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**PROPOSAL FOR INVENTORY AND MONITORING PROGRAMS
VIRGIN ISLANDS NATIONAL PARK
BUCK ISLAND REEF NATIONAL MONUMENT
DRY TORTUGAS NATIONAL PARK**

INTRODUCTION

Virgin Islands National Park (VIIS), Buck Island Reef National Monument (BUIS), and Dry Tortugas National Park (DRTG) together form a group of parks with highly significant terrestrial and marine resources. VIIS and DRTG are both biosphere reserves. All of these parks are under increasing pressure from human activities. While they have many things in common, each of these parks also has something unique to contribute to our understanding of ecological processes. High levels of visitation, with severe consequences primarily to marine resources, occurs in all of the parks. VIIS alone faces substantial habitat loss and degradation from development of private inholdings and lands along the park's boundary. All of these NPS units have been hit with major storms in the last 4 years, with Hurricane Hugo smashing forests and reefs in BUIS and VIIS in 1989 and the severe storm in March 1993 damaging reefs in DRTG. Dry Tortugas National Park was spared the devastation of Hurricane Andrew. The location of Dry Tortugas 70 miles from the U.S. mainland renders it less susceptible than VIIS to sedimentation increases. Likewise, Dry Tortugas is a particularly important reference site for examination of global climate change on coral reefs, because other factors which could be responsible for any documented changes in abundance of organisms can be ruled out.

Significance of Natural Resources of VIIS and BUIS

The significance of the natural resources of Virgin Islands National Park (Figure 1) led to its designation as a biosphere reserve in 1976, one of the first protected areas in the United States to receive this recognition. The park consists of 2947 ha of land and 2287 ha of surrounding marine waters. Very few biosphere reserves ##### (probably less than a dozen out of over 270) contain both marine and upland portions. This combination of upland and marine areas also characterizes Buck Island Reef National Monument with 72 ha of land and 283 ha of offshore waters. The forests on St. John and Buck Island represent remnants of the once-widespread tropical dry forest ecosystem in the Caribbean and the only ones which are under U.S. jurisdiction. Most of the remaining dry forest habitat which can be found on other islands is vulnerable to development.

Extensive clearing of the vegetation on St. John (over 90% of the land) during the plantation era, intensive livestock grazing prior to the park's establishment, and introduction of several exotic plants did not apparently result in the elimination of native species but rather in a change in their relative abundance. The dry forests on Buck Island and St. John therefore represent secondary forests which have been allowed to recover under NPS protection. There is no evidence that any extensive dry forest areas which were never disturbed can be found at present in the Caribbean. A few areas on St. John, including locations of endangered plants, may never have been degraded by humans largely because of their inaccessibility.

Over 800 species of vascular plants have been identified on St. John. While only one plant species is currently on the Federal Endangered Species list, two other species will soon be proposed for listing. In addition to these three endemic species, several species are known to be rare. One endemic species, also Federally listed, is known from Buck Island.

The marine portions of Buck Island Reef National Monument (Figure 2) and Virgin Islands National Park were established in recognition of the significance of their marine resources, including the barrier reef which lies off the southern, eastern and northern shores of Buck Island and the numerous fringing reefs and deeper patch reefs off St. John. These coral reefs and nearby sea grass beds support a high diversity of fishes and other organisms, including endangered sea turtles.

extensive
marine res.
by Will
1970-80-

Buck Island is the most significant hawksbill nesting area under U.S. jurisdiction and protection and one of only 3 known areas of concentrated nesting in the Caribbean islands. Two other endangered species of sea turtles, the green and leatherback, also nest on Buck Island's beaches. Green and hawksbill turtles are also found in the waters around St. John, and limited nesting of hawksbills occurs on some St. John beaches.

BUS
1 of 4 Lt.
study Ee. in
world.

Recent studies of the migratory birds on St. John have led to the discovery that the island supports very high densities of warblers. The relatively intact forests of St. John provide habitat that is simply no longer found on most other Caribbean islands. VIIS is perhaps the only significant wintering area for migratory warblers under NPS jurisdiction.

BUIS and VIIS contain 3 of the 5 rookeries of the endangered brown pelican in the USVI. They provide nesting habitat for up to 90 pairs of adult birds.

Recent surveys of beetles on St. John and Buck Island have resulted in the identification of several beetles endemic to St. John and at least one new beetle known only to Buck Island.

update
←

Significance of Natural Resources of Dry Tortugas

Dry Tortugas National Park (formerly Fort Jefferson National Monument) comprises about 26, 200 ha of an area known as the Dry Tortugas Banks (Figure 3). Described as an atoll by Vaughan (1914), the banks have a rim of Holocene coral reef development that encircles an inner basin containing several sandy islands (Shinn et al. 1989). About 99% of the park's area is water and submerged lands.

The area's outstanding natural resources have impressed visitors ever since the Spanish explorer Ponce de Leon's visit in 1513. He named the islands Las Tortugas ("The Turtles") after his crew captured 160 turtles in just one day. The

earliest documented marine research was conducted by Agassiz in 1858, when he mapped the area's reef system. In 1904, the Carnegie Institution established a marine laboratory of Loggerhead Key, under the direction of Alfred Mayor. The lab was world-renowned for its pioneering work on coral reefs and as the site where the first underwater photographs were taken. As many as 18 scientists at a time participated in research conducted at the lab. By the time that financial constraints finally forced the lab's closing in 1939, 35 volumes of research had been published by the Tortugas lab.

The outstanding and nationally significant natural values of the area were first officially recognized in 1908, by an Executive Order which created the "Dry Tortugas Keys Reservation", establishing it as a wildlife refuge primarily to protect the Sooty Tern colony, which had been nearly decimated by egg collectors.

Fort Jefferson National Monument became the world's first marine protected area when it was established by Presidential Proclamation in 1935. The entire group of islands and the surrounding reefs and shoals were included for preservation in the monument. Additional legislation enacted in 1980 referred to "a pristine natural environment including the entire Dry Tortugas group of islands and their associated marine environments, significant coral formations, fish and other marine animal populations, and populations of nesting and migratory birds...". Like VIIS, Dry Tortugas National Park was designated a biosphere reserve in 1976.

DRTO is world-renowned for its bird life. Bush Key is the only significant Sooty and Noddy Tern colony in the U.S., consisting of nearly 100,000 birds during nesting season. Long Key is the most significant Magnificent Frigate bird colony and Hospital Key the only Masked Booby colony in the U.S. A great variety of passerines and raptors pass through DRTO during spring and fall migrations.

The marine environment of DRTO is less disturbed by human activities than any other coral reef ecosystem in North America. Although far north, the reefs possess a full complement of Caribbean coral species including some that are rare elsewhere. The diversity of fish (442) species may be unsurpassed on the Atlantic Coast of the U.S. These significant resources are threatened by the cumulative impacts of steadily increasing visitation, recreational fishing, illegal poaching, and inconsistent enforcement.

The significance of the natural resources of the Dry Tortugas was most recently underscored with the passage of legislation in 1992 redesignating Fort Jefferson National Monument as Dry Tortugas National Park.

Conceptual framework for monitoring and primary objectives

VIIS, BUIS, and DRTO are among the few NPS units which contain both marine and terrestrial areas. These parks have similar management concerns, including the consequences of increasing visitation, pressure from fishing, pollutants carried in currents, and endangered species (sea turtles). Especially in the case of VIIS, because of its location on the steep island of St. John, the potential exists for the degradation of marine habitats and water quality because of upland development.

The overall goal of the I and M program outlined in this document is the detection and evaluation of long-term trends in the structural and functional attributes of the marine and terrestrial systems and the associated populations of endangered and otherwise significant species within VIIS, BUIS, and DRTO to provide a basis for educated management intervention. Examples of structural changes include loss of forested habitat or sea grass beds, encroachment of exotic plants, decrease in the amounts of living coral, and shifts in fish and bird assemblages. Functional changes could include decrease in growth rates of dominant trees or corals, changes in marine primary productivity due to increased nutrient levels, and changes to plant succession from feral animals. *orchid popm.*

The design of any monitoring program requires identification of the temporal and spatial scales appropriate to the questions which are being asked.

Some of the management questions which are being addressed include the following (also see discussions in individual sections):

- is sediment input to marine waters increasing significantly because of increasing development and, if so, a) is water quality deteriorating; b) are reef corals dying? (VIIS)
- is encroachment by exotic plants having significant effects on native species? (VIIS, BUIS)
- are levels of nutrients and bacteria in waters around the parks increasing to unsafe or undesirable levels? (VIIS, BUIS, DRTO)
- how feasible is restoration of degraded ecosystems within VIIS, BUIS
- sea turtles
- is the continued development of St. John jeopardizing the winter habitat for migratory birds?

recruitment?

*plankton tows
for species +
recruitment
(each area)*

The monitoring program for these three parks is envisioned at the ecosystem, watershed, community, and species level (population) scales. Permanent study sites have already been established in coral reefs in all three parks and in dry and moist forests in St. John. In VIIS, the Lameshur Bay watershed, selected because it is relatively undisturbed and because it is in the core of the biosphere reserve, has been the focus of long-term monitoring efforts in the dry forest, coral reefs, and sea grass beds. Sediment input from this watershed is being compared to that from the Fish Bay watershed undergoing development adjacent to the Park's

western boundary.

The NPS Coral Reef Assessment Program which began in 1988 with NRP funding and which continues with funds from SERO resulted in the establishment of permanent long-term study sites and extensive studies of coral reefs and reef fishes in all of these parks. Earlier, from 1984-1988, members of the Virgin Islands Resource Management Cooperative carried out several research projects on VIIS and BUIS, including studies of the forests of St. John.

These and other individual studies, some of which have gone on for over a decade, provide an excellent basis for a fully integrated I and M program. The I and M program presented here represents an expansion of ongoing monitoring efforts and relies heavily on research by NPS staff (including the additional positions identified in this proposal), NBS/CPSU staff involvement (including new coral reef scientist to be hired by Florida CPSU), interagency cooperation (e.g., NOAA, Florida DEP/FMRI), and outside investigators.

The program calls for expansion of the monitoring which has been occurring at the permanent coral reef study sites in each of the parks, additional monitoring of air and water quality, consistent support of previously underfunded efforts by individual scientists (such as Dr. Bill Robertson's studies of sea birds at Dry Tortugas, and Zandy Hillis's sea turtle program at Buck Island), and integration of several disparate activities into a truly organized comprehensive program.

The program is based on the following tasks:

- inventory of resources (largely completed)
- identification of management questions
- establishing priorities for inventory and monitoring
- design of the program at appropriate spatial and temporal scales
- use of standardized protocols and development of protocols where none exist
- quality control/assurance of data
- archiving and interpretation of data using GIS and other tools
- writing of reports for scientific journals and for use by interpreters
- dissemination of results to park managers, park interpreters, and the community

We believe that the program we have outlined is both scientifically exciting and critical for effective management of these three parks. The programs are more comprehensive for BUIS and VIIS but include the highest priority marine resources in DRTO (coral reefs, sea birds, and sea turtles).

This proposal has been prepared by NPS scientists and resource managers Caroline Rogers, Jim Petterson, Ginger Garrison, Rikki Grober, Zandy Hillis, Skip Snow, and outside investigators Anne Reilly, Gary Ray, and Bob Askins.

1. *Recognized Management Need:*

The National Park Service's recognition of the need for ecological research on the marine and terrestrial resources of VIIS led to the creation of the Virgin Islands Resource Management Cooperative in 1983 and subsequent construction of the Virgin Islands Biosphere Reserve Center (completed in 1987). VIIS received substantial amounts of NRP funding for support of 30 biosphere reserve projects (1983-1988) carried out by VIRMC members. From 1988-1991, NRP funds supported the NPS Coral Reef Assessment Program which included research on reefs in VIIS, BUIS, (then) Fort Jefferson National Monument and Biscayne National Park. Most recently, the Coral Reef Fisheries project for BUIS and VIIS received NRP support (1992-1994). Regional funds have been supporting research on coral reefs and reef fishes at all of these parks in the last two years.

In December 1992, then Superintendent Marc Koenings, Assistant Superintendent Francis Peltier, Management Assistant Paul Thomas, the park's Resource Management Specialists, Research Biologist, and the other Division Chiefs met to establish priorities for project statements (or appropriate groups of statements) identified in the draft VIIS Resource Management Plan. Individual rankings were combined to arrive at an overall list of priorities which was incorporated into the RMP. These priorities are reflected in this proposal. All of the major marine and terrestrial monitoring projects outlined in this proposal were ranked in the top 5 priorities for the park including projects which related to damage from high visitation levels, to long-term vegetation monitoring, marine ecosystem monitoring, feral animal management, endangered and threatened species, and a geographic information system (GIS) to help store, analyze, and interpret the data from all of the monitoring studies.

The legislation which created Dry Tortugas National Park in 1992 stated several specific management purposes for DRTN, including:

"To protect and interpret a pristine subtropical marine ecosystem, including an intact coral reef community"

"To protect populations of fish and wildlife including (but not limited to)

loggerhead and green sea turtles, sooty tern, frigate birds, and numerous migratory bird species"

In 1990, Congress established the Florida Keys National Marine Sanctuary which surrounds Dry Tortugas National Park. The draft management plan and research proposals for the Sanctuary have repeatedly identified the Dry Tortugas as an essential component of long-term system-wide monitoring for the Florida Keys. We expect NOAA to look to DRTTO for support and cooperation in their monitoring efforts which will benefit both agencies.

Resource Management Plans

An initial draft of the VIIS RMP was submitted to SERO in July 1991. After a lengthy review process, the draft was returned to the VIIS for revisions. The revised plan was then submitted to SERO again in April 1993. It is still being reviewed. (See Appendix A for relevant Project Statements.)

A draft RMP for BUIS was submitted to SERO in June 1993. While not complete, the draft identifies all major resource management issues for the park.

The RMP for Dry Tortugas National Park (established in 1992) is now being revised. The park's Statement for Management and the RMP are to be addressed in a "scoping session" in December 1993, at which time the highest priority project statements will be identified, including strong support for long-term monitoring.

2. *Status of Inventory:*

Tables 1, 2, and 3 present the status of inventory for major natural resources in VIIS, BUIS, and DRTTO.

Beginning in the early 1980's, a series of marine and terrestrial projects produced extensive inventories of St. John's vascular plants and marine organisms (notably, corals and reef fishes). In many cases, these detailed inventories represented the initial phases of monitoring programs which continue today.

Flora

The list of over 800 vascular plant species from St. John can be considered virtually complete. The Smithsonian and a private sponsor (the Homeland Foundation) are supporting production of an illustrated flora for the island, an illustrated tree guide for over 200 species of common trees that occur on St. John.

STATUS OF BUCK ISLAND REEF NATIONAL MONUMENT INVENTORIES/BASELINE DATA

Inventory Type	Additional Inventory Needed?	Species List Complete	Distribution Known	Comments
Native Plants	Yes	No	No	1 endemic species
Exotic Plants	Yes	No	No	Prot. survey 3/96
Marine Plants	Yes	No	No	
Native Birds	No	Yes	Yes	
Exotic Birds	No	na	na	
Terrestrial Mammals	Yes	No	No	? mongoose / native mouse
Exotic Terr. Mammals	Yes	Yes	No	2 spp. of rats / ? mongoose
Marine Mammals	No	Yes	No	
Terrestrial Reptiles	Yes	Yes	No	
Marine Reptiles	No	Yes	Yes	3 spp. of nesting sea turtles, 2 spp. foraging
Amphibians	Yes	No	No	
Terrestrial Invertebrates	Yes	No	No	Beetle survey underway
Fungi	Yes	No	No	
Marine Fishes/Shellfish	No	Yes	Yes	# of spp. = ???
Marine Invertebrates				
Hard Corals	No	Yes	No	
Sponges/Gorgs	Yes	No	No	
Others	Yes	No	No	
Terrestrial Communities	No	na	Yes	Vegetation map needed

Marine Benthic Communities	No	na	Yes	Benthic maps need updating
Water Quality Bacteria Nutrients Clarity	Yes Yes Yes	na na na	na na na	Some historic data
Physical Oceanography	Yes	na	na	mapping Δ since hurricane
Soils	No	na	na	Recent work by SCS
Geology Terrestrial Marine	Yes No	na na	na na	
Air Quality	Yes	na	na	
Meteorological Data	Yes	na	na	
Museum Collections	na	na	na	Included w/i VIIS collection
GIS Data Digital Data Aerial Photos	na na	na na	na na	Some aerial photos and bathymetry available
Historical Database Ecological Hist. Bibliographic	Yes No	na na	na na	Annotated bibliography for marine studies

STATUS OF VIRGIN ISLANDS NATIONAL PARK INVENTORIES/BASELINE DATA

Inventory Type	Additional Inventory Needed?	Species List Complete	Distribution Known	Comments
Native Plants	No	Yes	Yes	810 spp. Flora in prep.
Exotic Plants	Yes	Yes	No	
Marine Plants	Yes	No	No	
Native Birds	No	Yes	Yes	Ongoing warbler and pelican studies
Exotic Birds	Yes	No	No	House sparrow invasion
Terrestrial Mammals	Yes	Yes	No	Bats poorly known
Exotic Terr. Mammals	No	Yes	Yes	14 spp. of exotic mammals
Marine Mammals	No	Yes	No	Migrate through park waters
Terrestrial Reptiles	Yes	Yes	No	No surveys since 1980
Marine Reptiles	No	Yes	Yes	Green & Hawksbill sea turtles
Amphibians	Yes	No	No	Several exotic frogs introduced
Terrestrial Invertebrates	Yes	No	No	400 spp. of endemic beetles. Ectoparasite study ongoing
Fungi	Yes	No	No	Recent surveys conducted
Marine Fishes/Shellfishes	No	Yes	Yes	Historic info & current studies
Marine Invertebrates				
Hard Corals	No	Yes	Yes	
Sponges/Gorgs	Yes	No	No	
Others	Yes	No	No	

Marine Benthic Communities	No	na	Yes	Benthic maps need updating
Water Quality Bacteria Nutrients Clarity	Yes Yes Yes	na na na	na na na	Data taken monthly from 30 sites around island
Physical Oceanography	Yes	na	na	
Soils	No	na	na	Soils map due from SCS in 1994
Geology Terrestrial Marine	Yes Yes	na na	na na	
Air Quality	Yes	na	na	Particulate sampler in use
Meteorological Data	Yes	na	na	USGS station in operation
Museum Collections	Yes	na	na	VIIS collection includes very good herbarium & fish specimens
GIS Data Digital Data Aerial Photos	na na	na na	na na	18 data coverages available. Series of aerial photos from 1947
Historical Database Ecological Hist. Bibliographic	Yes No	na na	na na	Comprehensive report of research conducted in park up to 1988.

Three new species of plants have just been described, with two known only from St. John and one only from St. John, St. Thomas, and adjacent islands (Acevedo 1993). In 1991, information on the status of rare plants in VIIS was updated and compiled with assistance from the Center for Plant Conservation at a conference in San Juan, Puerto Rico. A vegetation map of St. John was produced in 1987.

Detailed information on species and species distributions come from studies in long-term plots in 8 different watersheds. For example, Anne Reilly from the Univ. of Georgia has identified, tagged, and mapped over 6,000 trees in plots in the moist and dry forests (two 1.0 ha, one 0.5 ha). Dr. Francisco Dallmeier from the Smithsonian Institution's SI/MAB Biodiversity Program established a 1-hectare permanent plot in a north-facing dry semi-evergreen woodland within the VINP in 1991. Initial inventory is complete and all trees ≥ 4.0 cm DBH have been mapped. Future plots are planned, and will contain a dry evergreen thicket, a cactus community and a coastal hedge. The longest forest monitoring project, begun in 1983 by Dr. Pete Weaver (Intern. Institute of Trop. Forestry), inventoried all species in 16 (size??) plots in the Cinnamon Bay watershed (moist gallery forest). The University of Wisconsin established a set of ten permanent plots each measuring 10 m X 50 m at five Park locations in 1988. These plots focus on the island's tropical dry forest in various stages of regeneration, and include stands ranging in age between 35 and 125 years. A chapter in a recent Ph.D. dissertation (Ray 1993) compares demographic traits and relative abundances of tree species in these plots.

A thorough vegetation survey of Buck Island was conducted in 1976 (Woodbury and Little 1976). A vegetation map should be prepared and more data are needed on the distributions of rare plants on the island. The extent of exotic plant species encroachment has not been monitored. An inventory of island vegetation should be conducted.

→ *Livistoe reintroduction - 1980s + 1993 plantings need mapped + monitored. Exotic encroachment survey. gum grass, Hummel*

Exotic plants

Approximately 150 plant species (<20% of island flora) on St. John are naturalized exotics. Only three tree species are noxious weeds, capable in certain habitats of displacing native species. The first, *Leucaena leucocephala*, is a fast growing early colonizer of pastures and other intensively disturbed sites, forming monospecific stands in the most degraded sites. *Leucaena* is so well distributed on the island that any steps taken to manage the species would be extremely impractical. The species should be left to its own devices for three reasons: 1) it fixes nitrogen, enriching the nutrient base on sites with otherwise impoverished soils, 2) it protects exposed soils on many degraded slopes from erosion, and 3) it is generally outcompeted by native species in recovering forests.

A second major exotic tree species, *Melicoccus bijugatus*, "Genip", often grows in monospecific stands. *Melicoccus* may pose a significant threat to the integrity of

those native dry forest communities where it is most abundant.

A third woody exotic, *Triphasia trifolia*, " Sweet lime", now dominates the understory of many disturbed basin forests on St. John's north shore and is common on trailsides in dry forests.

Marine organisms

The major groups of marine organisms within VIIS, BUIS, and DRTO, especially those associated with the coral reefs, are relatively well-known. The NRP Fisheries Project and previous studies have produced a comprehensive list of coral reef fishes. The list of stony corals is virtually complete, but we lack comprehensive knowledge of octocorals and sponges. Research by scientists and students at the West Indies Lab. on St. Croix focused on Buck Island for the 20 years which the lab. functioned. (This lab. was destroyed by Hurricane Hugo and never reopened.) Earlier collections and records of fish, corals, gorgonians, and sponges have been supplemented by recent inventories. Lobster and conch surveys have been done at all three parks but need to be repeated. A comprehensive list of marine plant species is available.

Sea turtles

Four (possibly five) species of sea turtles are known from DRTO and three from USVI waters. Intensive research on sea turtles has been conducted at BUIS since 1987 with emphasis on nesting requirements and nesting success. Over ~~70~~ 80+ female hawksbills have been tagged. A survey is needed to determine critical foraging and resident habitat use by both juvenile and nesting hawksbills. Greens and leatherbacks also nest on BUIS but in far fewer numbers. Some information is available on movements of hawksbill sea turtles from satellite telemetry data. Fewer turtles nest on St. John's beaches than on Buck Island. Intensive monitoring on this island took place in 1985, 1986 with more limited monitoring again in 1992 and 1993.

The threatened loggerhead and endangered green are known to nest on DRTO keys. Juvenile hawksbills and greens forage among reefs and lagoons, and hawksbills may nest on the islands. The endangered leatherback has been observed in deep water near the park, while the endangered Kemp's ridley has been reported from the area.

Relatively complete records of sea turtle nesting (primarily loggerheads and a few greens) are available for about six years (non-consecutive) at DRTO, mostly in the 1970's and 1980's. Data for some years include counts of eggs and records of

hatching success. Several years of tagging data are also available. In addition, partial surveys of nesting in other years and various anecdotal observations and photographs exist. The nesting population is believed to include 50 to 100 nesting females per year, but the data are not adequate to determine trends. (LH)

Future monitoring of sea turtles would be conducted with the standardized protocols used by Florida DNR and the USFWS.

Mammals

Of the 17 species of mammals that inhabit St. John, only the 5 species of bats are native and little is known of their status in the park. Bats have been observed at BUIS, but no detailed information exists. ? mouse.

Marine mammals, such as humpback whales and dolphins, are occasionally seen in within VIIS and BUIS waters.

St. John has 12 species of non-native mammals that have the potential for causing further large scale ecological changes to the island. Mongooses were introduced to St. John in 1872 to control rats and have since become naturalized, but large scale reductions in native birds, reptiles, and amphibians have resulted. Feral populations of goats, pigs, and donkeys have been steadily increasing since the 1960's, and pose a serious threat to park resources. Mongooses have been eliminated from BUIS, but rats are still present and are known to consume sea turtle eggs and hatchlings. *not sure ?*

No large grazing animals are indigenous to any of the Caribbean islands. Most forested lands in the Eastern Caribbean were cleared and converted to agricultural uses. On St. John, populations of feral donkeys have been on the increase since the 1960's. Goats are generally untethered and form large herds. Domesticated pigs frequently escape or are permitted to roam through forested areas. Cattle, horses and sheep also graze island-wide. The effects of grazing by farm animals on the VIIS forests are significant and increasing.

Donkeys

Donkeys prefer early successional dry forest areas (many of which were pastures when the VIIS was established in 1956) over the more mature, closed-canopy dry woodlands. These degraded parklands are typically species-poor, open thickets dominated by thorny leguminous vines and exotic trees (Ray 1993). Mangrove communities, particularly the swamps, salt ponds and mud flats are also sites of intensive donkey grazing.

Goats

herds of goats currently graze in the dry evergreen thickets and woodlands on St. John. In some areas, goats have created scrublands where diverse, dry evergreen thickets once thrived. The cactus community on Ram Head (south shore of St. John) has been stripped of much of its herbaceous cover. Woodlands with closed canopies are divested of most native seedlings and saplings. Soils thus exposed on steep coastal hillsides frequently erode, hindering forest recovery. It is not necessary to demonstrate the destructive effects of goat grazing on dry forest communities. The consequences of permitting goats to graze unattended on island vegetation are on display throughout the region.

Pigs

Feral pigs roam widely on St. John and are of increasing concern because of their effects on the island's vegetation. Even some of the more remote areas are now showing evidence of pig rooting, and pigs have already destroyed several sampling sub-plots within one of the long-term vegetation plots, on Bordeaux mountain.

Birds

Shared species of pantropical seabirds provide one of the strongest biological linkages between the NPS areas of the tropical island cluster (DRTO, VIIS, BUIS). The Caribbean seabird guild in oceanic areas of the cluster includes 17 species, of which 14 nest or occur regularly in and around DRTO and the USVI parks, including tropic birds, frigate birds, boobies, noddies, and terns. Extensive information on nesting seabirds is available for DRTO, notably studies by Dr. Robertson and others on terns, noddies, and masked boobies (Robertson 1964, Clapp and Robertson 1986).

A comprehensive inventory of birds for VIIS has been completed. This inventory includes basic distributional information and breeding/migratory phenology, and has been summarized in a checklist for St. John. The Audubon Christmas Bird Counts provide useful data. A population monitoring study begun in 1992 focuses on the wading bird community within salt-pond and mangrove wetlands on St. John. Initial results indicate widespread movement between wetlands by birds due to water fluctuations.

A current monitoring study by ornithologists from the Institute of Tropical Forestry, the Nature Conservancy, and Connecticut College is examining population densities and species assemblages of 13 species of winter-resident neotropical warblers that occur within VIIS. This study demonstrated that the intact forests of St. John contain higher densities and richer species diversity of warblers than the fragmented forests of neighboring St. Thomas.

The brown pelican was listed as an endangered species throughout its range in 1970, which includes the U.S. Virgin Islands, because of declining populations as a

BUS 40+ adults nesting 13 1995/96
result of pesticide contamination. Nesting populations have declined in the USVI from over 475 nesting pairs during 1980 to approximately 200-300 in the last several years.#### Pelican die-offs have occurred in the Puerto Rico/Virgin Islands area in recent years. Causes are unknown, but a prime presumed factor is a decrease in fish fry populations necessary for recruitment and survival.

Surveys of brown pelicans, boobies, terns, and other seabirds have been conducted in the USVI since 1975 by the VI Territorial Wildlife Department, U.S. Fish & Wildlife Service, and NPS staff.

Reptiles and amphibians

Reptiles and amphibians are the least well known of the VIIS and BUIS terrestrial vertebrates in terms of distributions and relative abundances. No systematic inventory has been done within the park for at least 10 years. Current sources of information concerning the herpetofauna are two identification guides. Plans at BUIS call for reintroducing the federally endangered ground lizard.

Terrestrial invertebrates

A list of invertebrates (*Platyhelminthes*, *Mollusca*, *Annelida*, *Onychophora*, *Arthropoda*, *Arachnida*, *Myriapoda*, and *Insecta*) known to occur in VIIS appears in Muchmore (1987).

A comprehensive survey of beetles on Buck Islands and St. John is ongoing.

Ectoparasites

In 1989, an incident of relapsing fever was traced to St. John (Flanigan, et al. 1991). Unfortunately, nothing is known of the species of ticks, fleas, and mites that live closely with the birds, rats, bats, mongooses, and sometimes humans on the island. An inventory of the ectoparasites on St. John and the presence or absence of any arbovirus associated with them would be of interest ecologically and epidemiologically. NIH's Rocky Mountain Laboratory is presently identifying ticks and fleas from trapped mongooses and testing mongoose blood for antigens to Lyme's disease, relapsing fever, and the latest "Navajo" hemorrhagic fever.

Soils

Scientists from the Soil Conservation Service are nearing completion of an updated soil survey of the Virgin Islands (including Buck Island and St. John). A soil map at 1:12,000 scale (higher resolution than the existing map) will be completed in 1994. Additional soil series have been proposed for St. John as a consequence of

new knowledge of the unique (?) soil mineralogies of the island. Updated soil maps will permit a synthesis of the relationship of plant communities known in detail from the long-term plots to the island's soils.

Computerized data stations, which record soil temperature and moisture readings on an hourly basis, have been installed in four locations in the Lameshur Bay watershed as part of a regional network of such stations intended for long-term monitoring of global climate change. Solar-powered weather stations at two of these sites record relative humidity, rainfall, windspeed and direction, solar radiation, and air temperature on an hourly basis.

All five University of Wisconsin plot locations have undergone thorough soil analyses and three of the five sites have had their soils described by U.S. Soil Conservation Service scientists. The three remaining forest monitoring projects will be receiving an expanded program of soil characterization and physical and chemical analyses.

Geology

A brief description of the geology of St. John appears in Rogers and Teytaud (1988). Dr. Douglas Rankin from the USGS came to St. John several times in the late 1980's to prepare a new map for the island. The map is apparently complete, but not yet officially available. *Bus Moune Geo / Hubbard.*

Water Quality

Since 1988 VIIS biologists have been gathering data on turbidity, percent light transmission, salinity, dissolved oxygen, pH, and conductivity at 30 sites around St. John. Recently, the Research Division acquired a LiCor Quantum Meter which is being used to gather baseline data on "photosynthetically active radiation" (PAR) and light extinction coefficients (an indication of the amount of light which reaches selected depths below the surface).

We need more information on nutrient concentrations in marine waters around the island and the input of nutrients from land to determine the significance of sewage and other contamination.

Only very limited information is available for water quality parameters at DRTO.

Bacteria A baseline inventory of E. coli and Staphylococcus aureus in the marine waters and monitoring on a 6 month basis would be sufficient (with the nutrient/chlorophyll testing) to detect the presence of untreated human sewage. This is obviously important as St. John is being developed rapidly, tourism increases yearly, and, at present, we have no information on the presence or absence of bacteria in the marine water. The only reliable sampling to date was done in Dec. 1992 when 5 sites in St. John waters were sampled for a UNEP

funded study; all cultures were negative for the St. John samples.

VIIS has just begun a 1 year study to document nutrient (nitrates, nitrites, and phosphates) concentrations in the waters surrounding St. John. Since an increase in nutrients may not be detected because of rapid removal during a phytoplankton bloom, it is also important to determine the amount of phytoplankton in the water by analyzing for chlorophylls a and c. This needs to be added to the study. Two factors contribute a seasonal influx of nutrients to St. John's waters:

- 1) heavy rains wash soil, animal feces, and organic debris from areas which are being cleared for development down into the intermittent stream beds on the island and into the ocean
- 2) the Orinoco River discharges its nutrient-laden water into the SE Caribbean where it is carried Northwest by currents, to exit the Caribbean, between St. Martin and the Dominican Republic. While transiting the Caribbean, the nutrient-rich Orinoco waters stimulate a phytoplankton bloom which rapidly takes up the nutrients and tightly recycles them.

This influx of nutrients is exhibited in the Caribbean islands by a dramatic decrease in visibility (to less than 30') with the normally blue waters turning a reddish-brown color for a few days to weeks in October or November. This moving "river" of phytoplankton feeding on the nutrients derived from South American soil can be followed in satellite photographs of the region (Muller-Karger et al. 1989).

Physical oceanography

VIIS/BUIS

Knowledge of current velocities and directions is essential for effective management of marine resources. Very little information exists on the currents around Buck Island and St. John. Information on currents is important for predicting the direction of transport of sediments, oil spills and other pollutants. Currents transport fish and shellfish larvae and other reef organisms from upstream sites and therefore can play a major role in the recovery of ecosystems after over fishing or hurricane damage.

Data on water temperature are being obtained from thermistors which are left in site at 3 coral reef study sites in St. John, one site at BUIS, and ### sites in Dry Tortugas

DRTO

Through a cooperative effort with the Florida Institute of Oceanography (FIO) SEAKEYS program, the NOAA National Data Buoy Center and Florida DNR, an

enhanced automated environmental monitoring system known as C-MAN has been installed at DRT0. This station is one of seven existing or planned stations in the Florida Keys. Data collected include: wind speed, direction, precipitation, solar radiation, and salinity. A cooperative agreement between FIO and DRT0 is needed for maintenance of the station. A SEAKEYS hydrolab station and a NOAA thermograph are also located in or adjacent to DRT0.

Air quality

VIIS is a Class 1 area. The park is currently operating a particulate sampler which operates over a 24 hour period twice a week. This sampler has been functional for two years.

In order to bring air quality monitoring up to par for a Class 1 area, it is suggested that a transmissometer be used. In addition, an Acid Deposition Station should be established, to determine what baseline levels are in a relatively pristine site.

Meteorological Data

The USGS maintains a meteorological station near the Biosphere Reserve Center which records wind velocity, wind direction, solar radiation, humidity, rainfall, temperature, and barometric pressure. This station was installed in 1992.

See Tables 4, 5, and 6 for a listing of the top priorities for additional inventory.

3. *Program Readiness:*

VIIS/BUIS

WE ARE READY!!

Background

Virgin Islands National Park has collaborated with numerous other organizations and agencies in establishing a basic, integrated long-term monitoring program. In 1982, the National Park Service founded the Virgin Islands Resource Management Cooperative (VIRMC). Signatories to the Memorandum of Understanding were: Virgin Islands National Park, The Department of Planning and Natural Resources (USVI Government), University of the Virgin Islands, West Indies Laboratory (Fairleigh Dickinson University), Island Resources Foundation, Eastern Caribbean Natural Area Management Program, U.S. Geological Survey, U.S. Fish and Wildlife Service, Southern Forest Experiment Station (USDA), University of Puerto Rico, Caribbean Fishery Management Council, the Ministry of Natural Resources and Labor of the British Virgin Islands Government, and the British Virgin Islands National Parks Trust. Between 1983 and 1988, VIRMC members conducted 29

**INVENTORY AND MONITORING PRIORITIES
VIRGIN ISLANDS NATIONAL PARK**

INVENTORY	
MARINE	TERRESTRIAL
Nutrients, Bacteria, Chlorophyll	Exotic amphibians
Currents	Bats
Update benthic maps (GIS)	Reptiles
Sponges/Gorgonians	Ectoparasites
Bait fish	Exotic plants
	Riparian fauna
	Pollutants in ghuts
MONITORING	
MARINE	TERRESTRIAL
Establish new coral reef study sites	Feral Animal Impacts
Continue ongoing studies	Establish additional long-term vegetation plots
Nutrient, Bacteria, Chlorophyll, Suspended Sediment	Continue paired watershed study
Population studies of commercially important fish/shellfish species	Continue ongoing studies of vegetation, birds, etc.
Visitation patterns	Forest Dynamics: Nutrient cycling, seedling recruitment, growth
Sea turtle nesting	Exotic plant encroachment

projects (see Appendix B)####. The park's research biologist, Dr. Caroline Rogers, served as the Executive Officer of VIRMC, and collaborated with Robert Teytaud in synthesizing the results of these projects (see "Marine and Terrestrial ecosystems of the Virgin Islands National Park and Biosphere Reserve).

Phase I of the VIRMC studies focused on obtaining baseline data on critical benthic habitats and fisheries around St. John and Buck Island. Phase II studies emphasized an interdisciplinary approach to selected watersheds on St. John and the initiation of long-term monitoring of some of the ecosystems. The third Phase included studies of the consequences of increasing recreational uses of marine resources, further work on long-term plots established in St. John's forests and watershed processes and an analysis of Buck Island fisheries.

Many of the more recent marine projects have been supported by NRP funds through cooperative agreements with VIRMC members. In many other cases, the park made in-kind contributions or covered transportation, lodging costs, purchased supplies and provided NPS biological technicians to assist with field work.

The National Park Service provided \$590,000 to support the NPS Coral Reef Assessment Program for a 5 year period beginning in 1988. The overall goal was to establish effective long-term research and monitoring sites at the four NPS units which have coral reef ecosystems: VIIS, BUIS, DRTO, BISC. Seven cooperating institutions participated in this program--University of Georgia, Northeastern University, Florida Dept. of Natural Resources, Southeast Fisheries Center (NOAA), USVI Division of Fish and Wildlife, West Indies Laboratory (Fairleigh Dickinson University), and Island Resources Foundation. The Regional Office has provided additional, limited funding to continue monitoring at these four sites. The emphasis has been on hard corals, octocorals, and reef fishes. Thermistors have been placed at several sites in all of the park units to collect continuous data on sea temperatures.

The effects of Hurricanes Hugo (1989) and Andrew (1992) have been documented at the respective parks but monitoring of recovery should continue. Cruise ship anchor damage to reefs has been documented and monitoring of recovery should continue.

The substantial amount of research which has been conducted on the marine and terrestrial ecosystems of St. John in the last decade has provided an excellent basis for an expanded and more systematic monitoring program. Significant amounts of NRP funding (for marine resources) and a commitment by the Regional Chief Scientist to sustaining long-term monitoring have been combined with funding and in kind contributions from several other agencies (including UNESCO's MAB [program] to support these efforts. The Research Biologist for VIIS has encouraged collaboration of the scientists working on the island (for example,

collection of soil samples in long-term vegetation plots) and concentration of much of the research in a few watersheds which were selected for their ecological significance. The Lameshur Bay watershed has been the focus of research on dry forests, coral reefs, seagrass beds, reef fishes, soil temperature/moisture, sediment runoff, etc. The forested, largely intact watersheds of Little Lameshur Bay, Great Lameshur Bay and Reef Bay are considered the core of the Virgin Islands Biosphere Reserve (although not officially designated as such).

Long-term vegetation plots have been established in 8 watersheds on St. John, and research on forest dynamics including succession, regeneration after Hurricane Hugo, seedling mortality, and germination requirements are ongoing. Additional terrestrial studies include mapping of the island's soils, and a paired watershed study to look at the effects of clearing of vegetation on sediment runoff rates (see Table 7).

Table 7. VIRGIN ISLANDS NATIONAL PARK FOREST STUDIES

RESEARCH PROJECT	INSTITUTION	DATE	OBJECTIVES	RESEARCH SITE
Vegetation mapping	Intern'tl Institute Tropical Forestry	1982	List plant species on island	Island-wide
Forest Dynamics Study I	Intern'tl Institute Tropical Forestry	1983-present	Long term monitoring of forest dynamics	16 plots on elevation gradient, Cinnamon Bay
Forest Dynamics Study II	New York Botanical Garden/ U of Georgia	1986-present	Long term monitoring of forest in 3 watersheds	3 (0.5-1.0 hectare) plots in 3 forest types
Seedling and Sapling Dynamics	New York Botanical Gardens/ U of Georgia	1989-present	Monitoring seedling and sapling survival, growth & mortality	3 permanent forest plots
Permanent Monitoring in Semi-evergreen Dry Woodland	Smithsonian Institution	1992	Establish dry forest plot as part of MAB Biodiver-sity Program	1 hectare dry forest plot
Dry Forest Restoration	U of Wisconsin	1988-1992	Research dry forest restoration and effects of Hurricane	5 long-term plots
Soil Characterization	Soil Conserv. Service	1992-1993	Prepare new soil map, character-ize soils	Island Wide Long term plots
Paired Watershed Study	USGS	1992 - present	Compare sediment loads	Developed and Natural watersheds

Standardized Protocols

Standardized protocols are available for all major proposed monitoring programs. One product of the NPS Reef Assessment Program is the comprehensive Coral

Reef Monitoring Manual which was prepared by VIIS and BUIS research staff with assistance from many other scientists who participated in the program. This manual includes all of the protocols which are relevant to research on coral reefs and reef fishes in VIIS, BUIS, and DRT0.

The Smithsonian has provided published, standardized protocols for establishing and monitoring of long-term vegetation plots and have established one hectare plot on St. John using these protocols. Additional terrestrial vegetation survey methods in use on St. John have appeared in Dr. Gary Ray's doctoral dissertation and associated publications and in publications by Dr. Pete Weaver and Anne Reilly.

An annotated bibliography is available for marine studies at Buck Island and the ecological history of VIIS prepared by Research Biologist C. Rogers and R. Teytaud includes an extensive bibliography.

DRT0

The system-wide marine resources planning brought about by the establishment of the Florida Keys National Marine Sanctuary in 1990 provides an excellent basis for establishing a systematic and coordinated monitoring program for DRT0.

Implementation of the FLKNMS management plan will involve numerous MOAs, MOUs and cooperative agreements. These should begin to come on line over the next two years. NPS staff have been participating in Sanctuary planning from the beginning, and will continue to be part of the Sanctuary management team and the management process.

4. *Monitoring Program Design:*

The monitoring program proposed here for VIIS, BUIS, and DRT0 is essentially an expansion of existing and prior monitoring and an effort to integrate ongoing monitoring activities into a systematic, comprehensive program with continuity and consistent funding. The integrations of these activities means placing them in a well-defined conceptual framework and coordinating the studies with each other so that the projects are not carried out in isolation from each other but rather pieces of an ecologically-based program. Tables 4,5, and 6 list the highest priority monitoring projects.

FUTURE MONITORING

Coral reefs: VIIS

Long-term coral reef research around St. John currently focuses on Newfound Bay (begun in 1990), Lameshur Bay (begun in 1988), the "Windspirit" anchor site

(begun in 1988). The emphasis has been on percent live coral cover, species diversity of hard corals and octocorals and sponges. This research has been one of the primary activities of the NPS research staff with complementary studies by outside investigators. The program will be expanded to include one or more permanent sites in additional areas around St. John to provide better representation of the island's marine hard bottom communities. Benthic maps prepared in 1986 as part of a VIRMC project indicate that gorgonian(i.e., soft coral)-dominated pavements are more widespread than the current monitoring sites at Newfound and Lameshur Bay which have higher amounts of hard corals and better-developed reef structures. Further research is necessary to determine the relative value of these different reef habitats to fish populations.

We propose to expand the current monitoring program for coral reefs with the addition of two or more new sites. Haulover Reef (Figure ###) is considered the highest priority because of the potential for degradation which could accompany development of the associated watershed. The park boundary cuts through Haulover Bay, a pristine watershed. Western Haulover Reef is one of the best developed reefs in the park, with exceptionally high cover by the Caribbean's primary reef builder, Montastrea annularis (star coral). Major road construction began in August 1993 along the steep hillside on the eastern side of the bay. Private development of thirty lots, 2-3 acres in size is proposed for the bay. Because of its windward ("upstream") location, Haulover has been considered less subject to some of the stresses which presumably influence other bays in the park (e.g., sedimentation). However, an oil spill in March of 1991 resulted in tarring of the rocky shoreline within the bay. No serious environmental consequences were observed after the spill.

We propose to establish a permanent, long-term site in Haulover using methods which we've used at our other reef sites. The second proposed reef site would be selected after preliminary surveys from an area dominated by octocorals rather than hard corals. Benthic maps and observations by park biologists indicate that these reef types are more representative than the hard coral-dominated areas which characterize our Newfound and Lameshur sites. Initially we selected those sites because well-developed physical structure of the reefs is generally associated with higher diversity of organisms. Our new study site would be chosen from an area with low topographical relief, low amounts of cover by live hard corals, and an abundance of gorgonians.

Belt transects or random quadrats would probably be chosen over line transects for collection of benthic data as they are more appropriate in octocoral-dominated areas (NPS Coral Reef Monitoring Manual). After establishment of the two new sites, biological monitoring would be conducted every 6 months with greater frequency in the event of a major storm, oil spill, or other disturbance.

Several episodes of bleaching of hard corals and other reef organisms have been reported in the last decade for Pacific and Caribbean reefs. Severe bleaching was documented on VIIS and BUIS reefs in 1987. Most coral colonies which were observed over several months recovered entirely or partially from the bleaching. Bleaching appears to be related to high water temperatures and UV radiation, and some scientists think that it is related to global climate change. Monitoring of reefs in DRTO, VIIS, and BUIS should include documentation of any bleaching events which occur following the protocols which have been expressly described in the NPS Coral Reef Monitoring Manual.

Coral reef fishes/VIIS

The proposed monitoring of reef fish assemblages in VIIS would include continuation of ongoing monitoring (including documentation of species within fish traps, visual censusing) with the addition of censusing on a regular basis (at least quarterly) at the two new coral reef sites (Haulover and one reef to be selected).

An NRP project on the effects of fishing in VIIS and BUIS is now underway. Visual censusing of fish populations around St. John, and in particular, at Lameshur Bay, and censusing of the fish caught in traps should be continued to allow evaluation of the effects of fishing on the reef fish assemblages. Similar monitoring is taking place at BUIS. Two VIIS sites, Yawzi Point (in Lameshur) and Cocoloba Reef, have been intensively sampled since Nov. 1988. This effort provided information on monthly/seasonal variations and allowed documentation of the effect of a large natural disturbance, (Hurricane Hugo), on reef fish assemblages. Annual sampling at 10 reef sites around St. John has been conducted since 1989. A previous study (Boulon 1986) sampled fishes among different habitats. Existing trends demonstrate seasonal variation in abundance due to recruitment peaks, natural variation in species abundance, and differences in assemblage structure among sites. A longer trend should provide information on cyclic changes in assemblage structure and in abundance of commercially important species such as groupers and snappers.

Reef fish assemblages exhibit high variability in numbers of individuals both seasonally and annually, and only long-term monitoring can reveal if abundance and sizes of fishes are declining. More data are needed to elucidate trends in fish populations and the relationship between habitat structure and the abundance and diversity of fishes. This information will augment the work (referred to earlier) by Nick Wolff, a graduate student from the University of Rhode Island. Nick is scheduled to begin his work in Fall 1993. He will be examining the relationship between habitat structure and fish assemblage characteristics through a combination of a trapping program and visual census techniques. A few studies

have shown a correlation between number of species and abundance of fishes and the percent live coral cover and/or topographical relief (substrate complexity). Areas with higher bottom relief may support more species because they provide better shelter from predators and/or more food organisms.

Studies of fish assemblages in octocoral dominated areas and knowledge of locations where fishermen generally set their traps will add to our limited knowledge of the effects of trap fishing around St. John.

In addition, density and abundance of groupers and snappers (large predators, of commercial importance) will be studied on at least three reefs (to be selected) within the park.

Baitfish, including Jenckensia and Herengula spp., are clearly of significance to local fisheries. Populations of these fish are very difficult to sample adequately. However, presence/absence surveys around the full moon when these fish are known to aggregate in nearshore waters can be conducted for bays around St. John. This simple monitoring activity can provide very useful qualitative data.

Recruitment of larval fish is known to be highly variable over periods of several years and it can be difficult to study effectively. However, recruitment of fishes of particular species to areas along the permanent transects established for several coral reef sites around St. John will be attempted as part of the proposed monitoring program.

Lobsters and conch will be surveyed for comparison with data collected during previous studies in the late 1960's (during the Tektite program) and in 1990 .

Finally, we propose to establish a marine reserve within VIIS within which fishing is prohibited. Reserves are beneficial because they are thought to 1) protect the spawning stock biomass, 2) supply recruits to fished areas, 3) enhance catches in adjacent areas through emigration, 4) insure against stock collapse due to successive years of poor recruitment, and 5) simplify enforcement (Davis 1989, Bohnsack 1990).

Marine reserves established in New Zealand, the Philippines, Australia, Kenya, Costa Rica, Belize and other countries have in the 1.5 to 13 years of their existence gained enthusiastic support from the public, fishing community, and researchers in the area. They range in size from large ($> 300 \text{ km}^2$) to small ($< 0.5 \text{ km}^2$), temperate to tropical, and occur in developed and developing countries. Unfortunately, very little quantitative information exists on the marine communities at these sites before they became reserves. Despite this lack of prior data, the changes have been so dramatic, many fisheries scientists consider marine reserves to be the newest and most promising fisheries management tool. Now all we need

is "hard" data.

VIIS is in the unique position of having 5 continuous years of data on fish assemblages and coral cover data. A marine reserve [at Lameshur] on the south-shore of VIIS would have as its foundation both long-term monitoring data and years of multi-disciplinary studies:

- our long-term coral reef monitoring site (since 1988)
- site of the Tektite studies (underwater habitat)--1968-1971
- sites of John Randall's classic early fish work (early 1960's)
- 3 long-term fish census sites (since 1988)
- 2 monitored turtle nesting beaches
- sites of an NPS/USGS paired watershed study
- site of 10 year study of the sea urchin Diadema antillarum, probably the most significant grazer on coral reefs
- site of an ecological field research station (VIERS) from which a multitude of "snapshot" and long-term studies are carried out
- site of long-term studies on sea grass beds

Monitoring the fish, conchs, lobsters, and living coral on the reefs would provide data on before and after reserve establishment, data which are not available from anywhere else.

We are very excited about observing, documenting, and ultimately analyzing the changes as they occur in the marine reserve. The information would be invaluable to other scientists and managers contemplating creation of other marine reserves. All of the studies necessary for evaluation of the effects of a marine reserve are ongoing.

The selection of the site for the reserve is very critical. If Lameshur Bay is selected, prior baseline data will be available. Elsewhere, data on fish assemblages (sizes, species) will have to be obtained prior to establishment of the reserve.

The USVI Government has been looking into the possibility of establishing several reserves around St. Thomas and St. John. Possibly the NPS reserve could adjoin a local government reserve along the park boundary, increasing the size of the area. In some cases, prohibition of fishing has resulted in surprisingly rapid increases in the size of target species.

Channel Islands National Park, under the direction of Dr. Gary Davis, is pushing for establishment of marine reserves. Creation of these reserves in a temperate (CHIS) and tropical (VIIS) park offers exciting opportunities for comparison.

Coral Reefs/Reef Fishes: BUIS

The proposed monitoring program for reefs at BUIS would include continued monitoring at all sites surveyed under the NPS Coral Reef Assessment Program. White band disease and storms have severely reduced the populations of elkhorn coral, Acropora palmata, which was the primary framework-building species at BUIS. Dr. Bill Gladfelter documented the decrease in the percent cover of this species as a result of physical damage during Hurricane Hugo. Prior to Hugo, this species appeared to be recovering from white band disease. Monitoring of the sites established by Dr. Gladfelter and additional sites on the generally less studied northwestern patch reefs around the island to document the status of this species are proposed.

Hurricane Hugo devastated portions of BUIS; some areas were scoured and leveled. Recruitment of hard corals and other reef organisms would be monitored as part of the proposed program. (Very limited data on recruitment are available for a very small area in Feb. 1993.) Coral reef fishes are being monitored twice a year at BUIS as part of the NRP Fisheries Program. Additional information on trap harvests is also being gathered on a limited basis.

Coral reefs/reef fishes/shellfish DRTO

Corals, octocorals, and reef fishes have been sampled at five long-term monitoring sites at DRTO since 1989. This sampling effort by Florida Marine Research Institute scientists has been limited to two trips per year. Additional information is needed on other sites, notably an extensive, well-developed reef north of the main island. The community structure of fishes associated with the various habitats within DRTO and surveys of recreational fishing are proposed for future monitoring.

The benthic habitat map published by Gary Davis (Davis 1982) for the Dry Tortugas serves as a starting point for collection of specific information on the various reef fish habitats. Future monitoring would include the comparison of differences in fish assemblage structure and abundances among habitat types. These studies will help to identify critical habitats which may need additional protection.

Presumably because of the park's remote location and the absence of commercial fishing, Dry Tortugas has large numbers of large reef fishes, lobsters and conchs within park boundaries. Groupers over 0.5 m are common. While lobsters and conchs are completely protected, reef fishes are not. Recreational fishing is apparently increasing. Charter boats land several hundred pounds of fish per trip. Adequate protection of the reef fish within DRTO depends on obtaining estimates of recreational landings and on the existing abundance and density of reef fish.

Limited monitoring of the lobsters and conchs in the park should be carried out for comparison with earlier work done by Gary Davis.

Monitoring of the recreational fisheries at DRT0 will be carried out using protocols established for Everglades National Park. Given the significant fishing pressure observed throughout the Keys and increasingly at DRT0, the comparative value of monitoring at DRT0 can not be overemphasized.

Sea turtles

Monitoring of nesting sea turtles will be continued at BUIS and DRT0. Information derived from the BUIS research and monitoring program is directly applicable to the continued listing and protection of hawksbills as priority 1 species under CITES in 1994. Caribbean hawksbills have been the target of black market bekko (tortoiseshell) sales to Japan; since Japan has agreed to stop importing bekko in 1994, they are looking elsewhere for a supply. It is critical to determine whether or not hawksbills undertake reproductive migrations and, through mitochondrial DNA analysis, the relatedness of the females nesting in the few concentrated "rookeries" known in the Caribbean.

Other Marine studies

Our proposed monitoring program includes continued support for a series of small projects, some of which have been ongoing for 10 years. (In most cases, travel expenses are all that is required.) Dr. Don Levitan started research on the black sea urchin Diadema antillarum in 1983, prior to the over 95% mortality of this important herbivore throughout the Caribbean. He has been able to document their slow recovery.

Dr. Lisa Muehlstein (University of Richmond) started monitoring of sea grass beds in Great Lameshur Bay in 1989 for change in species and density of sea grasses, and recovery of areas scoured by waves associated with Hurricane Hugo. Monitoring will be expanded to include additional sites in Lameshur and on the north shore of St. John. Sampling of permanent transects will be done on a quarterly basis and will provide data on seagrass community structure, densities, and productivity.

Effective September 6, 1993, anchoring is prohibited in Great and Little Lameshur Bays, St. John. Monitoring of the sea grass beds in these bays will demonstrate if mooring buoys effectively provide protection to these resources.

Dr. Pete Edmunds (California State University) started monitoring of black band disease on hard corals in 1985 and established permanent quadrats and transects

in Lameshur Bay coral reefs. He has documented the effects of Hurricane Hugo, and has just begun studies of coral recruitment and DNA fingerprinting in corals.

Monitoring of water quality

VIIS

We propose to continue the monitoring of water quality on a monthly or bi-monthly basis around St. John and to augment the basic data we have been obtaining with information on nutrients, chlorophyll, and bacteria collected on a quarterly or semi-annual schedule.

Suspended matter concentrations at all sites will also be sampled as an indication of the amount of sediment in the water column. This will be done in conjunction with the LiCor Quantum Meter readings.

Development on St. John poses a serious threat to the water quality and, therefore, to the coral reefs of VIIS. By monitoring nutrients, bacteria, and chlorophyll, any short-term large increase or long-term continuous increase could alert park and territorial government managers to 1) the need to restrict further development of lands on St. John or to require more protective measures during development; 2) put a ceiling on the number of boats anchoring in bays (most boats discharge human wastes directly into the ocean); 3) advise swimmers of bays which are unsafe for swimming; or 4) or restrict the dumping of raw sewage from boats or houses into park waters.

BUIS

Water quality (including nutrients and bacteria) will be sampled at Buck Island on a quarterly basis.

Dry Tortugas

The Dry Tortugas are the first land masses along the Florida reef tract to receive nutrients, pesticides, and other pollutants from the waters of the Gulf, Central America, and South American rivers. They are also the first to be affected by decimation of fisheries in Central America and could suffer from a loss of fish recruits from overfishing of spawning aggregations. Additional influences from Gulf states are likely. Water quality must be monitored within the park, with emphasis on nutrients and chlorophyll.

The Water Quality Protection Program for the Florida Keys National Marine Sanctuary (FKNMS) focuses on the development of a water quality monitoring program for the 2800 square nautical mile Sanctuary and the waters within DRTO. DRTO is considered critical in this system-wide monitoring scheme because of its

comparative value as a relatively "pristine" site. Standardized protocols are being developed, and the sampling design has already been outlined. DRTTO will be expected to provide support for this monitoring effort.

Marine monitoring projects proposed for VIIS appear in Table 8.

VIIS FORESTS

Permanent forest plots have been established in a variety of ecological zones on St. John to investigate regeneration, recruitment, and mortality of tree species; seedling survivorship, recruitment and mortality; decomposition rates of leaf litter and woody debris; as well as the possibility of restoring a degraded forest ecosystem (Ray 1993, Reilly 1990, 1991, 1992; Weaver 1992) These forest plots represent a continuum from lowland elevation dry forest to upland moist forest.

Ecosystem processes other than succession and regeneration have been under-represented in terrestrial research on St. John. An emphasis should be made to monitor net primary productivity, organic matter accumulation, and nutrient cycling. A logical starting point would be to use the existing permanent plots as monitoring sites for these activities. Because of the inter disciplinary nature of these studies, efforts will be made to work closely with other agencies and academic institutions. It may be possible to arrange with the International Institute of Tropical Forestry for the use of St. John as a satellite site for the Luquillo National Forest LTER site in Puerto Rico.

The following vegetation types are currently included in the monitoring program on St. John: upland moist forest, gallery moist forest, and dry semi-evergreen woodland. We propose to establish a total of three additional sites, in the dry evergreen thicket, the cactus/coastal hedge ecosystem, and mangrove swamp. The dry thicket is considered the highest priority because it contains several rare plant species and constitutes a significant portion (21%) of the island's forests. The coastal hedge is home to several endemic and rare species. Mangroves stabilize the shorelines, filter sediments in runoff, and provide nursery habitat for juvenile fish.

We will continue to census all existing permanent vegetation plots every 5 years, with more frequent maintenance (replacement of plot boundary markers, tree tags, etc.) Successional processes will be monitored to examine the rates of growth, mortality, and recruitment of all seedlings, saplings and trees, and recovery following Hurricane Hugo. Future efforts will focus on dispersal of fruits, identification of pollinators, and the role of the seed bank.

Exotic plants

Experiments could be implemented in one or more of the island's Genip groves to 1) track the expansion of existing populations, 2) to test ecological restoration methods, such as underplanting existing Genip canopies with native tree seedlings to enrich the native species diversity in the groves, and 3) to test the usefulness of seedling, sapling, and tree removal of Genip in converting groves in more diverse native species assemblages.

Development

Development of all of the numerous private inholdings in VIIS, construction of roads and buildings, would seriously jeopardize the integrity of the park. In fact, it might not be clear to residents or visitors that they were actually in a national park. Road construction can lead to fragmentation of the forest such that their normal functioning is impaired. Preliminary data suggest that even an unimproved, moderately used road can have dramatic effects on species composition and forest structure (Reilly, unpublished)

The park's new GIS can be used to assist in identification of the highest priority areas for land acquisition, including areas where new roads would have the most devastating effects. The park's Land Protection Plan can be updated and enhanced with data organized through the GIS.

An inventory is needed to examine the level of disturbance (as evidenced by encroachment by exotic plant species, size of seedlings, etc.) along existing roads within VIIS. This assessment will provide a framework within which one can determine the appropriateness of creating new roads or improving old ones.

One objective of a monitoring project would be to identify appropriate "buffer zones" which are required to protect the intact forest. Permanent transects should be established prior to construction of the road and monitored yearly.

Paired watershed study

The National Park Service and USGS are collaborating on a study which compares the sediment runoff from the Fish Bay watershed which is being developed on the western boundary of the park to that from the relatively undisturbed Lameshur watershed (Figure 1). Scientists from Colorado State University are preparing a hydrologic model for the island which will incorporate data from the stream gauge samplers and pertinent soil studies, e.g. data on erodibility of soils. This study will be continued because of the lack of quantitative data on runoff for tropical islands.

Feral animals

Pigs, goats and donkeys present a serious threat to native plants. Currently, the Bordeaux Mountain plot established in 1986 is exhibiting dramatic effects from the rooting of feral pigs. Eleven out of 100 1 m² seedling plots were destroyed by pig rooting activity (Reilly 1993). The Mary Point plot has suffered from grazing by feral donkeys. Donkeys create networks of trails causing soil erosion on steep slopes, which encourages the growth of exotic weeds. Donkeys also selectively graze on seedlings of certain native tree species. The long-term effects of these disturbances are unknown. Hard data are necessary as a basis for serious management intervention. Semi-annual population estimates will be made of feral animals causing destruction to plant communities in the VIIS.

Exclosure studies offer a logical way of measuring the impact of grazing, and will be set up to identify initial conditions of the forest community in conjunction with non-enclosed areas to quantify changes in community development. Mary Point, an anvil-shaped peninsula with a narrow isthmus, is topographically well-suited for assessing the impacts of donkey grazing on degraded, young Caribbean dry forests. A fence constructed across the isthmus at Mary Point would: a) protect from grazing nearly 50 hectares of dry semi-evergreen woodland (in early and middle recovery stages), b) set the stage for potential restoration efforts, and c) obtain hard data on donkey grazing impacts.

Vegetation will be sampled along permanently marked transects on both sides of exclosure fences. Seedlings will be sampled in 1-m² quadrats, semi-annually. Diversity, recruitment, survival and growth of seedlings will be evaluated.

The vegetation of Ram Head, the best example of a native cactus community in the VIIS, has been heavily damaged by goats and donkeys in recent years. Ram Head Point should be fenced at the landward end to exclude goats and donkeys, and a set of permanent plots should be established to monitor vegetation recovery.

BUIS Vegetation

We propose to establish a long-term vegetation monitoring plot on Buck Island. Because Buck Island lacks donkeys, pigs, and goats which are having detrimental effects on the vegetation of St. John it serves as a natural reference site (an "exclusion" study) for increasing our understanding of the effects of these feral and exotic animals on dry forest plants. It is acknowledged that Buck Island may not be a perfect "control" site, but it offers a natural experiment with the potential for very valuable data. Following site selection and the mapping and identification of all tree within the plot, monitoring could be conducted every 3 to 5 years.

Intermittent stream beds/freshwater communities

The water quality of intermittent freshwater streams within the VIIS has not yet been tested. Locally permitted discharges of sewage, and pollutants from other developments may be causing algal blooms observed in Battery Gut (near the western boundary of VIIS). Streams in affected park watersheds will be sampled. Analyses will include nitrates, ammonia, phosphates, and Staphylococcus:E. Coli ratios. Fish and macroinvertebrate populations will also be monitored.

Bird Monitoring Program

Wetland bird communities

Although the wetlands on St. John are not extensive, they serve as critical habitat for migrating and overwintering shorebirds and waterfowl, as well as some resident birds. Many wetlands have been destroyed or degraded outside of park boundaries within the Virgin Islands. As remaining wetlands shrink, those within the park become even more valuable refugia.

Birds in selected wetlands within park boundaries on St. John will be counted on a weekly basis from September through May. Special attention will be given to shorebirds and waterfowl. During the first 2 years only population numbers will be monitored; thereafter wading birds will be banded to get information on turnover rates and habitat use across different wetland areas on St. John.

Migratory warblers

Dr. Bob Askins and Dr. Dave Ewert began working on migratory birds in VIIS in 1989, comparing abundance and species assemblages of migrants found in the large blocks of contiguous forest in the park with their abundance in remnant patches of similar forest on the nearby, extensively developed island of St. Thomas (Askins et al. 1992, Askins and Ewert 1992). Permanent survey points were established and fixed-radius point counts were made during the winters of 1989-1992. This research has shown the importance of having intact forest as winter habitat, as the intact forests of St. John contained higher densities and richer species diversity of warblers than the fragmented forests of neighboring St. Thomas. With the exception of a project in Puerto Rico that has been running since 1972, this work is the first systematic monitoring program of winter residents in the West Indies.

The project on migratory and resident warblers will be continued for several more years. The permanently marked survey points will be repeated every winter. In 1993, this study will begin to evaluate the foraging behavior of winter-resident warblers and the availability of the insects they feed on. Information on prey abundance will help to interpret changes in migrant abundance on St. John.

Brown pelicans

Monitoring production of chicks by brown pelicans is difficult because of asynchronous breeding, and pelicans must be monitored throughout the year. Since pelicans take ca. 60 days to fledge, surveys should be conducted at least every month so that chicks can be observed during development and accurate counts made. The pelican colonies within VIIS and BUIS will be monitored. If breeding birds are present, numbers of nests and individuals (classified by age class) will be counted.

Mammal Monitoring Program

The main focus of mammal monitoring at VIIS will be on the bat fauna. First, presence/absence and distributional information will be obtained from all major vegetation types in the park. Then, studies will concentrate on assessment of food habits during the dry season, when fruit bats are most likely to be food-limited (but fruit phenology needs to be checked on - the dry season may not be "crunch-time" for frugivorous bats). (Dr. Gary Ray has extensive phenology information for trees on St. John.) Only after these studies are done will actual population estimates be attempted.

Estimating numbers of bats that are widely distributed manner is very difficult. As is true of most tropical forest bats, the species at VIIS roost in tree cavities and foliage. Locating large concentrations of bats is thus impracticable, and capture efforts need to be spread out over large areas. Bat population monitoring activities will be conducted for three week periods. These periods will coincide with the occurrence of the dry season and also following an episode of extensive rainy weather. Mist nets will be hung in the canopy at night, and trees will be searched for roosting bats during the day. Any buildings used by bats for potential roost sites will also be searched.

Feral animal numbers and their impacts to vegetation definitely need to be better quantified (discussed above).

Mongoose will be trapped and removed from VIIS beaches where sea turtles nest during the June through November season. No other efforts will be made to monitor mongoose because of their ubiquitous distribution over St. John.

Rats will be monitored at BUIS to assess whether or not control actions are needed prior to any reintroduction attempts of the federally endangered ground lizard (*Ameiva polops*).

Reptile and Amphibian Monitoring Program

A thorough inventory of the herpetofauna of St. John is needed, followed by monitoring of rare and introduced species. Many of the species that have survived mongoose predation are very secretive and hard to find. Therefore, a combination of direct focused searching and systematic trapping grids will be used to capture and identify herps throughout the wet and dry periods over a one year period. Following that, species of concern will receive more extensive monitoring efforts. Particular emphasis will be given to detecting the presence of, and preventing the spread of introduced species. Dr. Gregory Mayer, of the University of Wisconsin, has confirmed the recent introductions of two tree frog species to St. John, the Cuban tree frog and Puerto Rican coqui.

Comparisons of aerial photos using GIS

A series of aerial photographs are available for St. John, with a more limited set on Buck Island. We propose to use GIS technology to quantitatively compare the major features of terrestrial and marine ecosystems in VIIS and BUIS. For example, Hugo is known to have effectively shifted the southern reef crest at least 30 m towards the island and to have reduced the extent of sea grass beds (through scouring and burial). Also, new roads and houses are being constructed every week on St. John. Many of these changes can be charted through comparison of values from digitization of aerial photographs. It would be very valuable to do an update of the benthic map prepared by Gary Davis for Dry Tortugas (Davis 1982).

See Table 9 for proposed terrestrial monitoring projects for VIIS.

5. *Scientific Credibility and Capability:*

VIIS has a Division of Research and Resource Management with 4 permanent positions, including a Research Biologist (GM 13), a Biological Technician (GS 7) with a Masters Degree, and two Resource Management Specialists (GS 11), both of whom have completed the resource management training program. There are currently two temporary Biological Technicians both of whom have Master's Degrees. The Research Biologist has 19 years of experience in tropical ecology with an emphasis on long-term research and the effects of disturbances on coral reefs. One of the resource management specialist has GIS expertise. Presently BUIS has 1.0 FTE/Biological Technician, GS-07/2, who has completed the Natural Resource Management Training Program in 1992. This biological technician has responsibility for natural resources at BUIS. She is supervised by the Chief, Interpretation and Resource Management.

The park's Research Biologist who will coordinate the overall I & M program has worked for NPS for 9 years and has a great deal of experience coordinating large research programs (such as the NWRMC, NRP programs noted above).

Table 9

RESEARCH TOPIC	PROPOSED MONITORING OF TERRESTRIAL RESOURCES
FORESTS	1) Add two 1-hectare forest plots to MAB Biodiversity study. 2) Establish permanent sites in underrepresented habitats; dry evergreen thicket, coastal hedge, cactus community and mangrove swamps. 3) Continue long-term monitoring in existing permanent vegetation plots; completely recensus all plots every 5 years. 4) Install fruit/seed traps in each of the plots to quantify reproductive success and dispersal events. 5) Collect soil cores from each plot following dry & rainy season to evaluate role of seedbank. 6) Conduct germination trials
EXOTIC PLANTS	1) Track expansion of existing population of genips 2) Test ecological restoration methods of native tree species 3) Test usefulness of seedling, sapling, and tree removal of Genip in converting groves to native species assemblages
DEVELOPMENT	1) Establish transects which bisect a road to conduct vegetation study. 2) Identify appropriate "buffer zones" which are required to protect an intact forest.
FERAL ANIMALS	1) Conduct exclosure study at Mary Point; nearly 50 hectares of dry woodland. Collect data on donkey grazing impacts. 2) Establish fence exclosure areas for pigs at Bordeaux plots to examine species diversity, recruitment, survival, & growth.

FEATHERED FRIENDS	1) Monitor birds at all important wetlands within park boundaries weekly. After 2 years start banding birds to collect additional information. 2) Resurvey permanently marked migratory warbler census stations on an annual basis. 3) Monitor production of Brown Pelican chicks monthly. 4) Monitor habitat use by migratory and resident birds to determine importance of intact forest as winter habitat.
MAMMALS	1) Monitor populations of bats for three week periods. 2) Mist net bats at night and search roosts during day. 3) Monitor mongoose through trapping and removal efforts from beaches where sea turtles nest.
REPTILES	1) Monitor rare and ecologically relevant reptilian and amphibian species. 2) Monitor presence of, and prevention of the spread of exotic species.

Appendix ### includes abbreviated resumes for NPS scientists/resource managers and major collaborators.

6. *Budget and Cost Effectiveness*

[This section is incomplete!]

The I and M program envisioned here depends on research by an effective combination of VIIS, BUIS, and DRTTO research and resource management staff, local scientists working under cooperative agreements, and visiting scientists who come periodically to conduct research.

Personnel

VIIS

	Salary with benefits	
Data Manager/GIS Specialist	GS 12	\$60,447
Cartographic Technician	GS 7	34,075
Biol. Technician	GS 7	34,075
Biol. Technician	GS 7	34,075
Terrestrial Ecologist (Botanist)	GS 11	50,435
Wildlife Biologist	GS 11	50,435
Administrative Clerk	GS 5	27,510
Subtotal		\$291,052

BUIS

Biol. Technician	GS 7	34,075
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DRTTO

Resources Management Specialist	GS 9	35,796
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Cooperative agreements (with NOAA,
USGS,--)

GIS Equipment

Equipment

Travel

SPACE!! Purchase a trailer

Cost effectiveness:

We believe that this budget is cost-effective and incorporates the the major needs for the three parks

It is often sufficient to cover travel costs to bring scientists to these three parks, allowing them to continue the monitoring projects they already have in place. In many cases, one or two visits for 3 - 6 weeks each year are sufficient to sustain effective monitoring.

7. *Service-wide or multi-park applicability:*

The results of a prototype monitoring program, particularly the aspects related to monitoring of coral reefs, reef fishes, and dry forest vegetation, and recovery of marine and terrestrial ecosystems following hurricanes, could be translated to NPS parks in Florida which have similar ecosystems recovering from Hurricane Andrew. Some of the research could have implications for Haleakala National Park and Hawaii Volcanoes National Park both for feral animal control (hogs), vegetation restoration, exotic animal and plant control, and sea turtle monitoring programs.

Monitoring of coral reefs has applicability throughout the Caribbean and in fact, in all tropical areas with coral reefs. People from other Caribbean islands and countries have already benefitted from training on research/resource management and results of VIIS and BUIS monitoring programs is of direct relevance. Monitoring of the damage from snorkelers, boats and ships is also relevant to all tropical marine protected areas as is the documentation of the effects of establishing marine reserves.

The results of the NRP Fisheries Project, specifically the effects of trap fishing on reef fish diversity, abundance, and size, is relevant to the NPS units in Florida and to Caribbean islands and countries. Information from monitoring of the marine systems in these three parks has direct applicability to the new Salt River National Park in St. Croix.

Any effects on fish size and species due to a marine reserve would complement similar efforts in Channel Islands National Park and would be of great interest to tropical/neotropical countries worldwide, since this would be one of the first monitoring projects with data available from before establishment of the reserve.

The results of an expanded paired watershed study (i.e., information on the increases in sedimentation associated with clearing of vegetation and road construction) is directly relevant to other Caribbean parks, particularly those which occur on or are adjacent to steep slopes.

Information on the effects of forest fragmentation on diversity and density of migratory birds has applicability worldwide.

Research on dry forest vegetation can provide necessary information for restoration or reforestation efforts with native plants on other islands because many of the

species found on St. John are distributed throughout the Caribbean basin. Secondary forests make up a large portion of forests world-wide, although primary forests have received more research attention in the tropics. Effective monitoring of the biological processes within these forests will further our understanding of these fragile and complex ecosystems and will have direct applicability throughout the tropics on a large scale as well as provide opportunities for comparisons with Everglades, Big Cypress, and Hawaii Volcano National Parks. Little information on these forests is available in the scientific literature and a better understanding of these ecosystems is critical.

8. *Park Infrastructure and Organizational Structure:*

Virgin Islands Biosphere Reserve Center

The VIIS Division of Research and Resource Management (described in section 5 above) is housed at the Virgin Islands Biosphere Reserve Center. This Center, completed in 1987, consists of 4 buildings, an office building for the Division of research and resource management, a conference room a laboratory, and a small dormitory for visiting scientists. Additional housing for visiting scientists is also available in the park near the Center and at the Virgin Islands Ecological Resource Station run by the University of the Virgin Islands on park property.

VIIS and BUIS reference collection includes all research papers pertaining to the parks, including long-term research in coral reef systems (BUIS has a annotated bibliography of marine research reports and VIIS references are include in Marine and Terrestrial Ecosystems Synthesis document), sea turtles, birds, fisheries, geology (terrestrial and marine), plant life (terrestrial and marine), park management documents, and historical references.

Collections for VIIS are housed in a small building near the Center, but curation is inadequate. Collections include an extensive herbarium, insects, ##### and a historical reef fish collection.

A separate dive locker houses all dive equipment for the Division.

Equipment. There will be 5 IBM/PC compatible work stations, three notebook computers with printers, also 2 laser jet printers. [GIS hardware and software---] VIIS has 2 vehicles, 2 boats, a new diesel boat is on order with GSA, and scuba

equipment for 6 people. BUIS has access to one 25' Boston Whaler patrol boat; ranger and maintenance vehicles are made available as necessary; scuba equipment for up to 4 persons. Office space is at CHRI. One IBM/PC compatible with printer (also access to administration computers and laser jet printer). Park administration has always been supportive of all NRM programs. BUIS has no formal "laboratory" space, but ranger/scuba equipment room has served this purpose on occasion. CHRI/BUIS has one NPS house available for seasonal support until full time law enforcement ranger position is filled.

9. *Data Management Plan:*

A well organized data management program is a crucial component of a successful long-term monitoring program. If the huge amounts of data generated by the many facets of a complex monitoring program are to be easily retrieved for consideration in management decisions or to guide on-going monitoring efforts, it is best if a person is stationed on-site to oversee the data management. Therefore, a portion of funding received in this proposal would be devoted towards hiring a full-time, GS-11 GIS Specialist/Data Manager (GIS/DM) duty-stationed at Virgin Islands National Park in St. John.

An on-site data manager will provide the necessary focus at the park level to guarantee that all data from monitoring projects are documented, computerized, and archived and that spatial data are integrated into the GIS. This person will act as a consultant with park staff, NBS staff, and cooperators to develop tally sheets and data recording and entry procedures at the onset of projects, as well as assure that projects are designed upfront with pertinent spatial data considerations addressed. The data manager will also make certain that project scientists submit their data in GIS-compatible format with accuracy and precision figures adequately documented, enforce the QA/QC protocols on data entry and transfer, and handle requests for data by park staff, other agencies, and cooperators. Every year the data manager will print out a metadata catalog to illustrate the data available at the park and provide opportunity for cooperative research within the park and across parks with similar monitoring interests.

The VIIS GIS is described more fully in section 10: GIS Support and Integration. Data gathered from park monitoring programs is currently entered into files as a database format using Dbase III+ or Lotus 123. Current park data sets include: reef fish censuses, fish trap contents, coral reef transects, water quality, sea turtle nesting, bird population monitoring, mongoose control trapping records, and mooring buoy installation and maintenance records.

QA/QC Procedures

A monitoring program is only as good as the data that have been collected and analyzed; a GIS is only as good as the data that have been entered into it. Several procedures will be followed to assure that all data collected and entered into both non-spatial databases and the GIS is of the highest consistent quality, with known levels of accuracy and precision, and protected from accidental data corruption. Quality assurance procedures increase data precision by reducing sampling and analyzing errors. Quality control procedures are aimed at ensuring accuracy of results during sampling and analysis steps.

1. *Data documentation* - All data sets need to be documented, not just spatial data. A series of forms will be used to institutionalize data documentation for monitoring projects. The information from these forms will be entered into a metadata database. Examples of the type of information gathered from these forms are given below.

DATA ABSTRACT FORM (Every project has this one filled out first, ideally before the study starts.)

Data set name, data description, investigator name, investigator address and phone, study dates, study abstract, variables collected, method of data collection and actual/presumed accuracy, spatial location, positioning method, and accuracy.

SPATIAL DATA FORMS (If data is map.)

Hardcopy - map name, one sentence description, source (agency or individual, contact name, address and phone), map scale, production date, source data (photo, satellite, gps, or other), map projection (datum, projection, zone, units, x or y shift), accuracy (known or presumed), media (paper, mylar, back of envelope, or bar napkin), and storage location.

Digital - disk file name, one sentence description, disk file format, conversion (date, by whom, accuracy), projection, disk storage (location, media), file history or processing steps (projections, transformations, etc. include date and operator), features (points, arcs, polygons), and attribute names, descriptions, and codes.

A metadata database has already been established for the current park GIS coverages. This database will be kept current for all subsequent coverages developed on the GIS. When a Dept. Interior-wide standard has been set for metadata, the park will convert its database to that standard. The park has

ordered Pro-Site, a bibliographic archival and retrieval program to better organize its large library of scientific reprints, project reports, and management plans.

2. *Data Capture QC* - Following the collection of spatial data, formatting for digitizing, and capture into the system, check plots will be made. These plots will be overlaid on the original maps, errors marked, and subsequent corrections made to the digital data. The GIS/DM will then be responsible for field checking the data, by performing the checks personally, or working with project cooperators.

Non-spatial data will be transcribed from field data sheets directly into the computer, with the data sheets then copied and stored for future reference. Field data sheets from related project components will be designed to maximize the capacity to integrate data sets without manual re-entry. Data sheet designs will also closely match the structure of the computer database fields for accurate transcription from the data sheet into the computer file. Each database variable will undergo range checking limits to flag potential errors. The primary investigator will be provided with printouts of the data, summary statistics, and a list of potential errors. Corrections from the investigator will then be entered into the computer.

3. *Database Backup* - The GIS/DM will be responsible for regular backup of the database and operating system. Once original master files have been loaded onto the system, they will be backed up and archived along with the periodic system backup files in a separate, fireproof building. In addition, all data will be archived off-site at the new CPSU at Florida International University/University of Miami and with the NBS GIS Division. Project investigators will also be provided with copies of their data sets.

4. *Data Security* - Since the development of a monitoring program database represents a considerable investment of time and money, steps will be taken to minimize the likelihood of data corruption. The GIS/DM will be the system administrator, with prime responsibility for data entry, hardware and software updates, file backup and archiving, and password control. Ownership permissions will be set up that limit who can log-on to the GIS system, and what files a user can access. This will prevent accidental corruption of databases by an inexperienced user, and reduce the number of newly generated composite overlay maps that could be confused with the system "base maps."

Not all of the data will be available for distribution to the public or other governmental agencies. Information about archeological resources and the location of threatened or endangered species will not be released. Those data which are released are subject to the signing of a non-disclosure agreement between the park and the requestor.

Data Analysis Schedule

Data from current park monitoring programs is analyzed semi-annually or quarterly, depending on the particular project. While it is difficult to generalize on the interval between data analysis efforts for the multitude of projects not yet defined for this monitoring proposal, the primary responsibility for data analysis will be on the project investigator. The GIS/DM will be responsible for providing the investigator with current dataset copies, and receiving copies of all reports and manuscripts produced as a result of the data analysis.

10. *GIS Support and Integration:*

Virgin Islands National Park has made significant strides towards establishing a functional, on-site GIS. The park has an approved GIS Plan that identifies GIS objectives, staffing needs, data needs and priorities, and currently available data. As of September 30, 1993 the park has 17 data coverages that are digitized and operational on a Data General Arc-Info based system that resides at the U.S.G.S. office on St. Thomas, adjacent to St. John. From these coverages, overlay analyses have been made and composite overlay maps have been created.

The 17 data coverages include:

Vegetation Map	Archeological Sites
Marine Benthic Communities	Historical Buildings
Hydrography	T & E Species Locations
Land Contours	Land Status
Geologic Features	Water and Sewer Lines
Soils Map	Buildings
Roads & Trails	Boundaries
Study-site locations of I&M Plots	Ocean Bathymetry
Wildlife Observations	

Other themes scheduled for inclusion in the GIS include land ownership and ecological history/land use information.

Efforts are currently underway to transfer the data from the workstation-based U.S.G.S. system to a PC-based system residing in the Biosphere Office of VIIS. The Research and Resource Management Divisions are in the process of installing the necessary GIS hardware and integrating the software. Current plans call for operations involving data transfer and system integration to be completed by October 15, 1993. The GIS hardware consists of a 66 Mhz, DX-2 486 IBM PC with 700 MByte of storage, 16 MB RAM, tape backup, modem, CD ROM reader, a 12" by 12" digitizing tablet, and a HP Paint-Jet color printer. A navigational

quality GPS receiver is used for obtaining geo-coordinate locational fixes to 20 m accuracy using averaging techniques.

The primary software packages used are: 1) Arc-Cad, a PC-based Arc-Info package that runs in conjunction with Auto-Cad, 2) Arc-View, a menu-driven package that facilitates easy database query, map production, and output capabilities, and 3) IDRISI, a menu-driven, moderate performance package with raster analysis capabilities.

The GIS software chosen by the park has been carefully selected after numerous meetings with local governmental agencies with primary geographical land use responsibilities (British Virgin Islands Planning and Natural Resources Division, U. S. Geological Survey and U.S. Virgin Islands Territorial Planning and Natural Resources) to assure that any data can be easily shared between users, and that cooperative projects are undertaken between agencies whenever feasible.

While the focus until now has been to establish a functional GIS for VIIS, efforts are now underway to integrate the data themes from BUIS also. In addition, all data forwarded to the park from the numerous on-going monitoring projects has been requested to be in a format compatible with Arc-Info. Several of these projects have Arc-Info data files ready for transfer to the park GIS. An example of data from these projects include size classes of over 6,000 individual trees from three long-term plots and their geo-coordinates.

Several park databases have been or will shortly be integrated into the GIS. The Resource Management and Research Divisions maintain a wildlife observation database that is continually updated and linked with the GIS. This provides a continual source of inventory information for terrestrial and marine species. The natural history museum collection includes a valuable marine fish collection, marine and terrestrial invertebrates, and an excellent herbarium. The locations of the specimens from these collections are slated to be included in the GIS by November 30, 1993.

The park presently has a natural resource management specialist who has GIS training and a good background in computers that is administering the GIS on a collateral duty basis. This person devotes 0.4 FTE to GIS installation and administration, data management coordination, and data entry and applications work.

GIS Hardware and Software Needs

Although the current PC-based GIS is adequate for initial development, it is anticipated that this system will need upgrade within 2 years. Additional hardware

and software purchases proposed are:

500 MB hard disk \$1,200

Large format plotter \$8,000

24" by 24" digitizing tablet \$1,500

GRID (ARC-INFO Raster Module) \$1,200

After 2 years, it is suggested that a workstation platform be purchased that supports networking capabilities. The installation of a network would allow data to be shared between several machines. As the program grows and the number of project investigators increases, this capability will become more valuable.

11. *Linkage and Leveraging:*

A substantial number of cooperative arrangements were already described in section 4 "Monitoring Program Design".

The Smithsonian and the International Institute of Tropical Forestry are expected to continue providing some support for long-term vegetation surveys. Potential support for monitoring of marine ecosystems may come from under the auspices of the NOAA/Sea Grant Water Quality and Ecosystem Health Plan with funding from the Mitchell Bill. The Nature Conservancy is seeking to expand its operations in the Caribbean and has recently established an office in St. Thomas. TNC has already provided funds for the completion of the NPS Coral Reef Monitoring Manual. TNC is currently incorporating data from VIIS into the Biological Conservation Database. USDA is expected to continue providing support for an expanded migratory bird study on St. John. The National Science Foundation has committed funds for the V.I. Beetle Fauna Inventory, a four year project which began in 1993. Island Resources Foundation has received funding from the MacArthur Foundation, some of which will be used to support research on St. John.

"Partners in Flight" is a cooperative program which aims to sustain populations of landbirds that migrate between the North American temperate zone and the New World tropics. Populations of many species of migratory birds have been declining; their habitats are being degraded not only in breeding areas but also in wintering and stopover areas. Participants in this program include the National Park Service, USDA Forest Service, the U.S. Fish and Wildlife Service, several other federal and state agencies, environmental agencies in Canada, Mexico, Central America and the West Indies, and several non-profit conservation groups.

As part of its contribution to this effort, NPS is sponsoring monitoring and research programs on neotropical migrants at stopover sites at Gulf Islands National Seashore, and in breeding habitat in Great Smoky Mountains National Park and Shenandoah National Park. The research program in VIIS which began in 1987(//) complements these efforts because the tropical moist forest in the park provides excellent winter habitat for a diversity of neotropical migrants. Other similar habitat in the Caribbean has been destroyed.

The on-going coral reef monitoring program has been linked with similar efforts throughout the Caribbean to establish protocols and methods for baseline monitoring, and to standardize data gathering and reporting of information concerning coral reef environments and changes occurring throughout the region. In future, natural and man cause events, hurricanes, bleaching, die-offs, oil spills,

can and should be monitored with similar methods and communication of these events more immediately communicated to associated research areas.

VIIS & BUIS have been involved in the planning stages of the NOAA/SEA Grant program to study water quality and ecosystem health in the southeastern US and Caribbean area. Marine air and water quality monitoring ongoing in the parks will provide a baseline of information for this program.

The Soil Conservation Service is committed to continuing the monitoring of soil temperature and moisture on St. John and to working with VIIS to conduct further soil analyses. In addition, SCS has recently expressed an interest in funding the collection of marine water quality data, particularly data on bacteria and nutrients.

The BUIS hawksbill sea turtle research & monitoring program is linked to efforts throughout the Caribbean and South America to establish regional movements of hawksbills, rookeries, and genetic relatedness of nesting females. BUIS has worked with both U.S. Fish and Wildlife Service, National Marine Fisheries Service, Virginia Polytechnic Institute, University of Georgia at Athens, Louisiana State University, San Jose State University, and the V.I. Dept. of Planning and Natural Resources/Division of Fish and Wildlife on sea turtle research and monitoring program.

12. *Reporting System:*

We propose to hold annual meetings on research conducted under the I and M program in VIIS, BUIS, and DRTO###. Proceedings from the meetings will be published. The proposed I and M program is expected to generate scientific data of publishable quality. (Already, several publications are available on I and M activities in VIIS and BUIS.)

###Park Science

Investigators' Annual Reports

Reports which are products of all cooperative agreements

An ecological history for Virgin Islands Biosphere Reserve was prepared in 1988 by C. Rogers and R. Teytaud. This synthesis report includes a comprehensive bibliography. An annotated bibliography was prepared for marine studies at Buck Island by E. Gladfelter in 1992.

An ecological history needs to be prepared for BUIS and DRTO and the one for VIIS needs to be updated to include research on the effects of Hugo and results of this I and M program.

13. *Park Threats:*

This section of the proposal addresses major threats to the ecosystems and natural resources of VIIS (Table 6), BUIS, and DRT0 and indicates how the results of additional inventory and monitoring efforts could be used to define alternative courses of action for dealing with these threats and to provide park managers with a basis for making decisions.

Threats to the Natural Resources at VIIS and BUIS

Threats to the natural resources of VIIS, BUIS, and DRT0 include high levels of visitation, damage from recreational and commercial boats, overfishing oil spills, pollution, and natural disturbances (major storms). Threats which primarily affect VIIS include development, feral and other introduced animals, historical and present alteration of terrestrial habitat, and exotic plants.

Development

Development of private inholdings and land adjacent to the VIIS boundary and pressure to re-open and/or pave old roads within the park represent the most serious threat to the marine and terrestrial ecosystems of Virgin Islands National Park. Clearing of St. John's steep hillsides (over 80% of the island's slopes exceed 30 degrees) and construction of new roads (which must be 20' wide if federal funds are involved) can result in elimination of native plant (and possibly animal) species, spread of exotic plants, massive erosion, and fragmentation of the forest, making it incapable of supporting migratory birds and other animals. Careless development of land can also increase sediment input to the marine waters, causing deterioration in water quality which can adversely affect coral reefs (see attached ### map of St. John for areas which can be developed).

Monitoring of the consequences of road construction through intact forests can provide park managers with the necessary ammunition to counter current pressures from some residents to open up old Danish roads, one of which cuts across Reef Bay valley, one of the largest watersheds on St. John and the core of the biosphere reserve.

Very little quantitative data exist on the increases in sedimentation which accompany clearing of steep hillsides in the tropics. [Unfortunately, in August 1993, a new road was cut into the steep hillside above Haulover Bay, the site of one of the best-developed reefs in VIIS.] An ongoing paired watershed study compares the sediment input from a watershed being developed adjacent to the western boundary of VIIS with that from a relatively undisturbed watershed within

Table 10.

THREATS TO VIRGIN ISLANDS NATIONAL PARK RESOURCES	
NATURAL RESOURCES	THREATS
FORESTS	1) Development of private inholdings and land adjacent to park boundary 2) Re-opening and/or pavement of old roads within park 3) Clearing of steep hillsides (over 80% of island's slopes exceed 30 degree slope)
NATIVE PLANTS	1) Encroachment of exotic species 2) Feral animals grazing and dispersal of exotic plant seeds
BATS	Unknown; Inventory incomplete
BIRDS	1) Degradation and/or loss of mangrove saltpond wetlands important to winter-resident shorebirds and waterfowl 2) Fragmentation and clearing of forests used by migratory birds 3) Overharvest of fish species needed by seabirds
AMPHIBIANS AND REPTILES	1) Introduction of exotic animals; i.e. mongoose 2) Illegal collecting activities 3) Accidental introductions from stowaways
COASTAL WATER QUALITY	1) Development of land increases sediment input 2) Sewage 3) Road construction
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

CORAL REEFS	1) Natural disturbances; hurricanes, diseases, coral bleaching 2) Non-point source pollution, runoff, sedimentation 3) Boat groundings, anchor damage 4) Pollution from boats, oil, gasoline, human waste
SEAGRASS BEDS	1) Anchor damage 2) Pollution from boats 3) Coastal development, dredging, construction, increases in sedimentation and turbidity 4) Oil spills
FISHERY RESOURCES	1) Overfishing of lobster, conch, groupers, snappers, bait fish 2) Loss of coastal nurseries through conversion of wetlands and mangrove areas 3) Oil spills, coastal water pollution, increase in human nutrients in coastal waters
SEA TURTLES	1) Predation of mongoose on sea turtle hatchlings and eggs 2) Loss of undisturbed nesting beaches to development and erosion
AIR QUALITY	1) Fine particulate matter from the Sahara Desert 2) Possible pollution from volatile organic compounds from gasoline refineries in St. Croix

the park.

Coral reefs

A major objective of coral reef monitoring is to enable park managers to differentiate damage from natural processes from those due to human activities. The barrier reef at Buck Island and the reefs around St. John and Dry Tortugas have deteriorated as a result of several stresses including diseases of the primary reef-building corals, coral bleaching, hurricanes and other major storms, boat groundings, and possibly, non-point sources of pollution. Data from coral reef sites in VIIS, BUIS, and DRTO represent some of the best information available on long-term trends on coral reefs in the Caribbean.

Protection of coral reefs is crucial for survival of the endangered hawksbill sea turtles which feeds primarily on coral reef sponges and find shelter under coral ledges.

High levels of visitation/damage from boats and ships

The white sand beaches and clear waters which contribute to the spectacular beauty of BUIS, VIIS, and DRTO are the major attractions for visitors. Over 1 million people visit St. John each year, and prior to Hurricane Hugo BUIS had up to 90,000 visitors per year. Visitation to BUIS is expected to reach these levels again. These visitors use the numerous hiking trails within the parks but primarily affect the marine resources. Damage from snorkelers along the underwater trails at Buck Island and Trunk Bay (St. John) is evident in localized areas but less than the dramatic damage to coral reefs and sea grass beds from boat anchors and groundings. Increased numbers of cruise ships (VIIS) and smaller private vessels have resulted in increased incidents of anchor damage and boat groundings at both parks.

Pollution from boats (oil, gasoline, human wastes) represents an unquantified threat to the marine ecosystems in the two parks.

Visitation is expected to increase at VIIS, BUIS and DRTO. Since essentially all visitation is by boat, the effect of increased number of boats (particularly cruise ships), pollution from boats, and potential for boat groundings needs to be assessed to provide a practical limit both from safety standpoint and protection of the resources. Documentation of effects of visitation on the resources (e.g., monitoring of numbers of visitors and their use patterns) needs to be conducted to justify future management actions, e.g., "carrying capacity" limits. Further restriction on the size of boats which are allowed to anchor in park waters may be

warranted.

Natural disturbances

Natural disturbances such as hurricanes (Hurricane Hugo in 1989) and other major storms have caused severe damage to the St. John and Buck Islands' coral reefs, forests, and shorelines. The southern reef crest off Buck Island was completely relocated 30 m shoreward (towards the island) as a result of this powerful storm. Hugo caused significant decreases in the amount of living coral. Erosion of beaches, fallen vegetation and debris associated with Hugo caused statistically significant decreases in nesting success of hawksbill sea turtles. Global climate change may result in increased storm activity in the tropics.

Coral diseases have severely affected the primary reef-building corals on VIIS and BUIS reefs. It is not known if damage from human activities (such as physical breakage of corals, oil pollution, and boat bottom paint) increase the incidence of these diseases.

Bleaching of corals has been observed at BUIS and VIIS and is a symptom of stresses such as high sea water temperatures and sedimentation.

While it is understood that one cannot "manage" natural disturbances such as hurricanes and prevent their influence on park resources, it is essential to understand the recovery of ecosystems from such disturbances and to differentiate them from detrimental processes from human activities. It is also important to note that if ecosystems are disturbed by a combination of natural stresses and detrimental human activities, recovery can be hindered or even prevented. A series of publications are now available on the effects of Hurricane Hugo on coral reefs and forests of St. John.

Feral and other introduced animals

Feral populations of goats, pigs, and donkeys have been steadily increasing since the 1960's and pose a serious threat to VIIS resources. Pigs have rooted through the permanent vegetation plot established in Bordeaux (St. John). Goats and donkeys are adversely affecting mangroves and other native species on St. John.

The exotic mongoose introduced to the islands to control rats in sugar cane fields has already eliminated many species of indigenous birds, reptiles, and other animals. At present, mongooses appear to have been effectively eliminated from Buck Island, although mongooses continue to prey on sea turtle eggs and hatchlings on St. John's beaches.

Monitoring of the vegetation within exclosures will provide park managers with solid data as a basis for taking (undoubtedly unpopular) actions to reduce feral animal numbers. Monitoring of the effects of exotic animals on the distribution of exotic plants will allow evaluation of the extent of exotic plant encroachment.

Exotic plants

Exotic plants are a major component of the vegetation on VIIS and BUIS. Scientists working on St. John have expressed concern over several species of exotics which appear to be encroaching on native species, although hard data are lacking. Feral animals contribute to the spread of exotic plants.

Fishing

"Customary" fishing with fish traps of "conventional design" was authorized under the enabling legislation for VIIS while "existing" fishing was authorized within BUIS (outside the fully protected "Marine Garden"). Illegal fish traps have been found within the "Marine Garden" at Buck Island, and commercial fishing is now occurring within VIIS and probably BUIS waters. Some fishermen are setting "trap lines" with over 20 traps.

At BUIS, fishing activities allowed for in the legislation have increased. The full extent and effect of increased fishing needs to be determined. The legal boundaries of the Monument do not provide adequate protection for the entire marine ecosystem. Information gathered through monitoring of fishing activities and fish assemblages would provide the basis for alternative management options including restrictions of fishing.

Recreational fishing is increasing at Dry Tortugas.
[###marine reserve at Dry Tortugas]

Knowledge of the status of the fish assemblages around Dry Tortugas, Buck Island and St. John will enable park managers to decide if further restriction of fishing is necessary or if current levels of fishing are not causing significant declines. Any decision to restrict fishing in VIIS and BUIS will have to be based on excellent, defensible data as fishing is a traditional activity which should be respected, and any restriction will be controversial.

Oil spills

One of the world's largest oil refineries (Hess Oil) is situated on the south side of St. Croix and supertanker traffic passes windward of both Buck Island and St. John. An oil spill in March 1991 oiled mangrove roots and beaches on the east side of St. John. Tar balls are frequently found on the eastern beaches of Buck Island.

Threats to birds

Threats to the birds in and near VIIS include degradation and/or loss of mangrove swamps and saltponds important to winter-resident shorebirds and waterfowl, private land use practices within park boundaries that are detrimental to winter-resident warblers and resident breeding birds (e.g. forest clearing), and overharvest of fish species needed by seabirds. The proposed bird monitoring program contains separate elements addressing each of these issues.

Research on St. John has shown the importance of intact forests as habitat for migratory birds. Development of private lands within the park and elsewhere on the island and construction of roads through watersheds which are now largely undisturbed could have drastic consequences for the birds which winter in the Virgin Islands.

Threats to endangered species and their critical habitats

Of the several endangered species found on Buck Island and St. John, the most critically threatened is the hawksbill sea turtle. Continued monitoring of the nesting population in the Virgin Islands is contributing directly to its survival in the Caribbean. Long-term monitoring is providing an understanding of its nesting requirements, fecundity, nesting success, site fidelity. Telemetry studies are providing information on the regional distribution of the species, its long range movements and regional habitat. Genetic studies will determine the relatedness of the females nesting at BUIS and their association with distant foraging populations elsewhere in the Caribbean. Information gathered at BUIS on hawksbills will be critical for their continued protection under CITES when it is renewed in 1994.

[###more on Dry Tort]

Threats to reptiles and amphibians

The major impacts to the herpetofauna of St. John and the rest of the Virgin Islands has already occurred following the introduction of mongoose to the islands in 1872. Since virtually no records exist which describe the reptile and amphibian communities prior to mongoose introductions or forest clearing activities associated with the establishment of the sugar cane plantations, current understanding of

species distributions and abundances are hampered. Presumably, any extirpations of species due to mongoose predation have already occurred, and those species which are now considered rare have developed behavioral adaptations to reduce mortality from mongoose.

Extant threats to reptiles and amphibians include continued predation from mongoose, illegal collecting activities, accidental introductions occurring from stowaways on incoming plants used for landscaping in developed areas within and adjacent to the park, and largely unknown factors which have reduced amphibian populations around the globe in recent years. Particularly troubling is the possibility of an introduced snake or frog with aggressive predatory tendencies wreaking havoc with native species. Two current examples of such a scenario occurring in sub-tropical regions are the brown tree snake in Guam and Hawaii, and a giant African frog in Florida, both of which have caused major economic and ecological damage. Agricultural inspections of plants coming into the Virgin Islands through customs is cursory at best, and no inspections are done on cargo transported between the Virgin Islands. Consequently, accidental introductions are inevitable.

Three species of anurans (from South America, Cuba, and Puerto Rico) have already been introduced to St. Thomas. These species are native to South America, Cuba, and Puerto Rico. The species from South America is a 10 inch toad that has a voracious appetite. Because St. John is separated from St. Thomas by a narrow three mile channel, and there is constant movement of plants, cargo, and vehicles between the two islands, odds are very high that these species will find their way to the park. In fact, a Puerto Rican frog has already been found in St. John. The impacts of these exotic species on native fauna are difficult to interpret unless better information exists on current distributions and abundances of the native reptiles and amphibians.

Threats to native mammals

The threats to the only native mammals on St. John, 5 species of bats, are unknown. We are ignorant of the ways they disperse plants and affect insect communities.

Air quality

Virgin Islands National Park has been designated a Class 1 area in terms of the Clean Air Act air quality standards. Prevailing winds are from the southeast, which means that under normal circumstances, there are no major urban areas upwind for thousands of miles. Consequently, air quality is usually very good, though far from perfect. Fine particulate matter less than 10 um are transported to the Virgin Islands in the summer months from the Saharan region of Africa. This "Saharan

Dust" phenomenon at times reduces visibility to less than 10 miles (in some cases, less than 2). In addition, the world's second largest gasoline refinery is located on St. Croix. Volatile organic compounds are released in large quantities from this facility, but fortunately, St. Croix lies south of St. John and under normal circumstances, these compounds do not reach the park on St. John. Buck Island Reef National Monument lies less than 10 miles from the refinery and generally upwind, but may receive some influence during summer doldrums and/or wind shifts.

Water quality

Sewage from boats and houses, sedimentation, and nutrients from runoff all can cause degradation of water quality. Development is the biggest threat to the integrity of VIIS. Increases in nutrients in the water can cause algal overgrowth on coral reefs. If monitoring of water quality indicates unacceptably high levels of sewage contamination, park managers may decide to limit the number of boats permitted in certain bays.

Appendix A. Project Statements from VIIS RMP which are relevant to the I and M Program for the park (not in priority order):

- VIIS-I-003 Develop Computerized Geographic Information System
- VIIS-N-001 Protect Endangered/threatened species
- VIIS-N-002 Monitor endangered species, nesting sea turtles
- VIIS-N-004 Identification of habitats for endangered and threatened species
- VIIS-N-005 Develop and inventory and monitoring program
- VIIS-N-006 Complete resource baseline inventory
- VIIS-N-007 Support meteorological station at Lind Point
- VIIS-N-010 Develop air quality baseline for Class I area
- VIIS-N-012 Project visitor use patterns/assess impacts
- VIIS-N-013 Develop shoreline visitor management plan
- VIIS-N-015 Develop a geological map
- VIIS-N-029 Continue to assess long-term reef trends
- VIIS-N-030 Monitor quality of marine waters
- VIIS-N-031 Monitor/evaluate sewage outflow into marine water
- VIIS-N-032 Assess watershed input to marine environment
- VIIS-N-037 Conduct study of local oceanic currents
- VIIS-N-039 Develop/implement marine resource management plan
- VIIS-N-042 Measure impact of vessel groundings/anchoring
- VIIS-N-043 Assess reef fish assemblages
- VIIS-N-044 Determine impact of traditional pot fishing gear
- VIIS-N-045 Assess/manage conch, lobster, and whelk populations
- VIIS-N-049 Identify areas of undisturbed forest
- VIIS-N-050 Research native plant restoration
- VIIS-N-051 Develop vegetation removal guide
- VIIS-N-057 Long-term monitoring of vegetation succession
- VIIS-N-058 Assess damage from exotic plants
- VIIS-N-060 Develop field guide to flora of St. John
- VIIS-N-061 Describe and map soils
- VIIS-N-062 Assess bird populations
- VIIS-N-063 Monitor native bats
- VIIS-N-064 Feral animals, vegetation exclosures
- VIIS-N-067 Feral boars
- VIIS-N-070 Manage feral livestock (goats, cows, pigs)
- VIIS-N-071 Trap mongooses and test for vector-borne disease
- VIIS-N-073 Restore native fauna

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BIOGRAPHICAL SKETCHES

Jim Petterson has worked for the National Park Service and U.S. Fish and Wildlife Service for five year in parks and refuges in California, Alaska, and currently in the Virgin Islands. He has received a master's degree from U.C. California at Davis in Wildlife Ecology and a bachelors degree in Electronics Engineering. Jim is a graduate of the 6th class of the NPS Natural Resource Management Training Program. His specialties include terrestrial bird and mammal ecology, statistics, and GIS applications. Jim has conducted field research on opossums, shorebirds, brown bears, wolves, moose, musk oxen, and mongoose. He has also played major roles in developing functional GIS systems at three parks.

Virginia Garrison has worked for the National Park Service at Virgin Islands National Park, Lake Nakuru National Park in Kenya, and as a field naturalist throughout the Caribbean - for over 13 years. Her M.S. and B.S. degrees are in Chemistry (P. Chem. emphasis) from California State University, Hayward; in addition, she has many courses in field biology and ecology. Since her graduate work/research, Ginger's work experience includes teaching at state universities, research at the Pesticide/Toxicology Lab at UC Berkeley, running an ecological monitoring program on a high-altitude lake in East Africa, making detailed natural history observations of Caribbean marine communities, and conducting field work studying changes in the coral reef communities at VIIS - primarily fish assemblages and scleractinian corals.

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