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

Sept. 30, 1993

Approved by:

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VIIS Superintendent

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EVER Superintendent

INTRODUCTION

Virgin Islands National Park (VIIS), Buck Island Reef National Monument (BUIS), and Dry Tortugas National Park (DRTO) together form a group of parks with remarkable terrestrial and marine biodiversity and similar management concerns. VIIS and DRTO were both designated as biosphere reserves in 1976, two of the first protected areas in the U.S. to receive this recognition. Only 30 of over 311 international biosphere reserves contain both marine and terrestrial portions. VIIS consists of 2947 ha of land on the island of St. John and 2287 ha of surrounding waters, while BUIS includes the 72 ha on Buck Island and 283 ha of nearshore waters (Figs. 1, 2). About 99% of DRTO's 26,200 ha is water and submerged lands. (Please see accompanying brochures.)

Significance of Natural Resources of VIIS and BUIS

The enabling legislation for VIIS and BUIS recognizes the significance of their marine resources, including Buck Island's barrier reef and the numerous fringing reefs off St. John. These coral reefs and nearby sea grass beds support a high diversity of fishes, endangered sea turtles, and other organisms.

Buck Island is the most significant hawksbill nesting area under U.S. jurisdiction and one of only 3 known areas of concentrated nesting in the Caribbean. Endangered green and leatherback turtles also nest on Buck Island's beaches. Green and hawksbill turtles inhabit the waters around St. John, and limited nesting of hawksbills occurs on some St. John beaches.

The forests on St. John and Buck Island represent remnants of the once-widespread tropical dry forest ecosystem in the Caribbean, the only ones which are under U.S. protection. Most of the remaining dry forest habitat which can be found on other islands is vulnerable to development.

St. John's forests have a very high diversity of native plants. (One long-term plot on St. John is part of the Smithsonian's MAB Biodiversity network.) 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 lead to the elimination of native species but rather to a change in their relative abundance. The dry forests on Buck Island and St. John represent secondary forests which have been allowed to recover under NPS protection. A few areas on St. John may represent remnants of the original forests.

Over 800 species of vascular plants have been identified on St. John. One species is on the federal endangered species list, and two others are being proposed for listing. In addition to these three endemic species, several species are known to be rare. One endemic plant, also federally listed, is known from Buck Island.

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.

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. 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 Louis Agassiz in 1858, when he mapped the area's reef system. In 1904, the Carnegie Institution established a marine laboratory on Loggerhead Key. The lab was world-renowned for its pioneering work on coral reefs. By 1939, 35 volumes of research had been published by the Tortugas lab.

The outstanding natural values of the area were first officially recognized in 1908 when an Executive Order created 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. Additional legislation enacted in 1980 referred to "significant coral formations, fish and other marine animal populations, and populations of nesting and migratory birds...".

DRTO is world-renowned for its bird life. The park has the only colonies of magnificent frigate birds and masked boobies and the only significant sooty and noddy tern colonies (nearly 100,000 birds during nesting season) in the continental 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.

The significance of the natural resources of the Dry Tortugas was most recently underscored in 1992 when Fort Jefferson National Monument was redesignated as Dry Tortugas National Park.

Conceptual Framework for Monitoring and Primary Objectives

The overall goals of this prototype I and M program are to complete inventories for all areas and to develop the structure for long-term monitoring. Monitoring is necessary to detect and evaluate 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. The foundation of the program will be

the design and production of a series of protocols within one conceptual framework. Existing protocols will be fine-tuned, and new ones will be written as necessary. The design of any monitoring program requires identification of the temporal and spatial scales appropriate to the questions which are being asked. The monitoring program for these three parks is envisioned at the ecosystem, watershed, community, and species level (population) scales.

Some of the management questions which are being addressed include the following:

- ♦ 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)
- ♦ is the continued development of St. John jeopardizing the winter habitat for migratory birds?
- ♦ what effects are high levels of visitation having on park resources (DRTO, VIIS, BUIS)
- ♦ how can reef fish assemblages and traditional fisheries be maintained (all 3 parks)?

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 a new coral reef scientist to be hired by Florida CPSU), interagency cooperation (e.g., NOAA, Florida DEP/FMRI), and outside investigators.

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 Jenny Bjork, with assistance from Anne Reilly, Gary Ray, and Bob Askins. Gary Davis (CHIS) reviewed an earlier draft.

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). In Dec. 1992, the VIIS Superintendent and Division Chiefs met to rank the projects identified in the draft VIIS Resource Management Plan in order of their priority. All of the major marine and terrestrial monitoring projects outlined in this proposal were ranked in

the top 5 priorities for the park.

The legislation which created Dry Tortugas National Park in 1992 stated several specific management purposes for DRTO, including protection of coral reefs, sea turtles, and sea birds.

In 1990, Congress established the Florida Keys National Marine Sanctuary (FKNMS) which surrounds Dry Tortugas National Park. The draft management plan for the Sanctuary identifies the park's critical role in long-term, system-wide monitoring for the Florida Keys.

Resource Management Plans

The draft RMP for VIIS has been reviewed and the final version will soon be submitted to SERO. (See Appendix A for relevant Project Statements.)

A draft RMP for BUIS was submitted to SERO in June 1993. The draft identifies all major resource management issues for the park.

The RMP for the new Dry Tortugas National Park is now being prepared.

2. *Status of Inventory:*

Tables 1, 2, and 3 present the status of inventory for major natural resources in VIIS, BUIS, and DRTO. In many cases, these inventories were 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. Detailed information on species and their distributions come from studies in long-term plots in 8 different watersheds on St. John. The Smithsonian and a private sponsor (the Homeland Foundation) are supporting production of an illustrated flora for the island. Three new species of plants have just been described, with two known only from St. John (Acevedo 1993). A vegetation map of St. John was produced in 1987.

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.

Approximately 150 plant species (< 20% of the flora) on St. John are naturalized exotics. Only two of these are problem species which should be monitored. The first, *Melicoccus bijugatus*,"Genip", often grows in monospecific stands. It may pose a significant threat to the integrity of some dry forest communities where it is most abundant. The second, another 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.

Table 1. 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./2 endemics
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
Native Terrestrial Mammals	Yes	Yes	No	Bats poorly known
Exotic Terrestrial Mammals	No	Yes	Yes	12 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	Over 400 spp. of beetles. Ectoparasite study
Marine Fishes/Shellfishes	No	Yes	Yes	Historic info & current studies
Marine Invertebrates - Hard Corals Sponges/Gorgs/Other	No Yes	Yes No	Yes No	Historic info & current studies
Marine Benthic Communities	No	na	Yes	Benthic maps need updating
Water Quality: bacteria, nutrients, clarity	Yes	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	Yes	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 good herbarium & fish specimens
GIS Data - Digital data and Aerial Photos	na	na	na	17 data coverages available. Aerial photo series from 1947
Historical Database: Ecological Hist. Bibliographic	Yes No	na na	na na	Comprehensive report of research conducted in park up to 1988.

Table 2. 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	
Marine Plants	Yes	No	No	
Native Birds	No	Yes	Yes	
Exotic Birds	No	na	na	
Terrestrial Mammals	Yes	No	No	
Exotic Terr. Mammals	Yes	Yes	No	2 spp. of rats
Marine Mammals	No	Yes	No	
Terrestrial Reptiles	Yes	Yes	No	
Marine Reptiles	No	Yes	Yes	3 spp. of nesting sea turtles
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	Yes	na	na	Some historic data
Nutrients	Yes	na	na	
Clarity	Yes	na	na	
Physical Oceanography	Yes	na	na	
Soils	No	na	na	Recent work by SCS
Geology				
Terrestrial	Yes	na	na	
Marine	No	na	na	
Air Quality	Yes	na	na	
Meteorological Data	Yes	na	na	
Museum Collections	na	na	na	Included w/i VIIS collection
GIS Data				Some aerial photos and bathymetry available
Digital Data	na	na	na	
Aerial Photos	na	na	na	
Historical Database				
Ecological Hist.	Yes	na	na	Annotated bibliography for marine studies
Bibliographic	No	na	na	

Table 3. STATUS OF DRY TORTUGAS NATIONAL PARK INVENTORIES/BASELINE DATA

Inventory Type	Additional Inventory Needed?	Species List Complete	Distribution Known	Comments
Native Plants	Yes	No	No	Probably fewer than 50 spp. Historic info back to 1907.
Exotic Plants	Yes	Yes	No	>50% of present flora may be non-native. Ongoing program to eradicate Australian pine.
Marine Plants	Yes	No	No	Historic info from 1928 and some very limited recent work.
Native Birds	Yes	Yes	No	Info on current seasonality and abundance.
Exotic Terr. Mammals	No	Yes	Yes	Program to eradicate black rats.
Marine Mammals	No	Yes	No	Migrate through park waters.
Terrestrial Reptiles	Yes	Yes	No	All currently known are exotics.
Marine Reptiles	No	Yes	Yes	Significant habitat for 3 - 5 species of T&E sea turtles.
Amphibians	Yes	Yes	No	Almost none; one record of Cuban tree frog.
Terrestrial Invertebrates	Yes	No	No	Very limited study; list of butterflies.
Marine Fishes	No	Yes	Yes	Historic info and current studies.
Marine Invertebrates: Hard Corals	Yes	No	No	Historic and current studies. Significant work on spiny lobster. No comprehensive soft coral species inventory.
Sponges, Gorgs, Others	Yes	No	No	
Terrestrial Communities	Yes	na	No	Historic info available.
Marine Benthic Communities	No	na	Yes	Community characterizations and benthic mapping currently under study in cooperation with TNC, FKNMS, and DEP. Significant historical info available.
Water Quality: bacteria, nutrients, clarity	Yes	na	na	Some limited info available; C - MAN program installed.
Physical Oceanography	Yes	na	na	A C-MAN automated monitoring system has recently been installed at DRTO.
Soils	Yes	na	na	Calcareous sand and coral rubble.
Geology: Terrestrial and Marine	Yes	na	na	Supratidal DRTO has a history of disappearance-reappearance, and all shorelines tend to change continually in response to storms. Historical info available. Sea level rise is a concern.
Air Quality	Yes	na	na	Trash burning on site by NPS.
Meteorological Data	Yes	na	na	The recently installed automated C-MAN station. Some meteorological data are recorded locally at the Fort. Coast Guard maintains records at Loggerhead Key.
Museum Collections	Yes	na	na	DRTO collections are maintained at EVER and include fair to good collections of plants, sponges, and corals. Poor representation for other groups.
GIS Data				
Digital Data	na	na	na	Three data coverages are currently available. Aerial photos dating from 1945 to the present. Most recent images obtained by TNC and FKNMS for benthic mapping.
Aerial Photos	na	na	na	
Historical Database				Comprehensive summaries and bibliographies are needed.
Ecological Hist. and Bibliographic	Yes	na	na	

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 20 years until the lab was destroyed by Hurricane Hugo in 1989. Lobster and conch surveys have been done at all three parks but need to be repeated.

Marine reptiles (sea turtles)

Four (possibly five) species of sea turtles are known from DRTO and three from USVI waters. Intensive research on hawksbill turtles, the most endangered species in the Caribbean, has been conducted at BUIS since 1987 with emphasis on nesting requirements and nesting success. Over 70 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 than on Buck Island. Intensive monitoring on St. John took place in 1985-1986 followed by limited monitoring in 1992-1993.

Threatened loggerheads, endangered greens, and possibly hawksbill turtles nest on DRTO keys. The endangered leatherback has been seen 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. The nesting population is believed to include 50 to 100 nesting females per year.

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.

St. John has 12 species of non-native mammals that have caused large scale ecological changes on the island. Mongooses were introduced to St. John in 1872 to control rats and have since become naturalized. 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 continue to 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.

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

Birds

Shared species of pantropical seabirds provide one of the strongest biological linkages between the NPS areas of this 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 terns, noddies, and masked boobies is available for DRTO (Robertson 1964, Clapp and Robertson 1986).

A comprehensive inventory of birds for VIIS has been completed. A population monitoring study begun in 1992 focuses on the wading bird community within saltpond and mangrove wetlands on St. John. Another study by ornithologists from the Institute of Tropical Forestry, the Nature Conservancy, and Connecticut College is examining population densities of 13 species of neotropical warblers which overwinter on St. John.

Surveys of seabirds have been conducted in the USVI since 1975. Nesting populations of the endangered brown pelican have declined in the USVI in the last several years. Recently, pelicans have been dying in Puerto Rico and the USVI from unknown causes.

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 these parks for at least 10 years.

Terrestrial invertebrates

A list of terrestrial invertebrates known from St. John appears in Muchmore (1987), and a comprehensive survey of beetles on Buck Island and St. John is ongoing. To date, 460 beetle species are known from St. John including two endemics. Eight endemic species have already been found on Buck Island.

In 1989, an incident of relapsing fever was traced to St. John (Flanigan et al. 1991). An inventory of the ticks, fleas, and mites on mammals on St. John and discovery of any associated viruses would be of epidemiological interest. 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 "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 will be completed in 1994. Soils from some of the long-term vegetation plots on St. John have been characterized.

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, wind speed and direction, solar radiation, and air temperature on an hourly basis.

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, they began collecting data on "photosynthetically active radiation" (PAR). More information is needed on nutrient concentrations in marine waters around the island and on the input of nutrients from land to determine the significance of sewage and other contamination.

VIIS has just begun a 1 year study to document nutrient concentrations (ammonia, nitrates, nitrites, and phosphates) 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. 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, during southerly winds, it is carried in currents which flow towards the USVI (Muller-Karger et al. 1989).

Monitoring of the water quality at 2 Buck Island sites has been conducted for 20 years by the territorial government. Data exist for fecal coliform, turbidity, salinity, nutrients, Ph, dissolved oxygen and temperature. Very limited information is available for water quality parameters at DRTO.

Physical oceanography

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

Through a cooperative effort with the Florida Institute of Oceanography SEAKEYS program, NOAA, and Florida DNR, an automated environmental monitoring system known as C-MAN has been installed at DRTO. 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.

Air quality

VIIS is a Class 1 area. A fine particulate sampler has been in operation for 2 years.
In order to bring air quality monitoring up to par for a Class 1 area, a transmissometer should be added. An Acid Deposition Station should also be established to determine what baseline levels are in a relatively pristine site.

St. Croix has 2 air quality monitoring stations, both located near industrial complexes. If feasible, an air quality station should be established on Buck Island or the eastern end of St. Croix.

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:*

WE ARE READY!!

Background
Virgin Islands National Park has collaborated with numerous other organizations 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 included VIIS and 15 other private and governmental agencies concerned with conservation in the USVI, British Virgin Islands, and Puerto Rico. Between 1983 and 1988, VIRMC members conducted 30 projects supported by NRP funds (see Appendix B). The results of these projects were synthesized in an ecological history for VIIS (see Rogers and Teytaud 1988).

NPS 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 including the University of Georgia, Florida DNR, and the Southeast Fisheries Center (NOAA).

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 VIIS, BUIS, and DRTO for the last two years. The effects of Hurricanes Hugo (1989) and Andrew (1992) have been documented at the respective parks but monitoring of recovery should continue.

Research which has been conducted on St. John in the last decade has provided an excellent basis for an expanded and more systematic monitoring program.

Table 4. **INVENTORY AND MONITORING PRIORITIES**
VIRGIN ISLANDS NATIONAL PARK

INVENTORY	
MARINE	**TERRESTRIAL**
1) Water Quality: nutrients, bacteria, chlorophyll	1) Exotic amphibians
2) Currents	2) Bats
3) Updating of benthic maps (GIS)	3) Reptiles
4) Sponges/Gorgonians	4) Ectoparasites
5) Bait fish	5) Rare and exotic plants
	6) Riparian fauna
	7) Pollutants in stream beds
MONITORING	
MARINE	**TERRESTRIAL**
1) Establish new coral reef study sites	1) Feral animal impacts
2) Continue ongoing studies	2) Establish additional long-term vegetation plots
3) Nutrient, Bacteria, Chlorophyll, Suspended Sediment	3) Continue paired watershed study
4) Population studies of commercially important fish/shellfish species	4) Continue ongoing studies of vegetation, birds, etc.
5) Visitation patterns	5) Forest dynamics: Nutrient cycling, seedling recruitment, growth
6) Sea turtle nesting	6) Exotic plant encroachment

Table 5. I AND M PRIORITIES: BUCK ISLAND NATIONAL MONUMENT

INVENTORY	
MARINE	**TERRESTRIAL**
1) Updating of benthic maps	1) Exotic and rare plants
2) Survey sea turtle foraging habitat	2) Bats
	3) Bird species list
	4) Vegetation map
MONITORING	
MARINE	**TERRESTRIAL**
1) Sea turtles	1) Establishment of vegetation plot
2) Addition of new coral reef study sites	2) Exotic mammals
3) Population studies of commercially important fish/shellfish	3) Pelican nesting surveys
4) Continue ongoing studies	
5) Visitation patterns	

Table 6. I AND M PRIORITIES: DRY TORTUGAS NATIONAL PARK

INVENTORY	
MARINE	**TERRESTRIAL**
1) Octocoral populations	1) Exotic plants
2) Corals and sponges	2) Invertebrates
3) Updating of marine benthic communities map (ground truthing and GIS)	3) Native birds
4) Water quality and physical oceanography	
5) Invertebrates	
MONITORING	
MARINE	**TERRESTRIAL**
1) Continuation of ongoing coral reef studies (support FKNMS replenishment zone studies)	1) Continuation and improvment of ongoing monitoring of nesting seabirds
2) Water quality and physical oceanography (support FKNMS program)	
3) Establish recreational fisheries monitoring program (cooperate with state and NOAA)	
4) Sea turtle nesting	

Much of the research has been concentrated in a few watersheds selected for their ecological significance. The Lameshur Bay watershed has been the focus of research on dry forests, coral reefs, sea grass beds, reef fishes, soils, and sediment runoff. The largely intact watersheds of Lameshur and Reef Bay are considered the core of the Virgin Islands Biosphere Reserve.

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 a paired watershed study to look at the effects of clearing of vegetation on sediment runoff rates (see Table 7).

The system-wide marine resources planning brought about by the establishment of the Florida Keys National Marine Sanctuary (FLKNMS) in 1990 provides an excellent basis for establishing a systematic and coordinated monitoring program for DRTO. Implementation of the FLKNMS management plan will involve numerous MOAs, MOUs and cooperative agreements. NPS staff will continue to participate in planning of the Sanctuary.

See Tables 7, 8, 9, and 10 for current studies in the three parks.

Standardized protocols

Standardized protocols are available for all major proposed monitoring programs, although they have not been produced in an integrated handbook. 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 DRTO.

The Smithsonian has published standardized protocols for monitoring of long-term vegetation plots which are being used on St. John.

Bibliographies

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.

4. *Monitoring Program Design:*

The monitoring program proposed here for VIIS, BUIS, and DRTO (see Tables 11, 12, 13, and 14) is essentially an expansion of existing and prior monitoring and an effort to integrate ongoing monitoring activities into a systematic, comprehensive program. Tables 4, 5, and 6 list the highest priority monitoring projects for each park.

Table 7. CURRENT VIRGIN ISLANDS NATIONAL PARK TERRESTRIAL STUDIES

RESEARCH PROJECT	INSTITUTION	DATE STARTED	OBJECTIVES	RESEARCH SITE
Vegetation mapping	International Institute Tropical Forestry	1982	List plant species on island	Island-wide
Forest dynamics study I	International Institute Tropical Forestry (ITF)	1983	Long term monitoring of forest dynamics	16 plots on elev. gradient, Cinnamon Bay
Forest dynamics study II	New York Botanical Garden/ U of Georgia	1986	Long term monitoring of forest in 3 watersheds	3 (0.5-1.0 hectare) plots in 3 forest types
Seedling and sapling dynamics	NY Botanical Gardens/ U of Georgia	1989	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 Biodiversity Program	1 hectare dry forest plot
Dry forest restoration	U of Wisconsin	1988	Research dry forest restoration and effects of Hurricane Hugo	5 long-term plots
Soil characterization	Soil Conserv. Service	1992	Prepare new soil map, characterize soils	Island-wide Long term plots
Paired watershed study	USGS	1992	Compare sediment loads	Developed and natural watersheds
Migratory birds	Connecticut College, TNC, ITF	1989	Species distribution of migratory and resident warblers and effects of forest fragmentation	Island-wide
Wading birds	VIIS	1992	Population, distribution	Island-wide
Seabirds: pelicans	VIIS/DPNR/F&W	1975	Population studies	USVI
Beetles	U of Montana	1993	Species inventory	Island-wide
Ectoparasites	VIIS/ NIH, Rocky Mtn Laboratory	1992	Identify fleas and ticks. Test mongoose blood and ticks for arbovirus antibodies.	Island-wide - primarily turtle nesting beaches.

Table 8. CURRENT VIRGIN ISLANDS NATIONAL PARK MARINE STUDIES

RESEARCH PROJECT	INSTITUTION/ INDIVIDUAL	DATE STARTED	OBJECTIVES	RESEARCH SITE
Coral Reef Studies	VIIS	1989	Measure percent cover and spatial complexity of reefs	Yawzi Point and Newfound Bay
Anchor Damage Assessment and Recovery	VIIS	1989	Measure effect of anchor damage and recovery of living cover in scar area	Windspirit Scar, Whistling Cay
Reef Fish Study	VIIS and Division of Fish and Wildlife	1991	Collect baseline information on reef fish assemblages, determine effect of fish trapping on reef fish	12 reefs around St. John, Yawzi Point and Newfound Bay
Black Band Disease Study	CSU-Northridge	1985	Monitor presence and extent of black band disease on head corals	Greater Lameshur Bay
Sea Urchin Study	UC-Davis	1983	Examine sea urchin population	Greater Lameshur Bay
Sponges and Octocorals	Dr. William Gladfelter	1991	Examine sponge and octocoral populations	Yawzi Point, Newfound Bay, Windspirit scar
Sea turtles	VIIS	1985	Nesting activity	Island-wide
Seagrass Beds	University of Richmond	1989	Examine species composition and density of sea grass beds	Greater Lameshur Bay
Shallow Reef Community Disturbance	Northeastern University	1987	Examine changes in percent cover of sessile reef invertebrates	Cabritte Horn, Lameshur Bay
Water Quality	VIIS	1989	Measure temp., salinity, pH, conductivity, transmissivity, NTU's, and secchi depth	30 coastal sites around island of St. John. Tempmentors at 3 coral reef sites.

Table 9. CURRENT BUCK ISLAND REEF NATIONAL MONUMENT STUDIES

RESEARCH PROJECT	INSTITUTION	DATE STARTED	OBJECTIVES	RESEARCH SITE
Sea Turtles	BUIS	1989	Monitor nesting activity of female sea turtles	Island-wide
Coral Reef Monitoring	BUIS	1989	Measure percent cover and spatial complexity of reefs, Elkhorn coral population study	6 permanent coral reef sites
Reef Fish Study	BUIS	1992	Collect baseline information on reef fish populations	6 census sites
Sea Water Temperature Monitoring	BUIS	1989	Record temperature every 2 hours with Ryan thermisters	Forereef on eastern shore
Water Quality Monitoring	DPNR	1970	Measure temp, salinity, pH, conductivity, transmissivity, NTU's, and secchi depth	Island-wide
Brown Pelicans	BUIS, Territorial F&W, USFWS	1968	Monitor nesting activity and population study	Island-wide
Beetles	University of Montana	1993	Species inventory	Island-wide

Table 10. CURRENT DRY TORTUGAS NATIONAL PARK STUDIES

RESEARCH PROJECT	INSTITUTION	DATE STARTED	OBJECTIVES	RESEARCH SITE
Coral Reef Studies	Florida DNR	1988	Continue ongoing studies. Support FKNMS biological monitoring program.	5 permanent sites
Reef Fish Studies	Florida DNR	1988	Collect baseline information on reef fish assemblages.	5 permanent sites
Sea Turtles	DRTO	1970's	Document sea turtle nesting populations	DRTO nesting beaches
Sea Water Temperature	DRTO/ Florida DNR	1988	Record temperature every 2 hours with thermistors.	3 sites
Water Quality Monitoring	NOAA/ FKNMS	1992	Measure salinity	C-MAN buoy
Physical Oceanography	NOAA/ FKNMS	1992	Measure wind speed and direction, precipitation, and solar radiation.	C-MAN buoy

Table 11. PROPOSED MONITORING OF MARINE RESOURCES VIRGIN ISLANDS NATIONAL PARK

RESEARCH TOPIC	PROPOSED MONITORING OF MARINE RESOURCES
CORAL REEFS	1) Expand current long-term coral reef research to include two or more additional permanent monitoring sites a) Add a gorgonian-dominated research site b) Establish permanent site at Haulover Reef; currently a new road is being bulldozed through this pristine watershed 2) Document bleaching events 3) Continue monitoring recovery from hurricane at Yawzi Point site 4) Continue studies of recovery from cruise ship anchor damage; coral recruitment.
CORAL REEF FISH	1) Continue long-term censusing to provide information on cyclic changes in reef fish assemblages 2) Expand reef fish study to determine relationship between habitat structure and abundance/diversity of fishes 3) Study fish assemblages in octocoral-dominated areas 4) Conduct fish censuses specifically designed to determine abundance of commercially important species (groupers,snappers) 5) Establish a marine reserve within VIIS to study effects of prohibition of fishing
BAIT FISH	1) Monitor populations of bait fish in nearshore bays
LARVAL RECRUITS (FISH)	1) Sample along established permanent transects for recruitment of larval fish
LOBSTER AND CONCH	1) Survey coral reef sites for lobster and conch
SEA URCHINS	1) Continue research on recovery of sea urchin population
SEA GRASS BEDS	1) Continue monitoring sea grass beds for changes in species composition and density, document recovery from Hurricane Hugo and effect of new ban on anchoring in Lameshur Bay
CORAL DISEASE	1) Continue monitoring of black band disease on hard corals at permanent study sites
WATER QUALITY	1) Continue monitoring water quality on a monthly basis 2) Expand sampling to include information on nutrients, chlorophyll, suspended matter, and bacteria
SEA TURTLES	1) Continue limited monitoring

Table 12. PROPOSED MONITORING OF TERRESTRIAL RESOURCES VIRGIN ISLANDS NATIONAL PARK

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) Expand studies of ecological processes to include nutrient cycling, etc. 5) Install fruit/seed traps in selected plots to quantify reproductive success and dispersal events 6) Collect soil cores from selected plots following dry & rainy season to evaluate role of seedbank 7) 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
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/ AMPHIBIANS	1) Monitor rare and ecologically relevant reptilian and amphibian species 2) Monitor presence of, and prevent the spread of exotic species

Table 13. PROPOSED MONITORING BUCK ISLAND REEF NATIONAL MONUMENT

RESEARCH TOPIC	PROPOSED MONITORING
CORAL REEFS	1) Continue monitoring at existing permanent sites 2) Establish additional study sites 3) Document bleaching events 4) Continue monitoring recovery of Acropora palmata from white band disease and Hurricane Hugo. 5) Continue coral recruitment studies.
CORAL REEF FISH	1) Continue censusing to provide information on cyclic changes in reef fish assemblages
LOBSTERS AND CONCHS	1) Survey coral reef sites for lobsters and conchs
SEA TURTLES	1) Continue nesting studies of 3 species of sea turtles 2) Survey critical and resident habitat used by hawksbills
WATER QUALITY	1) Monitor water quality quarterly.
VEGETATION	1) Establish long-term vegetation plot
VISITATION	1) Continue documenting number of visitors and damage at the underwater trail
BIRDS	1) Record numbers of brown pelican adults and chicks
MAMMALS	1) Monitor Rattus sp populations on the island

Table 14. PROPOSED MONITORING DRY TORTUGAS NATIONAL PARK

RESEARCH TOPIC	PROPOSED MONITORING
CORAL REEFS	1) Expand current coral reef community monitoring to include additional sites 2) Study octocoral diversity and distribution 3) Update benthic habitat maps
CORAL REEF FISH/SHELLFISH	1) Expand current monitoring to include additional reefs and more frequent fish censuses 2) Monitor recreational fishing pressure 3) Compare differences in fish assemblages among habitat types 4) Survey lobster and conch populations
SEA TURTLES	1) Continue monitoring sea turtles
SEA BIRDS	1) Continue monitoring of noddies, terns, other sea birds
WATER QUALITY	1) Continue water quality 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), and the "Windspirit" anchor site (begun in 1988). The emphasis has been on percent live coral cover and species diversity of hard corals, 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 two or more permanent sites in additional areas around St. John to provide better representation of the island's marine hard bottom communities (as determined from benthic maps prepared in 1986). Further research is necessary to determine the relative value of these different reef habitats to fish populations.

Specifically, we propose to establish another long-term site at Haulover Reef, a reef with exceptionally high live coral cover (Fig. 2). This is considered the highest priority because of the potential for degradation which could accompany current development of the associated watershed. Road construction began in August 1993 along the steep hillside upcurrent and on the eastern side of the bay. The plans call for a subdivision of 30 lots.

The second coral reef site would be established in an area dominated by octocorals rather than hard corals. 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. Monitoring of reefs in DRTO, VIIS, and BUIS should include documentation of any bleaching events.

Cruise ship anchor damage to reefs has been documented in VIIS and monitoring of recovery will continue. Monitoring of the recovery following grounding of the "Mavro Vetranic" in DRTO should also be continued.

Coral reef fishes/shellfishes: 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 and of the fish caught in traps should be continued. Five years of data are available from 2 St. John sites. Annual sampling at 12 reef sites around St. John has been conducted since 1989.

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 and if the trophic structure is changing. More data are needed to elucidate the relationship between habitat structure and the

abundance and diversity of fishes. 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.

Bait fish are clearly of significance to local fisheries. 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 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 conchs 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 simplify enforcement and protect the spawning stock biomass. They are also thought to supply recruits to fished areas, enhance catches in adjacent areas through emigration, and insure against stock collapse due to successive years of poor recruitment (Davis 1989, Bohnsack 1990). Many fisheries scientists consider marine reserves to be the newest and most promising fisheries management tool.

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. 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.

The management plan for the new Florida Keys Marine Sanctuary recommends that a portion of DRTO and adjacent waters be set aside as a marine reserve.

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

Coral Reefs/Reef Fishes/Shellfish: BUIS

Future monitoring at BUIS would include continued assessment 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. Expanded monitoring of this species, significant throughout the Caribbean, is proposed. Hurricane Hugo devastated portions of BUIS; some areas were scoured and leveled. Studies of recruitment of hard corals and other reef organisms to these sites will continue.

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. Studies done in the 1970s and 1980s helped establish a baseline on shellfish and fish assemblages.

Coral reefs/reef fishes/shellfish: DRTO

Corals, octocorals, and reef fishes have been sampled at five long-term monitoring sites at DRTO by Florida Marine Research Institute scientists since 1989. 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.

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. Given the significant fishing pressure observed throughout the Keys and increasingly at DRTO, the comparative value of monitoring at DRTO can not be overemphasized.

Marine reptiles (sea turtles)

Monitoring of all nesting sea turtles will be continued at BUIS, VIIS, and DRTO. The past 6 years of research on the nesting hawksbills at BUIS has documented over 70 nesting females, their growth rates, nesting success, fecundity, and nesting site fidelity. 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.

Other marine studies

Our proposed monitoring program includes continued support for a series of small projects by visiting scientists, some of which have been ongoing for 10 years (see Table 8). For example, sea grass beds in Great Lameshur Bay are being monitored for changes in species and density of sea grasses, and recovery of areas scoured by waves during 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 sea grass community structure, densities, and productivity.

Effective September 6, 1993, anchoring was prohibited in Great and Little Lameshur Bays, St. John (Fig. 2). Monitoring of the sea grass beds in these bays will demonstrate if mooring buoys effectively provide protection to these resources.

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.

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

DRTO
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 and Central America. Water quality must be monitored within the park, with emphasis on nutrients and chlorophyll.

The Florida Keys National Marine Sanctuary is proposing 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.

Proposed marine monitoring projects are summarized in Tables 11, 13, and 14.

VIIS and BUIS 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; 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 effort will be made to monitor net primary productivity, organic matter accumulation, and nutrient cycling. 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 of highest priority because it contains several rare plant species and constitutes a significant portion (21%) of the island's forests. The coastal hedge has 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.

In addition, 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.

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. Following site selection and the mapping and identification of all tree within the plot, monitoring could be conducted every 3 to 5 years.

Exotic plants

Experiments will be implemented in one or more of St. John'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, and 3) to test the usefulness of seedling, sapling, and tree removal of "Genip in converting groves to more diverse native species assemblages.

Mammals

Information on the distribution of bats will be obtained from all major vegetation types in VIIS. Later studies will concentrate on assessment of food habits and attempts to estimate populations.

Semi-annual population estimates will be made of feral animals on St. John, and exclosure studies will be set up to quantify changes in forest communities as a result of the elimination of grazing.

Mongooses will be trapped and removed from VIIS beaches where sea turtles nest during the June through November season.

Rats will be monitored at BUIS prior to attempts to reintroduce the endangered

ground lizard (Ameiva polops).

Reptiles and amphibians

A thorough inventory of the herpetofauna of St. John is needed, followed by monitoring of rare and introduced species. Recent introductions of the Cuban tree frog and Puerto Rican coqui to the island have already been confirmed.

Paired watershed study

NPS and USGS are collaborating on a study which compares the sediment runoff from the Fish Bay watershed, being developed on the western boundary of the park, to that from the relatively undisturbed Lameshur watershed (Fig. 2). 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 how readily particular soils erode. This study will be continued because of the lack of quantitative data on runoff for tropical islands.

Birds

Wetland bird communities Shore birds and waterfowl within VIIS will be counted every week from September through May. Wading birds will be banded to get information on turnover rates and habitat use in park wetlands.

Migratory warblers Research over the last 4 years on St. John has shown the importance of having intact forest as winter habitat (Askins et al. 1992, Askins and Ewert 1992). 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.

Permanent census stations will be resurveyed every winter, and the project will be expanded to look at the food base and habitat use.

Seabirds
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. Monitoring of sea birds at DRTO will be continued.

Intermittent stream beds/freshwater communities

The water quality of intermittent freshwater streams within the VIIS has not yet been tested. Sewage and other pollutants may be causing algal blooms observed near the western boundary of VIIS. The intermittent streams in affected park watersheds will be analyzed for nutrients and bacteria. Fish and macroinvertebrate populations will also be inventoried and monitored.

Comparisons of aerial photos using GIS

A series of aerial photographs are available for St. John, with a more limited set

on Buck Island. GIS technology will be used to quantitatively assess any substantial changes in 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 BUIS 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 also be very valuable to do an update of the benthic map prepared by Gary Davis for Dry Tortugas (Davis 1982).

Recreational use/visitation

Monitoring of the numbers of people who visit VIIS, BUIS, and DRTO will continue. BUIS will continue to monitor the effects of heavy use of the underwater trail.

See Tables 12, 13, and 14 for proposed terrestrial monitoring projects.

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 Master's Degree, and two Resource Management Specialists (GS 11, GS 9), 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. The two RM Specialists have GIS expertise. BUIS has one Biological Technician (GS 7), who has completed the Natural Resource Management Training Program.

Appendix C includes abbreviated resumes for NPS scientists and resource managers, and some of our major collaborators.

6. *Budget and Cost Effectiveness*

The I and M program envisioned here depends on research by an effective combination of VIIS, BUIS, and DRTO research and resource management staff, local scientists working under cooperative agreements, and visiting scientists who come periodically to conduct research. We believe that the budget we have prepared (see following page) is cost-effective and incorporates the major needs for the three parks. It is not too difficult to persuade people to come to the USVI in to do research (especially in the winter!), and it is often sufficient to cover travel costs to bring scientists to these parks 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.Travel funds are also requested to bring all of the Principal Investigators to annual meetings for presentations of their work. Note that salary costs are calculated on the basis of term appointments and include benefits and (for VIIS, BUIS) Cost of Living Allowances.

BUDGET					
Item	FY1	FY2	FY3	FY4	FY5
NEW POSITIONS - VIIS					
Data Manager/GIS (GS-11/1)	$50,435	$52,116	$53,798	$55,479	$57,161
Cartographic Tech. (GS-7/1)	$34,076	$35,211	$36,347	$37,482	$38,618
Terrest.Ecologist (GS-11/1)	$50,435	$52,116	$53,798	$55,479	$57,161
Wildlife Biologist (GS-11/1)	$50,435	$52,116	$53,798	$55,479	$57,161
Ecological Tech. (GS-7/1)	$36,347	$37,558	$38,770	$39,981	$41,192
Ecological Tech. (GS-7/1)	$36,347	$37,558	$38,770	$39,981	$41,192
Administ. Clerk (GS-6/1)	$30,665	$31,686	$32,708	$33,729	$34,751
NEW POSITIONS - BUIS					
Ecological Tech. (GS-7/1)	$36,347	$37,558	$38,770	$39,981	$41,192
NEW POSITIONS - DRTO					
Resource Mgmt.Spec.(GS-9/1)	$38,905	$40,201	$41,497	$42,794	$44,090
SUBTOTAL	$363,990	$376,121	$388,253	$400,384	$412,516
EQUIPMENT					
Jeep Cherokee for VIIS	$25,000				
GIS Upgrade:	$10,700	$1,200	$20,000	$1,200	$1,200
SCUBA gear	$5,000	$4,000	$4,000	$4,000	$4,000
Field gear (nets, mylar...)	$3,000	$3,000	$3,000	$3,000	$3,000
SUBTOTAL	$43,700	$8,200	$27,000	$8,200	$8,200
ADMINISTRATION					
Rental of space & furniture	$50,000	$50,000	$50,000	$50,000	$50,000
Travel & transportation	$15,000	$40,000	$40,000	$40,000	$40,000
Office supplies	$4,000	$4,000	$4,000	$4,000	$4,000
Cooperative Agreements	$100,000	$100,000	$100,000	$80,000	$50,000
Printing & Reproduction	$8,000	$8,000	$8,000	$8,000	$8,000
Professional Services	$5,000	$15,000	$5,000	$5,000	$5,000
SUBTOTAL	$182,000	$217,000	$207,000	$187,000	$157,000
TOTAL	$589,690	$601,321	$622,253	$595,584	$577,716

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

The results of this 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 for feral animal control (hogs), vegetation restoration, exotic plant control, and monitoring of sea turtles.

People from other Caribbean islands and countries have already benefitted from training on research/resource management, and results of VIIS and BUIS monitoring programs are of direct relevance. Monitoring of the damage from snorkelers, boats and ships is also relevant to all tropical marine protected areas.

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

Studies of the effects of marine reserve establishment on fish size and species composition would complement similar studies in Channel Islands National Park and would be of great interest to tropical/neotropical countries worldwide. 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. Effective monitoring of the biological processes within these forests will be applicable throughout the tropics on a large scale as well as provide opportunities for comparisons with Everglades, Big Cypress, and Hawaii Volcano National Parks.

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 collections include all research papers pertaining to the parks. Collections for VIIS including an excellent herbarium are housed in a small building near the Center.

Equipment. VIIS will soon have a total of 5 IBM/PC compatible work stations, three notebook computers with printers, 2 laser jet printers, 1 color printer, and GIS hardware. VIIS has 2 vehicles, 2 boats, and SCUBA equipment for 6 people. A 24' diesel boat has been ordered. BUIS has one IBM/PC compatible work station with a laser jet printer, access to one 25' Boston Whaler patrol boat, and SCUBA gear for 4 people. Ranger and maintenance vehicles are made available as necessary.

See Appendix D for Organizational Structure.

9. *Data Management Plan:*

A well organized data management program is a crucial component of a successful long-term monitoring program. The budget for this proposal reflects the hiring of 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 methods for 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 all requests for data. Every year the data manager will print out a metadata catalog to illustrate the data available at the park.

QA/QC procedures

Several procedures will be followed to assure that all data in non-spatial databases and the GIS are of the highest consistent quality, with known levels of accuracy and precision, and protected from accidental data corruption. Precision and accuracy of results during sampling and analysis are ensured through quality assurance and quality control procedures, respectively.

1. *Data documentation* - All data sets will be documented. A metadata database has been established for the current park GIS coverages. This database will be kept current for all subsequent coverages developed on the GIS. A series of forms will be used to institutionalize data documentation for future I & M monitoring projects. The information from these forms will be entered into the metadata database. Examples of the type of information gathered from these forms are given below.

Data abstract form: 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 (maps):

> 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.

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 assuring that the data are field-checked.

Field sheets with non-spatial data will be transcribed directly into the computer, copied, and then stored for future reference. Field data sheets will be designed to facilitate integration of sheets from related project components and to minimize manual re-entry. Data sheet designs will also closely match the structure of the computer database fields for accurate transcription. Each 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.

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 made available to Principal Investigators and archived off-site at the new CPSU in Florida and with the NBS GIS Division.

4. *Data security* - 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."

Some data, e.g. on locations of 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 are analyzed semi-annually or quarterly, depending on the particular project. Project investigators will have primary responsibility for data analysis on new projects. 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:*

VIIS has an approved GIS Plan that identifies GIS objectives, staffing needs, data priorities, and available data. To date, 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. Overlay analyses have been made and composite overlay maps have been created.

VIIS DATA COVERAGES	
Vegetation Map	Land status
Marine Benthic Communities	Water and Sewer Lines
Hydrography	Buildings
Land Contours	Boundaries
Geologic Features	Ocean Bathymetry
Soils Map	Roads and Trails
Archeological Sites	Study-site location
Historical Buildings	Wildlife Observations
T & E Species	

VIIS is in the process of installing the necessary GIS hardware and integrating the software. Current plans call for data transfer from the USGS system to the Biosphere Office at VIIS to be completed in fall 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 are 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.

Presently, a Resource Management Specialist at VIIS with GIS training and a good background in computers 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

It is anticipated that our current system will need upgrade within 2 years. Additional hardware and software purchases proposed are a 500 MB hard disk, a large format plotter, a 24" by 24" digitizing tablet, and GRID (ARC-INFO Raster Module). 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 production 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 monitoring projects 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 NPS, USDA Forest Service, USFWS, 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 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 USFWS, National Marine Fisheries Service, Virginia Polytechnic Institute, University of Georgia, 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.

DRTO is working in cooperation with the Florida Institute of Oceanography SEAKEYS Program, NMFS, the Florida Keys Marine Sanctuary (NOAA), and Florida DNR.

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.)

Cooperative Agreements will require interim and final reports, plus articles for Park Science and presentations to park staff. Each scientist will also be requested to submit Investigators' Annual Reports.

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:*

Threats to Natural Resources

Threats to the natural resources of VIIS (Table 15), BUIS (Table 16), and DRTO (Table 17) include high levels of visitation, damage from recreational and commercial boats, overfishing, oil spills, pollution, and major storms. Threats which primarily affect VIIS include grazing by feral animals and development.

Development

Development of private inholdings and land adjacent to the VIIS boundary (Fig. 2) 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 the park. Clearing of St. John's steep hillsides (over 80% of the island's slopes exceed 30 degrees) and construction of new roads has resulted in elimination of native species, spread of exotic plants, erosion, and fragmentation of the forests.

Increases in sedimentation from careless development can cause deterioration in water quality adversely affecting coral reefs. Few quantitative data exist on the increases in sedimentation which accompany clearing of steep hillsides in the tropics. It is essential to continue the paired watershed study which compares the sediment input from a watershed being developed adjacent to the western boundary of VIIS with that from a relatively undisturbed watershed within the park.

Coral reefs

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, 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.

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 DRTO. Dry Tortugas National Park was spared the devastation of Hurricane Andrew in 1992. Global climate change may result in increased storm activity in the tropics. 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 VIIS forests and on BUIS and VIIS coral reefs (e.g., Reilly 1991, Rogers et al. 1991, Rogers 1992).

Coral diseases have severely affected the primary reef-building corals on VIIS and BUIS reefs. It is not known if damage from human activities (e.g., oil pollution, coral breakage) increases the incidence of these diseases.

Protection of reefs is crucial for survival of the endangered hawksbill sea turtles

Table 15. THREATS TO VIRGIN ISLANDS NATIONAL PARK

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 > 30 degrees)
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) Accidental exotic spp. 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 4) Oil spills
FISHERY RESOURCES	1) Overfishing of lobster, conch, groupers, snappers, bait fish 2) Loss of coastal nurseries through conversion of wetlands and mangroves 3) Oil spills, coastal water pollution, increase in human nutrients
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

Table 16. THREATS TO BUCK ISLAND NATIONAL MONUMENT

NATURAL RESOURCES	THREATS
CORAL REEFS	1) Pollution from boats, oil, gasoline 2) Boat groundings, snorkelers, visitation 3) Natural disturbance and disease 4) Oil and fuel spills
FISHERY RESOURCES	1) Commercial fishing; overfishing lobster, conch, etc. 2) Oil spills
SEA TURTLES	1) Erosion of beach 2) Human disturbance
NATURAL VEGETATION	1) Exotic species introduction
SEA BIRDS	1) Decline in prey base caused by overfishing (baitfish)
AIR QUALITY	1) Pollution from refineries on St. Croix

Table 17. THREATS TO DRY TORTUGAS NATIONAL PARK

NATURAL RESOURCES	THREATS
CORAL REEFS	1) Pollution from boats, oil, gasoline 2) Large vessel groundings, boat groundings, anchor damage 3) Natural disturbances 4) Oil Spills
FISHERY RESOURCES	1) Recreational fishing 2) Overfishing of lobster, conch, groupers, snappers, bait fish 3) Oil spills, boat pollution 4) Changes in prey base from extensive commercial fishing at boundaries of park
COASTAL WATER QUALITY	1) Boat pollution 2) Solid waste, burning trash 3) Decline in regional water quality from water management activities in USA
SEA BIRDS	1) Human Disturbance from visitation (transport boats & planes, recreational boats) 2) Overharvest of food source (bait fish) 3) Introduced mammals foraging on nests
SEA TURTLES	1) Human disturbance on nesting beaches 2) Incidental killings by commercial fishing vessels 3) Erosion of nesting beaches
AIR QUALITY	1) Burning trash

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. Increasing numbers of visitors 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 in VIIS, BUIS, and DRTO. Pollution from boats (oil, fuel, human wastes) represents an unquantified threat to the marine ecosystems in all three parks.

Documentation of effects of visitation on the resources (e.g., monitoring of numbers of visitors and their use patterns) needs to be conducted as a basis for future management actions. Further restrictions on the size of boats allowed to anchor in park waters may be warranted.

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 native plants in VIIS. On St. John, pigs have rooted through the permanent vegetation plot established in Bordeaux, and another research plot on Mary Point has suffered from grazing by 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. Goats have created scrublands where diverse, dry evergreen thickets once thrived. Hard data from exclosure studies are necessary as a basis for serious management intervention.

Mongooses introduced to the USVI to control rats in sugar cane fields have already eliminated many species of indigenous birds, reptiles, and other animals. Mongooses appear to have been eliminated from Buck Island, although they continue to prey on sea turtle eggs and hatchlings on St. John's beaches.

Exotic plants

Exotic plants are a major and growing 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

Current fisheries within VIIS and DRTO (and possibly BUIS) cannot be sustained. Fishing intensity is increasing in all three parks. "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.

Preservation of traditional fisheries and protection of the coral reef and sea grass ecosystems jeopardized by commercial fishing will require careful management. Creation of marine reserves within portions of VIIS and DRTO will allow overfished populations to recover and may result in the enhancement of fish stocks in nearby areas outside the reserves. Decisions to restrict fishing will be controversial and must be backed up with excellent, defensible data.

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 frequently wash up on VIIS and BUIS beaches.

Threats to birds

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 birds include loss of mangrove swamps and saltponds important to winter-resident shorebirds and waterfowl, disturbance from humans near nesting areas, and overharvest of fish species eaten by seabirds.

Threats to endangered species

Threats to the endangered sea turtles in VIIS, BUIS, and DRTO include human disturbance on nesting beaches, erosion of these beaches following storms, mongooses which prey on hatchlings and eggs, and incidental killing by commercial fishing vessels.

Construction of roads and buildings and grazing by feral animals represent the most significant threats to rare native plant species.

Threats to reptiles and amphibians

The major impacts to reptiles and amphibians in the USVI occurred following introduction of mongooses to the islands in 1872. Extant threats include continued predation from mongooses, and accidental introductions occurring from stowaways on incoming plants used for landscaping in developed areas near and within VIIS. 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. Two species of frogs have already been introduced to St. John. Because St. John is separated from St. Thomas by a narrow three mile channel, and there is constant movement of cargo between the two islands, odds are very high that other species which have already been introduced to St. Thomas will reach VIIS.

Air quality

Under typical wind conditions, no major urban areas are upwind of the USVI for thousands of miles. Consequently, air quality is usually very good. Fine particulate matter less than 10 µm are transported to the USVI in the summer from the Saharan region of Africa. This "Saharan Dust" phenomenon at times reduces visibility to less than 2 miles. 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 do not normally reach BUIS or St. John. BUIS may receive some influence from this refinery 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. Increases in nutrients in the water can cause algal overgrowth on coral reefs. Data from monitoring of nutrients, bacteria, and chlorophyll, can alert managers to the need to 1) restrict further development or to require more protective measures during development; 2) put a ceiling on the number of boats anchoring in park waters (most boats discharge human wastes directly into the ocean); 3) advise swimmers of bays which are unsafe for swimming; or 4) restrict the dumping of raw sewage from boats or houses into park waters.

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(See the May 1992 "Park Science" and Appendix B for other pertinent articles.)

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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

APPENDIX B Virgin Islands Biosphere Reserve Research Report Series

The following reports were published jointly by the U.S. National Park Service and the Virgin Islands Resource Management Cooperative (VIRMC) as part of research, resource management, and educational activities related to the Virgin Islands Biosphere Reserve. Most reports are now out of print, but photocopies of individual reports in the series may be purchased from Island Resources Foundation, which has acted as the local contingent for VIRMC since its formation in 1982. For more information on the Virgin Islands Resource Management Cooperative, please write: VIRMC Executive Officer, V.I. National Park, Post Office Box 710, Cruz Bay, St. John, U.S. Virgin Islands 00831.

Report #1	Report Abstracts	$5.00
Report #2	Beets, J., Lewand, L and Zullo, E. Marine community descriptions and maps of bays within the Virgin Islands National Park / Biosphere Reserve. 118 pp., including maps, figures, and tables.	$15.00
Report #3	Beets, J. and Lewand, L. Collection of common organisms within the Virgin Islands National Park / Biosphere Reserve. 45 pp.	$6.00
Report #4	Anderson, M., Lund, H., Gladfelter, E., and Davis, M. Ecological Community type maps and biological descriptions for Buck Island Reef National Monument and proposed marine park sites in the British Virgin Islands. 249pp., including maps.	$37.50
Report #5	Lund, H., Anderson, M., Cladfelter, E., and Davis, M. Trends in recreational boating in the British Virgin Islands: A preliminary assessment of impact from human activities on anchorages and development of a monitoring program for safe anchorages. 40 pp.	$6.00
Report #6	Davis, M., Gladfelter, E., Lund, H., and Anderson, M. Geographic range and research plan for monitoring white band disease. 28 pp.	$4.50
Report #7	Gladfelter, E., Anderson, M., Lund, H., and Davis, M. Marine ecosystems of the Lesser Antillies: Identification of representative sites. 44 pp.	$6.00
Report #8	Boulon, R. Map of fishery habitats within the Virgin Islands National Park / Biosphere Reserve 70pp., including maps.	$11.00
Report #9	Boulon, R. Fisheries habitat of the Virgin Islands region of ecological importance to the fisheries resources of the Virgin Islands Biosphere Reserve. 22 pp.	$3.50
Report #10	Dammann, A. Assessment of fish and shellfish stocks produced in the biosphere reserve. 22 pp.	$4.50
Report #11	Boulon, R. and Clavijo, I. Utilization of the Virgin Islands Biosphere Reserve by artisanal fisherman. 37 pp.	$5.50
Report #12	Koester, S. Socioeconomic and cultural role of fishing and shellfishing in the Virgin Islands Biosphere Reserve. 24 pp.	$3.50
Report #13	Boulon, R. Long-Term monitoring of fisheries in the Virgin Islands Biosphere Reserve. 32 pp.	$5.00
Report #14	Goodwin, M. Characterization of Lesser Antillean Fisheries. 47 pp.	$6.50

The Foundation can also make available a 30 minute video tape on the biosphere reserve concept as a resource management tool for developing countries. The tape focuses specifically on a workshop held at Caneel Bay, St. John in 1983 at the time the Virgin Islands National Park was formally dedicated as an international biosphere reserve, the only such site recognized by UNESCO in the Eastern Caribbean. A loan copy of the VIRGIN ISLANDS BIOSPHERE RESERVE video tape is available for a $75.00 refundable deposit (specifiy whether ¾" or ½" tape is required). A copy of the tape can also be purchased for $50.00 (3/4") or $45.00 (1/2").

APPENDIX C

BIOGRAPHICAL SKETCHES

Dr. Caroline Rogers, Research Biologist at VIIS, will coordinate the overall I & M program. She has worked for NPS for 9 years and has a great deal of experience coordinating large research programs (such as the VIRMC, NRP programs noted above). Caroline received a B.S. from Stanford and a Ph.D. in coral reef ecology from the University of Florida. She has 19 years of research experience in the Caribbean.

Jennifer Bjork has worked for the National Park Service for 11 years in Florida, New Mexico, Texas and now in the Virgin Islands. Previous experience was as a biological consultant to the U.S. Fish and Wildlife Service, an ecologist for a U.S. Navy contractor, a science teacher. She received a Bachelors Degree from North Dakota. Jenny is a graduate of the 2nd class of the NPS Natural Resource Management Training Program and has functioned at the Division Chief level in the last two parks. She has conducted research in ultrasonic sewage treatment, bird roost repellents, donkey immunocontraception, GIS for small areas, and oil spill impacts. She has monitored water quality, fine particulates in air, marine debris and endangered species. Her specialties include program design, long-term planning and environmental assessments.

Jim Petterson has worked for NPS and USFWS for five years 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 from California State University, Hayward. 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, and studying the natural history of Caribbean marine communities - primarily fish assemblages and scleractinian corals.

Zandy-Hillis, BUIS Biol. Technician, has been with NPS for 6.5 years. She has a B.S. degree in Zoology and over 30 years experience in the Virgin Islands as a visitor, student, marine researcher, and concessioner to Buck Island Reef National Monument. In 1991, she completed the NPS Natural Resource Management Training Program and continues to be responsible for natural resource programs at BUIS under the supervision of the Chief of Interpretation and Resource Management at CROW/BUIS. In March 1989, she participated in a NOAA/National

Undersea Research Program completing a 10 day saturation mission in the "Aquarius" Habitat at Salt River, St. Croix, to assist in establishing the coral reef monitoring program for Salt River. She has participated extensively in the NRP Coral Reef Assessment and Fisheries Assessment Programs. She is actively involved in the Hawksbill Sea Turtle Recovery Program and Caribbean-wide efforts to study this endangered species.

Dr. Jim Beets has worked as Chief of Fisheries for the Division of Fish and Wildlife of the Government of the Virgin Islands for seven years. Currently Jim is working as a research scientist with the University of Richmond, Department of Biology, Richmond, Virginia and serves as the principal investigator for several fisheries projects in the Virgin Islands, Tarawa and Florida. Jim received his Ph.D. at the University of Georgia, Athens Georgia and his master's degree and Bachelor of Science in Biology at the University of Tennessee, Knoxville, Tennessee. Jim has worked extensively on fisheries management, coral reef fish ecology, fish recruitment, stock analysis of commercially important species, and tropical fisheries biology in the Virgin Islands for over 14 years.

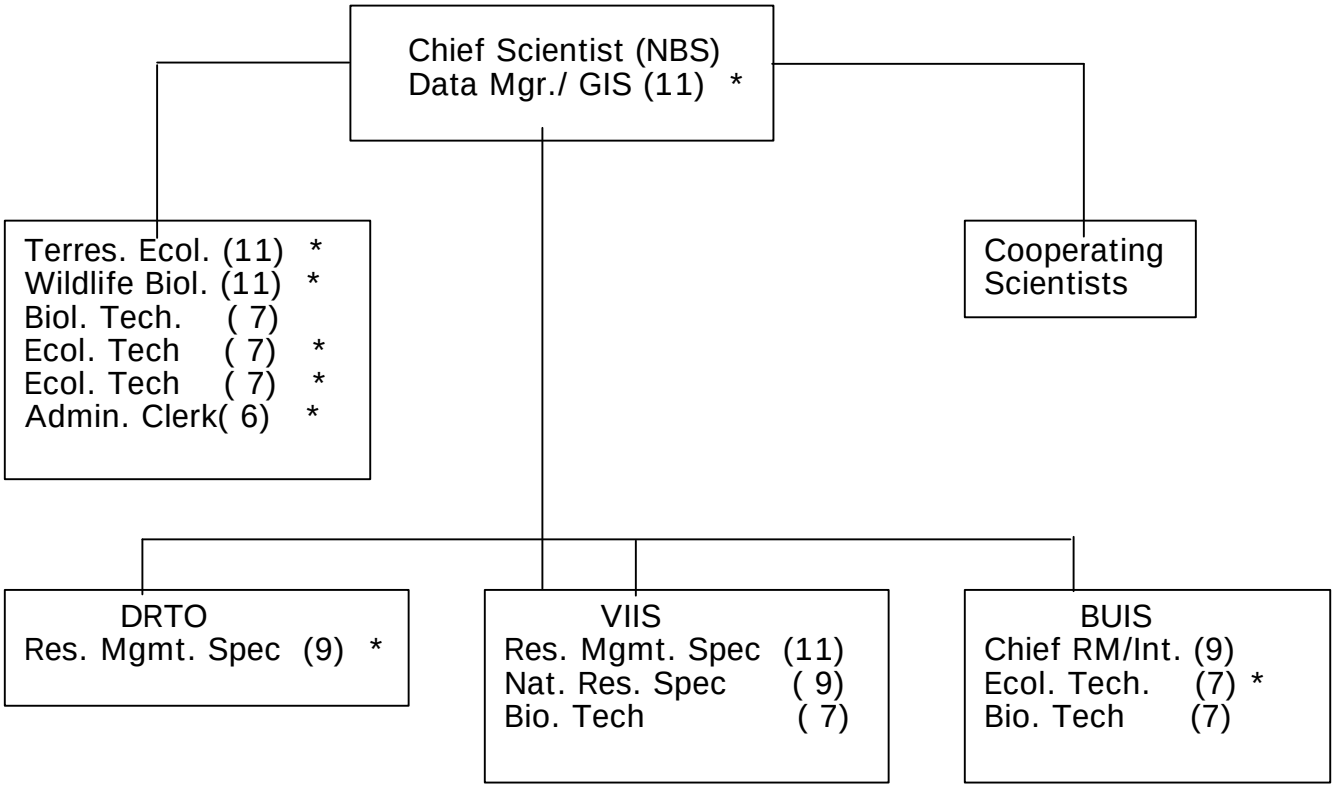
Dr. Lisa Muehlstein has worked at the Caribbean Research Institute at the University of the Virgin Islands for three years and is currently conducting a research project in collaboration with the Virgin Islands National Park studying the effects of anchor damage on sea grass beds. As Assistant Professor at the Department of Biology, University of Richmond, Virginia Lisa focuses her research on tropical sea grass ecology, marine fungi and algae and host pathogen interactions in marine systems. Lisa was awarded her Ph.D. at the University of Georgia, Athens Georgia, her master's degree at Wright State University, Dayton, Ohio and Bachelor of Arts at the University of Colorado, Boulder, Colorado.

Anne E. Reilly, a Ph.D. candidate at the University of Georgia, Institute of Ecology, has worked as a Research Associate at the Institute of Economic Botany at the New York Botanical Garden for three years. She has been investigating the impact of the colonial era on the development of the forest communities on St. John since 1985. In 1989, the research program expanded its focus in order to monitor the recovery process of the forest following Hurricane Hugo. Anne has published several papers on the forests of St. John. She is also co-author of the field guide to common trees of St. John, a publication which is nearly complete. Anne has a Master of Forest Science from Yale University School of Forestry and Environmental Studies and a Bachelor of Science from the State University of New York College of Environmental Science and Forestry.

Gary Ray earned a Ph.D. in Environmental Studies from the University of Wisconsin-Madison in June of 1993. Gary specializes in the development of techniques for restoring native Caribbean forests to degraded landscapes. Gary's research focuses on the conservation of tropical dry forests and includes basic ecological research, the study of rare plants, and the promotion of local environmental education initiatives. His dissertation research, which addressed dry forest succession, seed ecology, and methods testing for restoring native dry forests, was conducted at VIIS. He holds an M.S. in Botany from the University of Montana, with a concentration in community plant ecology.

APPENDIX D

Inventory and Monitoring Project Organizational Structure
Initial Communication Linkages



* = New Positions