Turdidae), 30 warblers (Parulidae), one tanager (Thraupidae), three grosbeaks and buntings (Cardinalidae), and two blackbirds (Icteridae) (USVI DFW 2005). Many Nearctic migratory landbirds, particularly warblers, utilize the mature intact forests of St. John as overwintering grounds (USVI DFW 2005). Kirtland's warbler (*Dendroica kirtlandii)* and the peregrine falcon *(Falco peregrinus)* are both federally listed endangered species that may be found on St. John.

Seventeen resident landbirds are also known to exist in the U.S. Virgin Islands, including one hawk (family Accipitridae), one falcon (Falconidae), two cuckoos (Cuculidae), one owl (Strigidae), three hummingbirds (Trochilidae), three flycatchers (Tyrannidae), two mimids (Mimidae), one warbler (Parulidae), one bananaquit (Genus *Incertae Sedis*), and two seed-eating finches (Emberizidae) (USVI DFW 2005). In addition, ten species of pigeons and doves (family Columbidae) have been recorded (USVI DFW 2005).

Loss, fragmentation, and degradation of habitat are the primary threats to landbirds. Other threats include predation by non-indigenous species, collisions with vehicles and man-made structures, and poisoning by herbicides, insecticides, and other chemicals (USVI DFW 2005).

Terrestrial amphibians and reptiles on St. John are also quite varied. Recently, USGS completed a herpetological survey of the island (Rice et al. 2005). Outcomes of the survey included species lists for reptiles and amphibians, as well as information on population status for amphibian species. Three native species of frogs, the Antillean frog (*Eleutherodactylus antilliensis*), whistling frog (*E. cochranae*), and white-lipped frog (*Leptodactylus albilabris*), as well as three introduced frog species, the Cuban tree frog (*Osteopilus septrionalis*), mute frog (*E. lentus*), and common coqui (*Eleutherodactylus* *coqui*) were found within park boundaries (Rice et al. 2005). Two potentially present toad species, the non-indigenous marine toad (*Bufo marinus*) and threatened Puerto Rican crested toad (*B. lemur*), were not detected during the USGS survey (Rice et al. 2005). The researchers concluded that amphibian populations in the park are very healthy. The Antillean frog was the most common amphibian detected during the surveys (Rice et al. 2005). Along with the whistling frog, it was found in every habitat type across the island. Of concern to the researchers was the presence of the Cuban tree frog. This species preys on other frogs and can out-compete other species for limited food supplies. The USGS researchers have predicted that the Cuban tree frog population will continue to grow and spread across the island (Rice et al. 2005).

The following species of reptiles were detected during the USGS survey: Amerafrican house gecko (*Hemidactylus mabouia*), common dwarf gecko (*Sphaerodactylus macrolepis*), Peurto Rican crested anole (*Anolis cristatellus),* salmon lizard (*A. stratulus*), sharp-mouthed lizard (*A. pulchellus*), green iguana (*Iguana iguana*), common ground lizard (*Ameiva exsul*), and Virgin Islands blind snake (*Amphisbaena fenestrata*) (Rice et al. 2005). The researchers also described three additional reptiles that were not detected during the survey, but for which there is sufficient evidence to presume their existence on St. John: the red-footed tortoise (*Geochelone carbonaria*), garden snake (*Arrhyton exiguum exiguum*), and common worm snake (*Typhlops richardi*) (Rice et al. 2005). The presence of two additional reptiles, the Puerto Rican racer (*Alsophis portoricensis*) and slipperyback skink (*Mabuya mabouya*), has been documented in other park reports (Boulon 1999).

The three species of *Anolis* lizards can be found across the island and are the most common reptiles found in the park (Rice et al. 2005). The green iguana, house gecko, and red-footed tortoise are all introduced species, but according to the USGS survey report, do not appear to be having negative effects on native flora or fauna (Rice et al. 2005). Because the methods utilized in the USGS survey were more suitable for amphibian populations, the researchers have recommended that additional studies on reptile populations be undertaken.

The dominant terrestrial life form on St. John is the invertebrate fauna, including a wide range of tropical species of snails, slugs, crabs, spiders, scorpions, centipedes, millipedes, and insects (USVI DFW 2005). In 1987, 232 species of invertebrates representing 124 families were identified on the island (Boulon 1999). Arachnida (scorpions, pseudoscorpions, harvestmen, spiders) is the largest order. Thirteen species of dragonflies and damselflies (Odonata) have been documented in the park, and over 1,500 species of beetles have been identified in the Virgin Islands, most of which could be expected to be found within the park. Ghost crabs (*Ocypode quadrata*) are common on sandy beaches, where they dig burrows near the high tide mark (USVI DFW 2005). Blue crabs (*Callinectes sapidus*) and semi-aquatic mangrove crabs (*Aratus pisonii*) and fiddler crabs (*Uca* spp.) are found in salt ponds, mangroves, and lagoons (USVI DFW 2005). Soldier (hermit) crabs (*Coenobita clypeatus*) are terrestrial except during the breeding phase, and occur in coastal scrub and mangrove, riparian, and upland forest areas of the park (USVI DFW 2005). Three species of scorpions have been identified on St. John: *Heteronebo yntemai*, *Microtityus waeringi*, and *Centuroides griseus* (USVI DFW 2005). Additionally, a variety of spiders such as the tarantula (*Cyrtopholis bartholomei*) and golden weaver spider (*Nephilia clavipes*) are found on St. John (USVI DFW 2005). Additional inventories covering a greater number of families are needed to more fully document the species and distributions of invertebrates within the park.

Of the 24,618 known fish species in the world, more than 400 reef-associated or inshore-ranging pelagic species are found in the nearshore waters surrounding St. John (Garrison 1998). The two most important herbivorous fish families on Caribbean reefs in terms of density, biomass, and impact on the macrophyte (large aquatic plant) community are the family Scaridae (parrot fish) and the family Acanthuridae (surgeonfish) (USVI DFW 2005b). Examples of parrot fish include the rainbow parrotfish (*Scarus guacamaia*) and queen parrotfish, (*Scarus vetula*). Examples of surgeonfish include the ocean surgeonfish (*Acanthurus bahianus*) and blue tang (*Acanthurus coeruleus*). Both of these families face strong fishing pressure in waters around the U.S. Virgin Islands (USVI DFW 2005b).

"Aggregating fish predators" are also important components of Caribbean reef systems (USVI DFW 2005b). In this context, aggregating fish predators does not refer to fish that feed in large groups, but to large piscivorous fish that are solitary hunters, but must gather in large aggregations to effectively reproduce. This group primarily includes snappers (Lutjanidae) and groupers or sea bass (Serranidae) (USVI DFW 2005b). Some examples of the family Serranidae that have historically inhabited the waters around St. John include the Nassau grouper (*Epinephelus striatus*), coneys (*Epinephelus fulvus*), red hinds (*Epinephelus guttatus*), rock hinds (*Epinephelus adscensionis*), tiger groupers (*Mycteroperca tigris*), and graysbys (*Epinephelus cruentatus*). The Nassau grouper is considered a keystone species in the marine environment around St. John (Boulon, pers.

comm., 2006). Unfortunately, the likelihood of encountering mature adults of the Nassau grouper or any other species of Serranidae has decreased due to a variety of stresses, including commercial and recreational fishing pressure (USVI DFW 2005b). Examples of snappers found in Caribbean reefs include mutton snapper (*Lutjanus analis*), schoolmasters (*Lutjanus apodus*), mangrove or gray snappers (*Lutjanus griseus*), lane snappers (*Lutjanus synagris*), cubera (*Lutjanus cyanopterus*), and yellow-tail snappers (*Ocyurus chrysurus*).

For many fish species in the region, including the foureye-butterflyfish (*Chaetodon capistratus*) and the butter hamlet (*Hypoplectrus unicolor*), coral reefs provide shelter from predation, a source of food, and a place to spawn. Juvenile fishes of many species (such as the great barracuda [*Sphyraena barracuda*] and gray snapper) find shelter amidst red mangrove prop roots. Some species, such as the bucktooth parrotfish (*Sparisoma radians*) and fringed filefish (*Monocanthus ciliatus*) live their entire lives in seagrass beds, whereas other species use the seagrass beds as nursery areas (such as French grunts [*Haemulon flavolineatum*]) or for nocturnal feeding (many snappers and grunts) (Garrison 1998). Even habitats dominated by gorgonians, sand, or algae are essential for some fishes, including the scrawled filefish (*Aluterus scriptus*), which feeds on gorgonians; the spotted snake eel (*Ophichtus ophis*), which lives in sand; and the chalk bass (*Serranus tortugarum*), which lives on the algal plain (Garrison 1998).

A wide variety of marine invertebrates are also found in the waters of Virgin Islands National Park and Virgin Islands Coral Reef National Monument. This diverse group of organisms includes sponges, a variety of reef-building (hermatypic) and non-reef building (ahermatypic) corals, anemones, annelid worms, mollusks, arthropods, bryozoans, echinoderms, and tunicates (USVI DFW 2005b). Harvestable invertebrate species include the Caribbean spiny lobster (*Panulirus argus*), queen conch (*Strombus gigas*), and whelk (*Cittarium pica*) (USVI DFW 2005b).

Marine mammal abundances and distributions in U.S. territorial waters of the Caribbean are poorly understood. At least 17 species of whales and dolphins have been reported in the region including the federally endangered humpback whale (*Megaptera novaeangliae*) and West Indian manatee (*Trichechus manatus*) (USVI DFW 2005b). The area provides feeding grounds for some marine mammal species, and reproductive grounds for others. Most cetacean species in this area are sighted during the winter and early spring, with an increase in sightings beginning in December, peaking in February, and gradually decreasing in March and April (USVI DFW 2005b). There are few sightings from May through November. Additionally, some species do not migrate but utilize northwestern Caribbean waters for feeding and reproduction throughout the year (USVI DFW 2005b).

Two federally listed sea turtles are commonly found in park and monument waters (Boulon 1999). The hawksbill sea turtle (*Eretmochelys imbricate*) requires coral reefs for food and refuge. Peak nesting season on park beaches is from July through November, although nesting activity may take place any month of the year. Green sea turtles (*Chelonia mydas*) are found in seagrass beds in park waters, but they infrequently nest on St. John beaches. The federally listed leatherback sea turtle may also be found in park and monument waters (*Dermochelys coriacea*) (Boulon 1999).

A number of threatened and endangered species are known or believed to occur in the park and monument. A list of these species is provided above in Table 2.

Additionally, the park is inhabited by a number of non-indigenous mammals, birds, amphibians, and reptiles. A complete list of non-indigenous species is included in Appendix B.

Threats to Species Composition – Fauna

Human poaching of threatened and endangered sea turtles and their eggs may be a problem in remote areas of the park. Sea turtle products, mostly hawksbill shells, are the most commonly confiscated products by the U.S. Customs at United States borders (Boulon 1999).

Humans are also potential poachers of endangered and threatened seabird eggs (brown pelican and roseate tern) in remote areas. Disturbance by human visitation to offshore cays results in low egg production, death of chicks to sun exposure, or even abandonment of the whole nesting colony. Decreases in baitfish populations due to overfishing may limit nesting populations and affect the breeding and fledging success of these birds (Boulon 1999).

Sea turtle mortality due to boat strikes has significantly increased over the last fifteen years (Boulon, 1999). In some years, over half of all reported turtle strandings involved damage to the carapace from boat propellers or hulls. Increasing populations of juvenile green turtles and increasing numbers of high-speed powerboats result in increased numbers of incidental mortalities. The numbers of high-speed boats traveling along the north shore of St. John en route to the British Virgin Islands continues to increase.

While other parts of the world (e.g., southeast U.S., Hawaii) have been reporting large numbers of green turtles affected with fibropapillomas, the U.S. Virgin Islands has only had a few reports of individuals having this disease (Boulon 1999). However, reports of infected turtles are on the increase and sizes of reported tumors are also increasing (Boulon 1999). This may become a significant concern if this disease starts to affect a large segment of the turtle population.

Both natural events and human activities can directly kill fish and degrade marine habitats, resulting in adverse effects to habitat-dependent species. When Hurricane Hugo swept through the Virgin Islands in September 1989, the total abundance of fishes and number of species on two St. John reefs decreased significantly for 2 to 3 months after the storm (Garrison 1998). Analyses of fisheries have shown a change in the relative abundance of reef fish species, a change in the species composition, a decrease in the numbers of many species of fishes, and a decrease in the size of fishes in the waters around St. John (Garrison 1998). Overfishing and habitat degradation are the primary causes of the decrease in fish populations (Garrison 1998).

Since 1992, the USGS-Biological Resource Division has coordinated an assessment of the effects of fishing on reef fish and conducted monitoring of reef fish populations at selected sites. The goal of the assessment and monitoring program are to determine trends in species composition, abundance, and size of fish, as well as effectiveness of park fishing regulations (Boulon 1999). Results indicate that fish traps significantly reduce the numbers of fish, change the relative abundances of species, and decrease the mean sizes of individuals on St. John reefs (Boulon 1999). Larger species such as groupers and snappers have all but disappeared, and those that are caught are below size at sexual maturity, indicating that recruitment overfishing is occurring (Boulon 1999). Populations of reef fish inside and outside the park are not significantly different, suggesting that park regulations are not protecting the resource (Boulon 1999).

The native wildlife of island ecosystems is particularly susceptible to impacts of non-indigenous species (e.g., competition, altered food webs, and predation). Of the 484 recorded animal extinctions since 1600, 75 percent have been island endemics (NPS 2002). Of the 147 cases where the cause of extinction could be determined, researchers concluded that introduced species were completely or partially responsible in 67 percent of the cases (NPS 2002).

Numerous non-indigenous species are found within Virgin Islands National Park. A complete list is provided in Appendix B. The species that have the most significant impacts on natural communities and processes are the domestic cat, Norway and black rat, West Indian mongoose, domestic goat, domestic sheep, wild hog, and donkey. Table 4 provides an overview of the origin, distribution, relevant behavioral characteristics, and impacts of each of these species. A more detailed discussion of impacts of non-indigenous species to faunal composition is presented below.

Large numbers of wildlife are lost each year on St. John to relatively small non-native rat, cat and mongoose populations (NPS 2002). Small islands typically have both smaller resident wildlife populations and lower species diversity, making the cumulative impact of these losses even more significant (NPS 2002). This is particularly true on very small and highly fragmented islands such as St. John, because negative impacts are concentrated.

Because reptiles, amphibians, and invertebrates, such as insects, are small, often slow, and readily available within the park, they are particularly susceptible to local extinction from non-native rat, cat, mongoose, and wild hog depredation (NPS 2002; 2003). This is a concern not only due to the direct impacts associated with the decline and potential local extinction of individual species, but because of the importance of reptiles, amphibians, and invertebrates to the ecological web of the island (NPS 2002; 2003). Non-native rats, cats, mongoose, and wild hogs prey upon frogs, geckos, *Anolis* lizards, ground lizards, legless lizards, blind snakes, Puerto Rican racers, and slipperyback skinks (NPS 2002; 2003). The Park contains over 232 common insect species, including 13 species of dragonflies and damselflies and over 1,500 beetle species; all of which may be eaten by rats, cats and mongooses.

Non-native rats, cats, and mongoose also prey upon endangered hawksbill and leatherback sea turtles that nest on St. John (NPS 2002). They kill emergent hatchlings as they crawl from the nest to the ocean at night, and also prey upon sea turtle nests soon after being laid, eating many eggs and spoiling the remaining ones. Mongoose predation accounts for up to a 23 percent loss of sea turtle eggs (Boulon 1999). Non-native rats, cats and mongooses also prey upon chicks, juveniles, and adults of most bird species that nest on St. John (NPS 2002). Of particular concern is predation of the federally endangered brown pelican and threatened roseate tern and territorially endangered bird species such as the bridled quail dove, Bahama pintail duck, and Antillean mango hummingbird. Several native bat species on the island are also preyed upon by rats, cats, and mongoose (NPS 2002).

Goats, sheep, and wild hogs are in direct competition with small animals for insects, earthworms, and other invertebrates and also compete with native species for other available food resources, especially hard mast (NPS 2004). In addition, selective herbivory of plant species by non-indigenous grazers is altering natural plant communities, which impacts the wildlife dependent on those communities by reducing available food and altering microhabitats (NPS 2004).

Hogs prey upon one territorially endangered and threatened animal species, the slipperyback skink (*Mabuya inabouia*) (NPS 2003). Areas uprooted by hogs undergo notable declines in small mammal and reptile populations (NPS 2003). Hogs may consume the eggs, chicks and adults of such territorially endangered species as the bridled quail dove, Bahama pintail duck, and West Indian nighthawk.

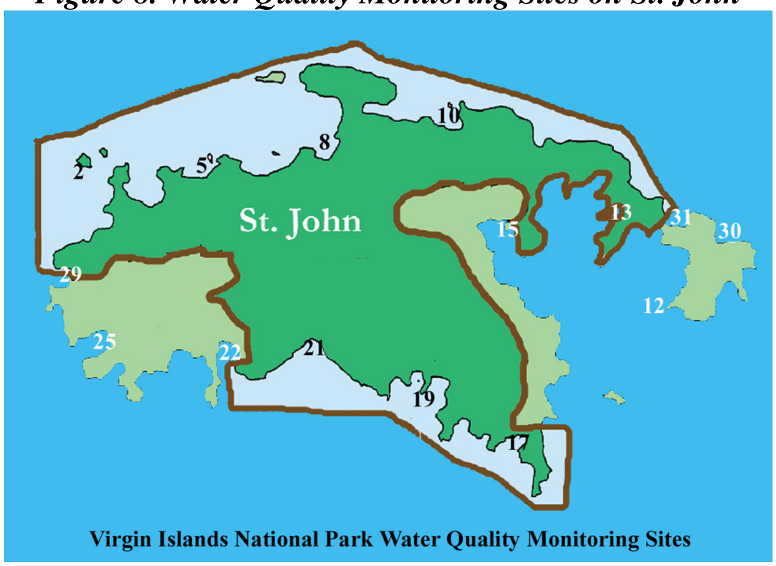
Wild hogs also serve as co-hosts with native wildlife and livestock for infectious and parasitic diseases such as hog cholera, swine brucellosis, trichinosis, foot and mouth disease, African swine fever, and pseudo-rabies (NPS 2003).

B. Environmental Quality and Biotic Health

i. Water Resources

A water quality monitoring program was established on St. John in 1988 to monitor water quality within and outside of the Virgin Islands National Park. Originally, 31 monitoring sites were established, but this was reduced to 15 in 1995 due to lack of funding and staff resources (Boulon 1999). Resource management staff sample the 15 sites every three months and monitor for turbidity, dissolved oxygen, temperature, salinity, transmittance, turbidity (NTUs), cloud cover, wind speed, sea state, conductivity, pH, total suspended solids, spectroradiometry at one meter and bottom, transmissivity, and micronutrient analysis (nitrates, ammonia, phosphates) (Garrison 2002). As development has increased on St. John, park staff have added chlorophyll a and bacteria testing (Boulon 1999). Currently there are no freshwater monitoring sites. Figure 8 shows the location of monitoring sites inside and outside the park boundaries marked by the dark brown line.

Figure 8. Water Quality Monitoring Sites on St. John



Source: Garrison 2002

In 1995, a summary of water quality was compiled using the Environmental Protection Agency (EPA) Storage and Retrieval (STORET) water quality database management system. This effort was between the NPS Servicewide Inventory and Monitoring Program, the NPS Water Resources Division (WRD), and Horizon Systems Corporation (NPS WRD 1995). The results of the STORET retrieval for the study area yielded 32,868 observations for 70 separate parameters tested by NPS and EPA Region 2 at 101 monitoring stations. Of the 101 monitoring stations, six were established by the EPA but contained no data. Forty-seven stations were located within the park boundary.

About half of the sampling stations represent either one-time or intensive single-year sampling efforts by the collecting agencies. Fifty-one stations within the study area yielded longer-term records consisting of multiple observations for several important water quality parameters, twenty six of these were within the park. The results of the Virgin Islands National Park water quality criteria screen found five parameters that exceeded screening criteria at least once within the study area. Copper, mercury, and zinc exceeded their respective EPA acute criteria for the protection of marine aquatic life. Total coliform and fecal coliform concentrations exceeded the WRD screening limits for bathing water (NPS WRD 1995).

One possible source of bacteria pollution could be from septic tank use throughout St. John. During large rain events, many septic tanks overflow into nearshore waters and can result in occasional algal blooms (Carter et al. 2001). Higher pollution levels are also expected in developed watersheds such as the main town of Cruz Bay, St. John. As development pressure increases in adjacent park lands, the threat to water quality from anthropogenic sources will also increase. Unpaved roads on St. John are a significant contributor to the sedimentation problems that are affecting the coastal waters (Boulon 1999). These unpaved roads deliver about 1-2 centimeters per year of sediment to the nearshore environment (Boulon 1999). Excess sediment can smother coral reefs, blocking sunlight from reaching the symbiotic photosynthetic algae residing in coral species (Rogers 1998). Without the presence of these algae, coral species will eventually die (Rogers 1998). Sediment runoff from roads as well as development of inholdings has resulted in an overall increase in turbidity and nutrient loading of park marine waters (Boulon 1999). Stricter regulations for construction buffers and septic tank placement and capacity could minimize some of these impacts. Nutrients carried in runoff has caused occasional localized algal blooms, but park staff do not feel that these blooms pose a significant threat due their limited occurrence (Boulon, pers. comm., 2006b).

The water quality for freshwater habitats on St. John has not been measured and a program needs to be developed to include these habitats, which support several species of fish, invertebrates, and aquatic plants. These fragile systems include ephemeral streams and freshwater pools. They are poorly studied and in danger of disappearing completely (Boulon 1999).

ii. Air Quality

Air quality is considered to be generally good in Virgin Islands National Park (Boulon 1999). It is considered a Class 1 air quality area and is part of the IMPROVE network. As part of IMPROVE, air quality has been monitored in the park using an aerosol sampler (2000 to present) and a nephelometer (1998 to present) (NPS 2005). The park has also been part of the CASTNet dry deposition and NADP/NTN wet deposition monitoring networks since 1998. These monitoring stations have not been in operation long enough to detect trends in the park. Ozone has been monitored in the park since 1998. These data show that ozone has not exceeded the 1-hour human health-based primary National Ambient Air Quality Standard (NAAQS), or any calculated 8-hour primary NAAQS (NPS 2005).

Visibility can be impaired during certain times of the year, as mentioned earlier, due to volcanic ash from Montserrat and dust events from the Saharan Desert in Northern Africa. African dust events are most prevalent in the summer months and can transport fungal spores, PCBs, nutrients, and other chemicals to the U.S. Virgin Islands (Garrison et al. 2003). Many coral disease outbreaks in the Caribbean have coincided with the largest dust event years (Garrison et al. 2003). Some coral diseases are caused by bacterial pathogens and fungal spores that are commonly transported on dust particles from the African desert (Garrison et al. 2003). Toxins and chemicals that have been applied in Africa as pesticides are also being transported to the Caribbean on dust particles and can negatively alter coral growth patterns and their resistance to disease (Garrison et al. 2003).

Another concern regarding air quality in the park is due to the fact that one of the world's largest oil refineries is located on the nearby island of St. Croix and can release large quantities of volatile organic compounds (Rogers 1997). However, there has yet been any evidence to show that these compounds are reaching the island of St. John (Rogers 1997).

iii. Soils and Sediments

There is a need for further research in soil chemistry and health on St. John. One study has measured and predicted erosion and sedimentation on St. John (Ramos-Scharron 2004). The soils of St. John were found to be shallow, moderately permeable, well-drained, and underlain by almost impervious surfaces or bedrock (Ramos-Scharron 2004). Heavy precipitation events on St. John can cause severe erosion events due to the steepness of the terrain. More than 80 percent of St. John's slopes are greater than 30 percent (Ramos-Scharron 2004). Additionally, erosion rates are high on St. John due to the large number of unpaved roads that still exist (Rogers 1997). Relatively intact and stable sediment can become susceptible to erosion as non-native wild hogs, goats, and sheep continue to graze in parklands (Rogers 1997). Erosion of sediment into nearshore waters can raise turbidity levels and cause significant damage to the coral reefs (Boulon 1999). Compaction can become an issue in developing areas that are susceptible to high-volume traffic. Many of the roads on St. John were not originally graded to handle the weight of newer, larger construction trucks, such as the concrete pouring vehicles that frequently travel throughout the park (Boulon 1999).

iv. Climate

Climate change can influence storm frequency and intensity, water and air temperatures, and sea levels (Carter et al. 2001). Over the past 100 years, the average annual air temperature in the Caribbean has increased by more than one degree Fahrenheit (Carter et al 2001). Relative sea level is showing a rising trend of about 3.9 inches per 100 years at sites being monitored throughout the Caribbean and Gulf of Mexico (Carter et al 2001). It is difficult to conclude what impact this could have, but there are models that suggest that rising sea level and surface water temperatures could lead to increasing wind speed and frequency of storms such as hurricanes and typhoons (Carter et al. 2001). Island ecosystems are particularly sensitive to changes in climate patterns due to their small size and isolation (Carter et al. 2001).

In an island system such as Virgin Islands National Park, the significant issues that should be considered when looking at climate change are freshwater drinking supply, public safety, protecting rare and unique ecosystems, and responding to sea level changes (Carter et al. 2001). The availability of freshwater resources is already limited in an island system. These islands have a lower elevation and receive less rainfall, which means that they retain less freshwater and have no perennial streams and limited groundwater resources (Carter et al. 2001). The tourism industry, agriculture, and private development all compete with the natural environment for these limited freshwater supplies. In the U.S. Virgin Islands, existing water supplies have been overused and remaining groundwater resources have been contaminated from sediment, leaky septic tanks, and wastewater facilities (Carter et al. 2001). An increase in hurricane activity could further degrade these resources by threatening saltwater intrusion into groundwater supplies (Carter et al. 2001).

Public safety is a concern with climate change projections because storms can directly damage infrastructure and lifeline systems that are typically built at low sea levels and near the coast in the U.S. Virgin Islands. Damage from storms to water supply, energy supply, waste management, sanitation, and medical services can be severe in isolated areas such as the U.S. Virgin Islands (Carter et al. 2001). As mentioned earlier, these islands are susceptible to flooding and landslide events with large amounts of rainfall that can also cause severe damage to basic island infrastructure.

A large portion of St. John was designated as a National Park and Biosphere Reserve due to the presence of unique and rare systems such as the dry tropical forest, mangroves, coral reefs, and seagrass habitats. Climatic changes may have a devastating effect on the unique ecosystems that exist in the park. Waves and winds can directly damage these resources, and increasing sea level and water temperatures may cause an increase in coral bleaching events, which make them more susceptible to disease (Miller and Patterson 2005). Coral reefs are believed to be the ecosystem most sensitive to climate change impacts (Carter et al. 2001). Terrestrial systems seem to recover quickly from events such as hurricanes, but an increase in frequency or intensity may limit recovery ability.

v. Biotic Health

The natural resources of Virgin Islands National Park are stressed in many ways (Boulon 1999). The land use practices of the sugar plantation era changed the landscape of St. John dramatically (Boulon 1999). National Park and Biosphere Reserve designation of the land on St. John has allowed for significant regrowth of native dry tropical forests, but they may never return to their original density. As mentioned earlier, grazing impacts from non-native animals and the presence of invasive non-native plants have also impeded the reforestation of these native forests (Boulon 1999). The natural resource staff at the park is undertaking efforts to reduce the impacts from these non-native species through sustainable reduction plans (NPS 2002; 2003; 2004). General vegetation removal occurs for trail and scenic vista maintenance, but there is still a need for the management of exotic plants affecting park resources.

Coral reefs in the Virgin Islands National Park are also under extreme pressure (Rogers 1988). Coral cover is decreasing in park and monument waters due to hurricanes and major storms, warmer than average water temperatures, coral disease, and damage from boat anchors and groundings (Rogers 1998). Improper land use planning on private inholdings within the park can increase sedimentation and pollution to nearshore waters, further stressing damaged coral reefs (Rogers 1988).

Poaching of both plant and animal species continues to occur within the park (Boulon 1999). Wild orchids and excessive wild vine poaching has become a problem on park lands (Boulon, pers. comm., 2006). Endangered sea turtles are also taken in neighboring British Virgin Islands waters, and egg poaching from park beaches still occurs (Boulon 1999). Rangers currently work in the park as enforcement staff and are in charge of the monitoring and protection of park resources. But due to limited resources and personnel, they are unable to effectively enforce park regulations (Boulon, pers. comm., 2006). There are five rangers currently employed, and park staff feel that three additional rangers would be adequate (Boulon, pers. comm., 2006b).

Feral and exotic animals can also cause significant damage to the parks natural resources. Mongoose predation has led to the decline of many ground nesting birds and reptiles, including endangered sea turtles (Boulon 1999). The population is too large to consider complete elimination, so current population reduction methods include trapping at certain sites such as sea turtle nests (Boulon 1999). Feral cats can also significantly alter populations of birds, frogs, and lizards (Boulon 1999). Feral cats are trapped and taken to the Humane Society on St. Thomas to reduce populations within the park (Boulon 1999).

Other animals such as goats, donkeys, and pigs are grazing on native vegetation that did not evolve in the presence of grazers and therefore has not developed any defense mechanisms (Boulon 1999). These animals are also spreading the seeds of exotic plants in their fecal matter, contributing to a change in the forest structure and species composition (Boulon 1999). Large populations of animals grazing along unpaved roads can also lead to increases erosion and sediment runoff to nearshore waters (Boulon 1999).

The most significant sources of stress on the overall biotic health of the park are from an increase in private development and increasing visitor impact (Allen 1992). As mentioned before, new development and unpaved roads during construction can cause significant erosion and sedimentation of nearshore areas. In addition to increasing development, visitation at Virgin Islands National Park is increasing every year, causing additional stress to the natural resources (Boulon 1999). Visitation to the park has increased from about 120,000 in the 1970s to over one million visitors annually today (Boulon, pers. comm, 2006). Many visitors spend their time in or near the water, where their impact is most severe (Boulon 1999). Direct impacts include damage to reefs and seagrass beds from snorkelers, divers, boat anchors, and boat groundings (Allen 1992). Indirect impacts include pollution from boat effluent, runoff from improper land use, septic tank seepage, and an increase in trash production (Allen 1992).

Many of these biotic impacts and stressors are being addressed by park natural resource staff in management activities mentioned earlier, such as the mooring system and sustainable reduction plans for non-native animal species.

IV. CONCLUSIONS AND RECOMMENDATIONS

This assessment has highlighted the significance of the natural resources present within Virgin Islands National Park and Virgin Islands Coral Reef National Monument, as well as the major threats to these resources. After a thorough review of park documents, management plans, and existing research conducted at the park, it can be concluded that there are many unique natural features and systems that should be maintained and protected from future degradation. The overall natural resource rating of this park is a 73 out of 100, which indicates a vulnerable status (refer to Appendix A). NPCA designates a vulnerable status to park units with fair estimated viability of ecosystems, but where natural resources are vulnerable to natural and anthropogenic threats.

A portion of the park was designated as a Biosphere Reserve in 1976, which emphasizes its international significance as a representative of the Lesser Antillean biogeographic province (Boulon 1999). With the addition of 5,650 acres of adjoining submerged lands in 1962 and the designation of the Coral Reef National Monument in 2001, Virgin Islands National Park contains examples of most tropical Atlantic terrestrial, coastal, and marine ecosystems including beaches, mangroves, salt ponds, seagrass beds, coral reefs, algal plains, and subtropical dry to moist forests (Boulon 1999).

These ecosystems are important to the natural health and diversity of the park, and current activities exist in and around the park that are threatening these critical systems. Forests are still trying to recover from the clear-cutting events of the sugar plantation era, while competing with invasive species and dealing with the grazing effects of non-native animals (Boulon 1999). Continuous development of lands adjacent to the park has increased sedimentation and pollution of nearshore habitats such as seagrass beds and coral reefs (Boulon 1999). In addition, the continuous rise in visitation to the park has negatively impacted these ecosystems through increasing boat and anchor damage, damage to coral from divers and snorkelers, cruise ship effluent, and septic tank overflows from land. Park managers have identified the main threats to the park, which are summarized in Table 5.

Table 5. Threats to Virgin Islands National Park

NATURAL RESOURCE	**THREATS**
CORAL REEFS	1) Natural disturbances; hurricanes, diseases, coral bleaching; 2) Non-point source pollution, runoff, sedimentation; 3) Boat grounding, anchor damage; 4) Pollution from boats, oil, gasoline, human waste
FISHERY RESOURCES	1) Overfishing of lobsters, conchs, groupers, snappers, bait fish; 2) Loss of habitat, e.g., damage to coral reefs and seagrass beds; 3) Oil spills, coastal water pollution
SEAGRASS BEDS	1) Anchor damage; 2) Pollution from boats; 3) Coastal development, dredging, construction, increases in sedimentation; 4) Oil spills; 5) Hurricanes
SEA TURTLES	1) Predation by mongoose on sea turtle hatchling and eggs; 2) Loss of nesting beaches to development and erosion; 3) Poaching of eggs and adults; 4) Loss of foraging habitat
COASTAL WATER QUALITY	1) Increase in sediment input associated with development; 2) Sewage; 3) Road construction; 4) Atmospheric deposition of nutrients associated with dust from Africa; 5) Oil spills and other hazardous substances
FORESTS	1) Development of private inholdings and land adjacent to park boundary; 2) Re-opening of old roads within park; 3) Clearing of steep hillsides (over 80% of island's slopes > 30 degrees)
NATIVE PLANTS	1) Encroachment of exotic plant species; 2) Grazing by feral animals and dispersal of exotic plant seeds
MANGROVE FORESTS	1) Foraging of pigs, donkeys and goats in mangrove forests; 2) Oil spills, coastal water pollution; 3) Conversion of wetlands and mangrove forests for development; 4) Natural disturbances: hurricanes, drought
BIRDS	1) Degradation and/or loss of mangrove and saltpond wetlands important to winter-resident birds; 2) Fragmentation and clearing of forests used by migratory birds; 3) Overharvest of fish species needed by seabirds; 4) Poaching of bird eggs on offshore cays
BATS	1) Unknown; information incomplete

Table 5. Threats to Virgin Islands National Park	
NATURAL RESOURCE	**THREATS**
AMPHIBIANS AND REPTILES	1) Introduction of exotic animals; i.e. mongooses; 2) Accidental exotic spp. introductions from stowaways; 3) Possible effects of UVB radiation
AIR QUALITY	1) Fine particulate matter from the African Desert and Montserrat Volcano; 2) Possible pollution from volatile organic compounds from gasoline oil refineries in St. Croix

Source: Boulon 1999

Park staff have undertaken efforts to manage these threats to natural resources, as mentioned throughout this report. As with many units in the National Parks System, staffing and funding shortfalls limit the type and scope of protection and restoration programs that can be implemented. In order to achieve the maximum level of resource protection, funding and staffing for natural resources programs must be increased. Park staff need the ability to enforce existing park rules and the capacity to handle new problems or threats as they arise. In addition, more data and information on ecosystem-level processes and status of park resources is required for staff to effectively manage resources. Park staff have not made specific natural resource staffing requests, but have stated that current staff limitations is impeding their ability to properly manage the park's natural resources (Boulon, pers. comm., 2006).

Existing management activities should be continued or expanded. The mooring buoy program has successfully reduced grounding and anchor damage. Future management actions should include the expansion of no-anchor zones, continuous monitoring and maintenance of existing mooring and marker buoys, and the deployment of additional buoys throughout park waters. The sustainable reduction plans for non-native wild hogs, goats, sheep, rats, cats, and mongoose should be evaluated for effectiveness and altered as necessary to achieve the desired results. A management plan for control of the donkey population should be developed. Finally, existing signage throughout the park should be upgraded and replaced as needed.

There are also additional management initiatives that should be considered. A recycling program should be developed and implemented in the park, as well as in "gateway communities" such as Cruz Bay, St. John. The U.S. Virgin Islands as a whole are running out of waste disposal space, and all landfills are near or over capacity (Boulon 1999). If recycling is not an option in the immediate future, a glass crusher would help to conserve waste disposal space in the short run.

The NPS should also be concerned with the development of the private inholdings throughout the park. Construction practices used to develop the inholdings and adjacent lands cause severe erosion and runoff events, impacting the park's natural ecosystems. Funding should be solicited to purchase property that is located in critical geographic locations within endangered watersheds. To alleviate impacts from existing construction sites, more stringent regulations should be developed to regulate sediment and pollution runoff from construction sites. The park should explore "green" technologies for road construction (such as the use of permeable materials) to combat sedimentation from unpaved roads within the park.

Visitor impacts should also be continuously monitored, and the idea of implementing visitor carrying capacities for particularly sensitive areas should be investigated. There is a cap on daily visitation at Trunk Bay, but this does not include the visitors that arrive on boats.

In order to improve the health of fisheries and other marine organisms, more stringent fishing regulations are needed in park waters. Although commercial fishing is not allowed in park waters, recreational fishing of most species is allowed with few limits or exceptions. Overfishing is likely a primary cause of reef fish population decline (Garrison 1998).

A Resource Management Plan should be prepared for Virgin Islands Coral Reef National Monument. Information regarding the resources present within this unit is severely lacking, and there is no overall strategy guiding the management of this system.

Virgin Islands National Park and Virgin Islands Coral Reef National Monument are unique units within the National Parks System because of the diversity and complexity of habitats and organisms they contain. However, controllable and uncontrollable pressures are threatening the integrity of some of the most critical systems within these units including coral reefs, mangroves, seagrass beds, and tropical dry forests. With implementation of the above recommendations, park managers will have the tools to improve the likelihood that these resources are present and healthy for future generations.

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APPENDIX A:
Natural Resource Ratings Worksheets

Virgin Islands National Park (VIIS) & Virgin Islands Coral Reef National Monument (VICR)

Ratings Category I. ECOSYSTEM EXTENT and FUNCTION (EEF)	
Park Unit and Ecoregion Characterization: VIIS & VICR - Leeward Islands moist forest/Cayman Islands xeric scrub (WWF 2001)	
Community Descriptors: moist forest, dry evergreen forest, salt flats, mangroves, seagrass beds, coral reef, algal plains	
Indicator or Representative Species: kapok, wild guava, seagrape, mangrove, elkhorn coral, turtle grass, sea turtles, reef fish, bats, migratory warblers	

Ratings Element	Specific Concern (s)/Events/Notes	Level	Reference
IA. Cover and Habitat Characterization			
IA1. Habitat loss or degradation	widespread coral loss/degradation; hurricane impacts to mangroves, seagrass; clearing of hillsides in uplands; history of cultivation affected all forest types	1	Rogers & Beets 2001; Boulon 1999
IA2. Intra-patch integrity	disease and visitors (e.g., anchor damage) impacting patches of remaining coral	2	Rogers & Beets 2001
IA3. Cover loss or bare soil increase	increased development resulting in cover loss and bare soil increase in uplands	2	Acevedo-Rodríguez et al. 1996
IA4. Cover density/homogeneity	cover density of coral and seagrass beds decreasing due to hurricanes, disease…	2	Rogers & Beets 2001; Boulon 1999
IA5.Canopy and understory architecture change	grazing and browsing of feral animals impacting terrestrial understory	2	Boulon 1999; NPS 2003; NPS 2004
IA6. Substrate quality/quantity	rapid development is leading to increased erosion rates and loss of sparse topsoil	2	Ramos-Scharron 2004; Boulon 1999
IA7.			
IB. Fragmentation			
IB1. Patch connectivity	development of inholdings leading to fragmentation and forest "patches" w/in park	2	Boulon 1999
IB2. Species Isolation		IND	
IB3. Dispersal barriers		IND	
IB4. Habitat loss	forest fragementation has been suggested as a cause for reductions in warbler pop.	2	USDOT 2004
IB5. Recolonization barriers		IND	
IB6.			
IC. Community Structure & Function			
IC1. Complexity and niche diversity	complexity of reef ecosystems degraded by hurricanes, disease, physical damage	2	Rogers & Beets 2001; Rogers 1998
IC2. Degradation of structure	grazer impacts on forest structure; reef structure damaged by hurricanes, disease	1	Boulon 1999; Rogers & Beets 2001
IC3. Patch size/shape changes	rapid development increasing size/number of forest patches	2	Boulon 1999; pers. comm. (Boulon)
IC4. Intra-patch microclimate alteration		IND	
IC5. Inter-patch isolation and edge microclimate		IND	
IC6. Generalist species domination of patches	appears to be good species distribution across patches	3	Acevedo-Rodríguez et al. 1996
IC7. Age class distribution	range of successional stages found across island	3	Acevedo-Rodríguez et al. 1996
IC8. Primary production		IND	
IC9. Decomposition/Cycling		IND	
IC10. Substrate/hydrologic change	hydrologic changes associated with hurricanes have impacted mangroves	2	Boulon 1999
IC11.			
ID. Disturbance Regimes			
ID1. Natural disturbance recovery	coral reefs, mangroves, and seagrass beds slow to recover from hurricanes	2	Boulon 1999; Rogers & Beets 2001
ID2. Perturbation resistance	marine systems (seagrass, coral, mangroves) exhibit low resistance; terrestrial veg more resistant to disturbance	2	Boulon 1999; Rogers 1992; UVI 2006
ID3. Adjacent lands development effects	rapid development on adjacent lands impacting terrestrial and marine systems (fragmentation, erosion, spread of exotics)	1	Boulon 1999; Rogers & Beets 2001
ID4. Fire	no issues	3	personal communication (Boulon)
ID5. Flood	intense storms may cause minor flooding, but no significant issues	3	personal communication (Boulon)
ID6. Drought	drought conditions have resuted in hydrological changes impacting mangroves	2	Boulon 1999
ID7. Grazing/Browsing, Fencing	grazing/browsing by feral animals has impacted forest structure/composition	2	Boulon 1999; NPS 2003; NPS 2004
ID8. Climate change	climate change connected to temp. induced coral bleaching (speculative)	2	Rogers & Beets 2001; Graham 2006
ID9. Visitor impact	anchor/boat damage to coral reefs and seagrass beds; visitor impacts to terrestrial systems minor in comparison to marine (social trails, some poaching of plants)	2	personal communication (Boulon) Rogers & Beets 2001; Rogers 1998
1D10.			

Virgin Islands National Park (VIIS) & Virgin Islands Coral Reef National Monument (VICR)

Ratings Category II. SPECIES COMPOSITION & CONDITION (SCC)
Park Unit and Ecoregion Characterization: VIIS & VICR - Leeward Islands moist forest/Cayman Islands xeric scrub (\
Community Descriptors: moist forest, dry evergreen forest, salt flats, mangroves, seagrass beds, coral reef, algal plains
Indicator or Representative Species: kapok, wild guava, seagrape, mangrove, elkhorn coral, turtle grass, sea turtles, re

Ratings Element	Specific Concern (s)/Events/Notes	Level	Reference
IIA. Total Species			
IIA1. Diversity (age, size class, distribution)	range of successional stages, ages, size classes distributed across park	3	Acevedo-Rodríguez et al. 1996
IIA2. Exotic species	increasing development resulting in spread of exotics; non-native animals impacting veg & food webs. Introduced plant species can be found in most communities across the island	1	Boulon 1999; NPS 2003; NPS 2004
IIA3. Invasive species	invasive animal impacts - sea turtle egg predation by mongoose; grazing/browsing. Brazilian pepper, tan tan, and limeberry may be affecting some of St. John's native plants	2	Boulon 1999
IIA4. Genetic variability		IND	
IIA5.			
IIB. Native Species			
IIB1. Composition change	grazing of feral animals changing forest comp.; disease impacting reef composition	2	Boulon 1999; Rogers & Beets 2001
IIB2. Disease and parasites	white band disease, plague type II causing serious reef degradation	1	Rogers & Beets 2001; Rogers 1998
IIB3. Threatened and endangered species	sea turtle egg predation by invasives, humans; elkhorn/staghorn coral decline. Two federally listed plant species found on St. John, the prickly-ash (Zanthoxyllum thomasianum) and St. Thomas lidflower (Calyptranthes thomasiana) are considered to have stable populations but are consumed by feral animals	2	personal communication (Boulon) Rogers & Beets 2001; Boulon 1999
IIB4. Extirpation	several extirpated plant species (from clearing associated with plantations)	2	Acevedo-Rodríguez et al. 1996
IIB5. Population change	reef fish populations declining due to overfishing/habitat deg.	2	Garrison 1998
IIB6. Dominant species density-dependence		IND	
IIB7. Reintroduction	no reintroductions	N/A	
IIB8. Keystone species	Nassau grouper threatened by overfishing; not enough info on bats	2	Boulon 1999; DFW 2005b
IIB9.			
IIC. Trophic & Biotic Interactions			
IIC1. Web dynamics -species loss	synergistic effects of seagrass beds, mangroves, corals degradation	2	Rogers 1998; Rogers & Beets 2001
IIC2. Predation rates		IND	
IIC3. Grazer/Browser effects	grazers impacts to forest structure result in impacts to other wildlife that use that habitat	2	NPS 2003; 2004
IIC4. Food chain length	introduction of non-indigenous species have had impacts on food webs	IND	NPS 2002; 2003; 2004
IIC5. Competitor change	introduction of non-indigenous species have had impacts on competitive interactions	2	NPS 2002; 2003; 2004
IIC6. Predator-prey disruption	cats, rats, mongoose exerting predation pressure not previously present (only native mammals are bat species)	2	NPS 2002; 2003; 2004
IIC7. Dominance alteration		IND	
IIC8. Species hybridization	none known	3	personal communication (Boulon)
IIC9. Allelopathy		IND	
IIC10.			

Virgin Islands National Park (VIIS) & Virgin Islands Coral Reef National Monument (VICR)

Ratings Category III. BIOTIC IMPACTS AND STRESSORS (BIS)
Park Unit and Ecoregion Characterization: VIIS & VICR - Leeward Islands moist forest/Cayman Islands xeric scrub (WWF 2001)
Community Descriptors: moist forest, dry evergreen forest, salt flats, mangroves, seagrass beds, coral reef, algal plains
Indicator or Representative Species: kapok, wild guava, seagrape, mangrove, elkhorn coral, turtle grass, sea turtles, reef fish, bats, migratory warblers

Ratings Element	Specific Concern (s)/Events/Notes	Level	Reference
IIIA. Animals			
IIIA1. Acoustics		IND	
IIIA2. Climate Change	Sea water temperarture has increased one degree F	2	Carter et al. 2001
IIIA3. Disease	Black band disease on coral reefs	1	NPS 2006
IIIA4. Environmental Quality	Overall environmental quality is considered good	3	Boulon 1999
IIIA5. Exotics Competition	Problem with mongooses eating sea turtle eggs	2	Boulon 1999
IIIA6. Land Use History	Problems from introduced species from agricultural era	2	Boulon 1999
IIIA7. Management	Management initiatives in place to address grazing/erosion problems assoc. w/non-native wild hogs, sheep, goats, and donkeys. Also, mooring system to address anchor damage to coral and seagrass.	3	Boulon 1999
IIIA8. Natural Disaster	Hurricanes can casue damage to seagrass beds, coral reefs	2	Rogers 1998
IIIA9. Food Source		IND	
IIIA10. Poaching	Poaching of sea turtles eggs on beaches, as well as taking of animals in nearby British waters	2	Boulon 1999
IIIA11. Population Dynamics	Overfishing and overharvesting of lobster and conch can alter population dynamics in marine ecosystem	2	Boulon 1999
IIIA12. Isolation/Insulation	No recent studies	IND	
IIIA13. Visitor Impact	Most severe damage is to coral reefs in snorkel areas from fin damage. Pollution from boat effluents is also a problem for coral and other nearshore environments. Damage to corals and seagrass is also severe from improper anchoring and boat groundings.	1	Boulon 1999
IIIA14. Other (Specify)			
IIIA15. Other (Specify)			
IIIB. Plants			
IIIB1. Climate Change	Climate change predictions include an increase in frequency and intensity of hurricanes, which cause damage to canopy trees.	2	Carter et al. 2001
IIIB2. Disease		IND	
IIIB3. Environmental Quality	Considered good overall	3	Boulon 1999
IIIB4. Exotics Competition	Mexican weavel eating century plants; caterpillars eating native tire palms. Brazilian pepper, tan tan, and limeberry may be affecting some of St. John's native plants.	2	pers. comm., Boulon, 2006
IIIB5. Land Use History	Forest is still recovering from Plantation Era and regrowing to original forest composition	2	Boulon 1999
IIIB6. Management	Management initiatives in place to address grazing/erosion problems assoc. w/non-native wild hogs, sheep, goats, and donkeys. Mooring bouy initiative to reduce anchor damage and boat grounding damage to seagrass beds.	3	NPS 2002, 2003, 2004
IIIB7. Natural Disaster	Hurricanes can casue damage to seagrass beds and the upper canopy of forests	2	Rogers 1998
IIIB8. Nutrient Supply		IND	
IIIB9. Poaching	Problems with poaching of wild orchids and vines from within the park	2	pers. comm., Boulon, 2006
IIIB10. Population Dynamics	Normal successional patterns after plantation era cutting; some issues w/exotics	2	Boulon 1999
IIIB11. Substrate Loss	Development and road construction has led to substrate loss	2	Boulon 1999
IIIB12. Isolation/Insulation		IND	
IIIB13. Visitor Impact	Problems from anchor damage and boat groundings in seagrass beds. Some social trails in uplands	2	Allen 1992
IIIB14. Other (Specify)			

Virgin Islands National Park (VIIS) & Virgin Islands Coral Reef National Monument (VICR)

Ratings Category IV. ENVIRONMENTAL QUALITY FACTORS (EQF)

Park Unit and Ecoregion Characterization: VIIS & VICR - Leeward Islands moist forest/Cayman Islands xeric scrub (WWF 2001)

Community Descriptors: moist forest, dry evergreen forest, salt flats, mangroves, seagrass beds, coral reef, algal plains

Indicator or Representative Species: kapok, wild guava, seagrape, mangrove, elkhorn coral, turtle grass, sea turtles, reef fish, bats, migratory warblers

Ratings Element	Specific Concern (s)/Events/Notes	Level	Reference
IVA. Air			
IVA1. Acid Deposition (Acid Rain)	Isolated events from volcanic eruptions on Montserrat carrying sulfur dioxide coated particulates, not frequent enough to be a concern	3	Boulon 1999
IVA2. Cl-oxides, Cl-nitrate		IND	
IVA3. HFC's, FHC's, HC's		IND	
IVA4. Nitrogen Oxides		IND	
IVA5. Sulfur Oxides		IND	
IVA6. Particulates	Particulates from Montserrat volcanic activity; dust from Sahara desert in summer months	2	Rogers 1997; Perry et al. 1997
IVA7. Ozone	Data indicate no exceedances	3	NPS 2005
IVA8. VOC's	VOC's release at nearby oil refinery on St. Croix are not reaching St. John except for rare occurances.	3	Rogers 1997
IVA9. Visibility	Visibility impaired by Saharan dust events in summer months as well as ash from Montserrat volcanic activity	2	Rogers 1997; Perry et al.1997
IVA10. Hg		IND	
IVA11.			
Ratings Element	**Specific Concern (s)/Events/Notes**	**Level**	**Reference**
IVB. Waters			
IVB1. Acid Deposition	Isolated events from volcanic eruptions on Montserrat carrying sulfur dioxide coated particulates, not frequent enough to be a concern	3	Boulon 1999
IVB2. Algae	Occassional summer algal blooms, but nothing severe	3	pers. comm., Caseau, 2006
IVB3. Alkalinity	No known problems	3	pers. comm., Caseau, 2006
IVB4. Benthic Index	Loss of seagrass habitat and coral reef habitat from boat anchors, groundings, storm damage, bleaching and disease events.	2	NPS 2006; Allen 2002
IVB5. Chlorphyll a	No known problems	3	pers. comm., Caseau, 2006
IVB6. Diatoms	No Known problems	3	pers. comm., Caseau, 2006
IVB7. Discharge/Drainage		IND	
IVB8. Dissolved Gasses	No known problems	3	NPS WRD 1995
IVB9. Diversion		IND	
IVB10. Drawdown		IND	
IVB11. Flow		IND	
IVB12. Metals	Zinc, copper and mercury tested over limits in STORET data retrieval done by NPS and EPA in 1995.	2	NPS WRD 1995
IVB13. Nutrients	Problems with runoff	2	Rogers 1997
IVB14. Organic Matter	Problems with runoff of organic matter such as cleared vegetation from construction sites	2	Rogers 1997
IVB15. Organic Wastes	Input from leaky and overflowing septic tanks during rain events	2	NPS WRD 1995; Carter et al. 2001
IVB16. pH	No known problems	3	NPS WRD 1995
IVB17. Plankton	Occassional summer algal blooms, but nothing severe	IND	pers. comm., Caseau, 2006
IVB18. Recharge		IND	
IVB19. Salinity	No known problems	3	NPS WRD 1995
IVB20. Sedimentation	Sedimentation can blanket coral reefs from land runoff due to unpaved roads and development.	2	Boulon 1999
IVB21. Submerged Macrophytes	Not enough research on freshwater systems (only intermittent streams)	IND	

IVB22. Temperature	Temperature can be affected by lack of deep water circulation during slow hurricane seasons. Warmer waters can cause stress to coral reefs and cause bleaching events.	2	Carter et al. 2001; NPS 2005
IVB23. Turbidity	Turbidity can occur during large rain events as excessive sediments are carried into nearshore waters from upland development and unpaved roads.	2	Rogers 1997
IVB24. Xenobiotics		IND	
IVB25. Climate Change	Climate change could have an effect on many water quality parameters if the following predictions occur: surface water temperatures continue to increase, storm frequency and intensity increases, and sea levels continue to rise.	2	Carter et al. 2001
IVB26.			
Ratings Element	**Specific Concern (s)/Events/Notes**	**Level**	**Reference**
IVC. Soils			
IVC1. Acidity, Alkalinity, pH	Soils considered slightly acidic	3	NRCS 1970
IVC2. Compaction	Compaction from grazing of non-native animals; construction traffic and overloaded concrete trucks.	2	Boulon 1999
IVC3. Erosion	Erosion of unpaved roads during rain events and from development construction	2	Rogers 1997; Ramos-Scharron 2004
IVC4. Infiltration/Permeability	No known problems	3	Ramos-Scharron 2004
IVC5. Metals		IND	
IVC6. Nutrients		IND	
IVC7. Organic Matter		IND	
IVC8. Organic Wastes	Leaky and overflowing septic tanks can leach organic wastes into surrounding soils	2	Boulon 1999
IVC9. Salinity & Sodicity		IND	
IVC10. Soil Fauna & Flora (micro & macro)		IND	
IVC11. Climate		IND	
IVC12. Xenobiotics		IND	
IVC13.			
IVC14.			

References:

Caseau, Sheri. 2006. Personal communication with Kelly O'Rourke and Kim Collini. June 5.

Natural Resources Conservation Service. 1970. Soil Survey U.S. Virgin Islands.

Ratings Category	Total Levels Values (TLV)	Total Levels Addressed (TLA)	Total Applicable Levels (TAL)	**RATING** 100 x (TLV/3TLA)	**BASIS** 100 x (TLA/TAL)
ECOSYSTEM MEASURES (ESM)	**75**	**37**	**50**	**67.6**	**74.0**
I. Ecosystem Extent and Function (EEF)	47	23	30	68.1	76.7
IA. Cover and Habitat Characterization	11	6	6	61.1	100.0
IB. Fragmentation	4	2	5	66.7	40.0
IC. Community Structure and Function	13	6	10	72.2	60.0
ID. Disturbance Regimes	19	9	9	70.4	100.0
II. Species Composition and Condition (SCC)	28	14	20	66.7	70.0
IIA. Total Species	6	3	4	66.7	75.0
IIB. Native Species	11	6	7	61.1	85.7
IIC. Trophic and Biotic Interactions	11	5	9	73.3	55.6
ENVIRONMENTAL & BIOTIC MEASURES (EBM)	**109**	**47**	**73**	**77.3**	**64.4**
III. Biotic Impacts and Stressors (BIS)	42	20	26	70.0	76.9
IIIA. Animals	20	10	13	66.7	76.9
IIIB. Plants	22	10	13	73.3	76.9
IV. Environmental Quality Factors (EQF)	67	27	47	82.7	57.4
IVA. Air	13	5	10	86.7	50.0
IVB. Waters	42	17	25	82.4	68.0
IVC. Soils	12	5	12	80.0	41.7
OVERALL	**184**	**84**	**123**	**73.0**	**68.3**

APPENDIX B: Non-indigenous Animal Species

NAME	SCIENTIFIC NAME
Mammals	
Cat, domestic	*Felis domesticus*
Cattle, domestic	*Bos taurus*
Deer, White-tail	*Odocoileus virginianus*
Dog, domestic	*Canis familiaris*
Donkey	*Equus asinus*
Goat, domestic	*Capra hircus*
Hog	*Sus scrofa*
Horse	*Equus caballus*
Mongoose, West Indian	*Herpestes auropunctatus*
Mouse, house	*Mus musculus*
Rat, black	*Rattus rattus*
Rat, Norway	*Rattus norvegicus*
Sheep, domestic	*Ovis aries*
Birds	
Bullfinch, Lesser Antilles	*Loxigilla noctis*
Fowl, domestic	Various sp.
Parakeet, Brown-throated	*Aratinga pertinax*
Sparrow, English	*Passer domesticus*
Amphibians	
Mute frog	*Eleutherodactylus lentus*
Tree frog, Cuban	*Osteopilus septentrionalis*
Tree Frog, Coqui	*Eleutherodactylus coqui*
Reptiles	
Gecko, house	*Hemidactylus mabouia*
Iguana, green	*Iguana iguana*
Tortoise, red-footed	*Geochelone carbonaria*

Source: Boulon 1999; Rice et al. 2005