APPENDIX A

ACRONYM LIST

APPENDIX A. ACRONYMS

AAD	Access to Archival Databases (NPS)
ACOE	Army Core of Engineers
AOML	Atlantic Oceanographic and Meteorological Laboratory
AT	CERP RECOVER Adaptive Assessment Team
BICY	Big Cypress National Preserve
BISC	Biscayne National Park
BOD	Board of Directors
BUIS	Buck Island Reef National Monument
CARL	Conservation and Recreation Lands Program
CASTNet	Clean Air Status and Trends Network
CCMA	Center for Coastal Monitoring and Assessment
CEM	Conceptual Ecological Models
CERP	Comprehensive Everglades Restoration Plan
CESU	Cooperative Ecosystem Studies Units
CHRI	Christiansted National Historic Site
CISMA	Cooperative Invasive Species Management Area
CREWS	Coral Reef Early Warning System
CSSS	Cape Sable Seaside Sparrow
CUSUM	Cumulative Sum
CWA	Clean Water Act
DASM	Digital Aerial Sketch Mapping
DERM	Dade County Environmental Resource Management
DMP	Data Management Plans
DRIs	Developments of Regional Impact
DRTO	Dry Tortugas National Park
EDEN	Everglades Depth Estimation Network
EEL	Environmental Endangered Lands Bond Program
EPA	Environmental Protection Agency
EPMT	Exotic Plant Management Team
EPOCs	Emerging Pollutants of Concern
EVER	Everglades National Park
FAC	Florida Administrative Code
FAU	Florida Atlantic University
FAWN	Florida Automated Weather Network
FDEP	Florida Department on Environmental Resources
FHAP-SF	South Florida Fisheries Habitat Assessment Program
FIU	Florida International University
FKNMS	Florida Keys National Marine Sanctuary
FLACO	Florida and Caribbean Office
FTE	Full Time Equivalent
FW	Fresh Water
FWC	Florida Fish and Wildlife Conservation Commission

FWRI	Fish and Wildlife Research Institute (Florida)
FWS	U.S. Fish and Wildlife Service
GIS	Geographic Information Systems
GMP	General Management Plan
GPRA	Government Performance and Results Act
GPS	Global Positioning System
GRTS	Generalized random-tessellation stratified (sampling design)
I&M	Inventory and Monitoring Program
ICON	Integrated Coral Observing Network
IMPROVE	Interagency Monitoring of Protected Visual Environments
IRMA	Integrated Resource Management Application
IT	Information Technologies
LATF	Land Acquisition Trust Fund Program
LIDAR	Light Detection and Ranging
LTER	Long Term Ecological Research group
MAB	Man and the Biosphere
MAP	CERP RECOVER Monitoring and Assessment Plan
MDN	Mercury Deposition Network
MOTE	Mote Marine Laboratory
NADP	National Atmospheric Deposition Program
NCCOS	National Centers for Coastal Ocean Science
NGO	Non-Governmental Organization
NOAA	National Oceanic and Atmospheric Administration
NPS	U.S. National Park Service
NPSEDD	National Park STORET Electronic Data Deliverable
NPSTORET	National Park STORage and RETrieval
NRR	Natural Resource Report
NRTR	Natural Resource Technical Report
NTN	National Trends Network
NWR	National Wildlife Refuge
OFW	Outstanding Florida Waters
OMB	Office of Management and Budget
ONRW	Outstanding Natural Resource Water
ORV	Off Road Vehicle
PAH	Polycyclic Aromatic Hydrocarbon
PCB	Polychlorinated Biphenyls
PDS	Protocol development summary
QA/QC	Quality Assurance/Quality Control
QASR	Quality Assurance Systems Requirements
RAWS	Remote Automated Weather Station
RECOVER	CERP Restoration Coordination & Verification Program
ReMI	Resource Management Intern
RNA	Research Natural Area
ROV	Remotely operated vehicle
RSMAS	Rosenstiel School of Marine and Atmospheric Science

RTE	Rare, threatened and endangered species
SARI	Salt River Bay National Historical Park and Ecological Preserve
SAV	Submerged Aquatic Vegetation
SCA	Student Conservation Association
SCUBA	Self Contained Underwater Breathing Apparatus
SEEPPC	Southeast Exotic Pest Plant Council
SEFSC	Southeast Fisheries Science Center (National Marine Fisheries Service)
SER	Southeast Region (NPS)
SERO	Southeast Regional Office (NPS)
SET	Soil Elevation Tables
SFC	South Florida and Caribbean
SFCN	South Florida/Caribbean Network
SFNRC	South Florida Natural Resources Center
SFWMD	South Florida Water Management District
SOC	Save Our Coast Program
SOP	Standard Operating Procedures
SQL	Structured Query Language
SRF	Systematic Reconnaissance Flights
STC	Science and Technical Committee
STORET	Environmental Protection Agency STORage and RETrieval
TBD	To Be Developed
TMDLs	Total Maximum Daily Loads
UF	University of Florida
UNESCO	United Nations Educational, Scientific and Cultural Organization
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
USVI	U. S. Virgin Islands
UVI	University of the Virgin Islands
VICR	Virgin Islands Coral Reef National Monument
VIDEP	Virgin Islands Department of Environmental Planning
VIDFW	Virgin Islands Department of Fish and Wildlife
VIDPNR	Virgin Islands Division of Planning and Natural Resources
VIIS	Virgin Islands National Park
VIRR	Virgin Islands Rules and Regulations
WASO	Washington Support Office (NPS)
WCA	Water Conservation Area
WMA	Wildlife Management Area
WRCC	Western Regional Climate Center
WRD	Water Resources Division (NPS)

APPENDIX B

GLOSSARY

APPENDIX B. GLOSSARY

Adaptive Management is a systematic process for continually improving management policies and practices by learning from the outcomes of operational programs. Its most effective form-"active" adaptive management-employs management programs that are designed to experimentally compare selected policies or practices, by implementing management actions explicitly designed to generate information useful for evaluating alternative hypotheses about the system being managed.

Attributes are any living or nonliving feature or process of the environment that can be measured or estimated and that provide insights into the state of the ecosystem. The term **Indicator** is reserved for a subset of attributes that is particularly information-rich in the sense that their values are somehow indicative of the quality, health, or integrity of the larger ecological system to which they belong (Noon 2003). See Indicator.

Baseline is the condition of the system or variable of interest that provides a standard against which future change of the system is measured. This can refer to an initial map of the system, to the first 3-10 years of the implementation of a monitoring protocol in which the baseline is defined by the mean and variability in the system, or it could refer to conditions at some point in the past.

Conceptual models are (1) purposeful representations of reality that provide a mental picture of how something works and is used to communicate that explanation to others; (2) "Explicit statements of the hypothesized functional relationships underlying management decisions regarding environmental resources." [A Proposal for the Development of a Comprehensive Monitoring Assessment and Research Program, April 24, 1998, page 30]; (3) "A simple non-quantitative model, developed for the purpose of building a consensus regarding the most important ecological elements and linkages that characterize a stressed ecosystem." [Nick Aumen, Conceptual Modeling Workshop, UC Davis, June 17-18, 1998].

Covariate is a variable such as precipitation or air temperature that is used in analyses to explain some of the variance in a variable of interest. For example, if animal detectability is temperature dependent, measuring temperature as a covariate will make it easier to detect population trends or experimental treatment effects.

Ecological integrity is a concept that expresses the degree to which the physical, chemical, and biological components (including composition, structure, and process) of an ecosystem and their relationships are present, functioning, and capable of self-renewal. Ecological integrity implies the presence of appropriate species, populations and communities and the occurrence of ecological processes at appropriate rates and scales as well as the environmental conditions that support these taxa and processes.

Ecological zone is a large unit of the SFCN landscape assumed to be affected by similar physical drivers and stressors. Each zone may contain multiple vegetation communities. The management challenge in some of these ecological zones is to maintain an appropriate balance of vegetation communities through management of system drivers and anthropogenic stressors, i.e. managing fire across the park to maintain a balance of slash pine communities as well as hardwood hammocks. The six ecological zones in the South Florida and Caribbean network are: "Wet Prairies and Marshes," "Forest Uplands and Wetlands," "Coastal Wetlands," "Island Interior," "Florida and Biscayne Bays," and "Coastal Shelf and Deep Oceanic."

Ecosystem is defined as, "a spatially explicit unit of the Earth that includes all of the organisms, along with all components of the abiotic environment within its boundaries" (Likens 1992).

Ecosystem management is the process of land-use decision making and land-management practice that takes into account the full suite of organisms and processes that characterize and comprise the ecosystem and is based on the best understanding currently available as to how the ecosystem works. Ecosystem management includes a primary goal of sustainability of ecosystem structure and function, recognition that ecosystems are spatially and temporally dynamic, and acceptance of the dictum that ecosystem function depends on ecosystem structure and diversity. Coordination of land-use decisions is implied by the whole-system focus of ecosystem management.

Edaphic means of or relating to soil, especially as it affects living organisms; influenced by the soil rather than by the climate (American Heritage Dictionary, 4th edition).

Focal resources are park resources that, by virtue of their special protection, public appeal, or other management significance, have paramount importance for monitoring regardless of current threats or whether they would be monitored as an indication of ecosystem integrity. Focal resources might include ecological processes such as deposition rates of nitrates and sulfates in certain parks, or they may be a species that is harvested, endemic, alien, or has protected status.

Habitats – Areas that provide specific conditions (e.g., temperature, moisture, soils, vegetation, and cover) necessary to support a community of organisms adapted to life under those conditions.

Halophytic means composed of plants adapted to living in a saline environment.

Hydric means having or characterized by excessive moisture; "a hydric habitat" (WordNet ® 2.0, © 2003 Princeton University).

Indicators are a subset of monitoring attributes that are particularly information-rich in the sense that their values are somehow indicative of the quality, health, or

integrity of the larger ecological system to which they belong (Noon 2003). Indicators are a selected subset of the physical, chemical, and biological elements and processes of natural systems that are selected to represent the overall health or condition of the system, known or hypothesized effects of stressors, or elements that have important human values.

Invasive species is a species that is non-native to the ecosystem under consideration and whose introduction causes or is likely to cause economic or environmental harm, or harm to human health (Executive Order 13112; http://www.invasivespecies.gov/laws/execorder.shtml). Invasive species can be plants, animals, and other organisms (e.g., microbes). Human actions are the primary means of invasive species introductions.

Inventory is an extensive point-in-time survey to determine the presence/absence, location or condition of a biotic or abiotic resource.

Measures are specific feature(s) used to quantify an indicator, as specified in a sampling protocol. For example, pH, temperature, dissolved oxygen, and specific conductivity are all measures of water chemistry.

Mesic means having or characterized by moderate or a well-balanced supply of moisture; "mesic habitats" (WordNet ® 2.0, © 2003 Princeton University).

Mesohaline is water containing 30-34 ppt salinity.

Metadata is data about data. Metadata describes the content, quality, condition, and other characteristics of data; its purpose it to help organize and maintain a organization's internal investment in spatial data, provide information about an organization's data holdings to data catalogues, clearinghouses, and brokerages, and provide information to process and interpret data received through a transfer from an external source.

Monitoring is the collection and analysis of repeated observations or measurements to evaluate changes in condition and progress toward meeting a management objective (Elzinga *et al*. 1998). Detection of a change or trend may trigger a management action, or it may generate a new line of inquiry. Monitoring is often done by sampling the same sites over time, and these sites may be a subset of the sites sampled for the initial inventory.

Monitoring variable (see *Measures*)

Non-indigenous species (also called exotic, invasive, introduced, or non-native species) are plants and animals that originate from geographic regions other than the ones that they are found in and, in the case of SFCN parks, originate from areas outside of Florida and the Virgin Islands. They may dominate the local species or

have other negative impacts on the environment. They are typically spread to new areas through human activities, either accidentally (Norway rats *(Rattus norvegicus)* hitched rides aboard ships) or deliberately (Eucalyptus was originally introduced as an ornamental). The principle difference between an "invasive" species and a "non-indigenous" species is invasive species are defined as causing harm.

Oligohaline is water containing up to 30 ppt salinity.

Oligotrophic means lacking in plant nutrients and having a large amount of dissolved oxygen throughout (American Heritage Dictionary, 4th Edition).

Protocols as used by this program, are detailed study plans that explain how data are to be collected, managed, analyzed and reported and are a key component of quality assurance for natural resource monitoring programs (Oakley *et al.* 2003).

State of the environment means the integrated manifestation of ecological processes, biological composition, ecological function, and rates of change that result in the condition of the system at any given time.

Stressors are physical, chemical, or biological perturbations to a system that are either (a) foreign to that system or (b) natural to the system but applied at an excessive [or deficient] level (Barrett et al. 1976:192). Stressors cause significant changes in the ecological components, patterns and processes in natural systems. Examples include water withdrawal, pesticide use, timber harvesting, traffic emissions, stream acidification, trampling, poaching, land-use change, and air pollution.

System drivers are physical driving forces such as climate, fire cycles, hydrologic cycles, and natural disturbance events (e.g., earthquakes, droughts, floods) that have large scale influences on natural systems. Biota that physically re-shape the environment are also included such as alligators and beavers.

Trend as used by this program, refers to directional change measured in resources by monitoring their condition over time. Trends can be measured by examining individual change (change experienced by individual sample units) or by examining net change (change in mean response of all sample units).

Vital Signs as used by the National Park Service, are synonymous with Indicator, and are defined as any measurable feature of the environment that provides insights into changes in the state of the ecosystem. Vital signs are intended to track changes in a subset of park resources and processes that are determined to be the most significant indicators of ecological condition of those specific resources that are of the greatest concern to each park. This subset of resources and processes is part of the total suite of natural resources that park managers are directed to preserve "unimpaired for future generations," including water, air, geological resources, plants and animals,

and the various ecological, biological, and physical processes that act on these resources. Vital signs may occur at any level of organization including landscape, community, population, or genetic levels, and may be compositional (referring to the variety of elements in the system), structural (referring to the organization or pattern of the system), or functional (referring to ecological processes).

Xeric means being deficient in moisture; "deserts provide xeric environments" (WordNet ® 2.0, © 2003 Princeton University).

APPENDIX C

SUMMARY OF LEGISLATION AND OTHER FEDERAL MANDATES RELEVANT TO THE VITAL SIGNS MONITORING PROGRAM

SFCN Staff
2005

APPENDIX C. Summary of Legislation and other federal mandates relevant to the Vital Signs Monitoring Program

Legislation	Summary Content
National Park Service Organic Act of 1916 *16 U.S.C. 1*	This Act created the National Park Service within the U.S. Department of the Interior and gave it jurisdiction over parks, monuments, and reservations acquired by the U.S. government for the purpose of wilderness conservation and public enjoyment. "The service thus established shall promote and regulate the use of the Federal areas known as national parks, monuments, and reservations hereinafter specified by such means and measures as conform to the fundamental purposes of the said parks, monuments, and measures as conform to the fundamental purposes of the said parks, monuments, and reservations, which purpose is to conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations."
Fish and Wildlife Coordination Act of 1958 and 1980	The Fish and Wildlife Coordination Act requires federal agencies to consult with the US Fish and Wildlife Service (USFWS), or National Marine Fisheries Service, and with parallel state agencies, whenever water resource development plans result in alteration of a body of water. The Secretary of the Interior is authorized to assist and cooperate with federal agencies to "provide that wildlife conservation shall receive equal consideration and be coordinated with other features of water-resource development programs."
Wilderness Act of 1964 *16 U.S.C. 1131 et seq. (1988), 78 Stat. 890, Pub. L. 88-577*	The Wilderness Act of 1964 established the National Wilderness Preservation System, composed of federal lands designated as Wilderness Areas. Wilderness Areas are to be administered "…for the use and enjoyment of the American people in such manner as will leave them unimpaired for future use and enjoyment as wilderness, so as to provide for the …preservation of their wilderness character…" NPS policy mandates that any proposed wilderness areas be managed as *de facto* wilderness until a final determination regarding wilderness designation has been made by Congress. (NPS Management Policies 2001).
National Historic Preservation Act of 1966, as amended (16 U.S.C. 470 et seq.)	Congress set forth in the NHPA includes preserving 'the historical and cultural foundations of the Nation' and preserving irreplaceable examples important to our national heritage to maintain 'cultural, educational, aesthetic, inspirational, economic, and energy benefits.' NHPA established the National Register of Historic Places composed of places and objects 'significant in American history, architecture, archeology, engineering, and culture.' NHPA requires federal agencies to account for effects of actions on historic (state and federal) properties.
National Environmental Policy Act of 1969	The National Environmental Policy Act (NEPA) is the fundamental national charter for environmental protection. "NEPA is intended to help public officials to: (1) make decisions that are based on an understanding of environmental consequences; and (2) take actions that protect, restore, and enhance the environment." The National Environmental Policy Act states that the federal government will "preserve important historic, cultural, and natural aspects of our national heritage." It directs that all practicable means be used to improve federal functions so that the nation may "...attain the widest range of beneficial uses of the environment without degradation, risk to health or safety, or other undesirable and unintended consequences..." Specifically, NEPA requires that an environmental impact statement (EIS) be prepared for major actions by federal government agencies. The primary purpose of an EIS is to evaluate the environmental impacts of proposed projects and facilitate public review. An environmental assessment may be prepared to determine if an EIS is required. An environmental assessment is not required as part of the Wetlands Regional Monitoring Program (WRMP) because the plan provides a general management direction for the Recreation Area. Specific actions recommended in this WRMP may be implemented depending on funding and staff availability. Compliance with NEPA will be completed when specific actions are likely to be initiated.
General Authorities Act of 1970	The General Authorities Act reinforces the National Park Service Organic Act by uniting all areas administered by the National Park Service into one National Park System. This was done in recognition of the growing variety of National Park Service units (e.g., national recreation areas, national seashores). The act assures a common preservation purpose for all units, regardless of title or designation. Hence, the fundamental duty of Recreation Area managers is to protect park resources, unless specifically exempted by Congress. Managers of all National Park Service units are accountable to the National Park Service Organic Act, related legislation and to National Park Service policies and guidelines.
Environmental Quality Improvement Act of 1970 (42 U.S.C. 56 § 4371)	Directs all Federal agencies, whose activities may affect the environment, to implement policies established under existing law to protect the environment.
Federal Water Pollution Control Act of 1972 (Clean Water Act)	This Act protects the biological, chemical, and physical nature of the Nation's waters through the elimination of pollutants and the creation of wastewater treatment plants. *"It is the policy of the Congress to recognize, preserve, and protect the primary responsibilities and rights of States to prevent, reduce, and eliminate pollution, to plan the development and use (including restoration, preservation, and enhancement) of land and water resources…"*

Legislation	Summary Content
Marine Protection, Research, and Sanctuaries Act of 1972 (16 U.S.C. 32 § 1431)	Recognizes that the United States has historically protected "Special areas of its public domain, but (that) these efforts have been directed almost exclusively to land areas above the high-water mark." For this reason congress elected to recognize and protect "Certain areas of the marine environment possess(ing) conservation, recreational, ecological, historical, scientific, educational, cultural, archeological, or esthetic qualities which give them special national, and in some cases international, significance." Specifically this law intends to "improve the conservation, understanding, management, and wise and sustainable use of marine resources; (to) enhance public awareness, understanding, and appreciation of the marine environment; and (to) maintain for future generations the habitat, and ecological services, of the natural assemblage of living resources that inhabit these areas."
Coastal Zone Management Act of 1972 (16 U.S.C. 33 § 1452)	"Congress finds and declares that it is the national policy - to preserve, protect, develop, and where possible, to restore or enhance, the resources of the Nation's coastal zone for this and succeeding generations."
Federal Advisory Committee Act of 1972 (FACA) (Public Law 92-463, 5 U.S.C.)	Creates a formal process for federal agencies to seek advice and assistance from citizens. Any council, panel, conference, task force or similar group used by federal officials to obtain consensus advice or recommendations on issues or policies which fall under the purview of FACA.
Endangered Species Act of 1973	The Endangered Species Act was enacted in 1973 and amended in 1978, 1982 and 1988. It provides for the conservation, protection, restoration, propagation and recovery of species of native fish and wildlife (including plants) that are listed as being threatened with extinction. All entities using federal funding must consult with the Secretary of the Interior (through authority delegated to the US Fish and Wildlife Service) on activities that potentially affect endangered or threatened flora and fauna.
Migratory Bird Treaty Act of 1974 *16 U.S.C. §703-711*	On January 10, 2001, the President signed Executive Order 13186, directing Federal agencies to minimize their negative impacts on migratory birds, to enter into an MOU with the U.S. Fish and Wildlife Service, and to carry out certain actions to further the implementation of the Migratory Bird Treaty Act. In addition, the Executive Order calls on Federal agencies to take reasonable steps that include restoring and enhancing habitat, incorporating migratory bird conservation into planning processes, promoting research and information exchange, providing training and visitor education, and developing partnerships beyond agency boundaries. The Migratory Bird Treaty Act (MBTA), signed in 1918 and amended in 1936, 1974 and 1989, is the domestic law that implements the United States' commitment to four international conventions (with Canada, Mexico, Japan and Russia) for the protection of migratory birds. The species protected by the MBTA are listed at 50 CFR § 10.13. In 2000, a Federal Court ruled that Federal agencies, like private citizens, are subject to MBTA regulations regarding take of migratory birds. An MOU between the National Park Service and the U.S. Fish and Wildlife Service is currently being drafted to address this issue, as required by the Executive Order.
Forest and Rangeland Renewable Resources Planning Act of 1974 (16 U.S.C. 36 § 1642	Mandates that the Secretary of Agriculture inventory and monitor renewable natural resources in National Forests, and has been cited as congressional authorization for the inventory and monitoring of natural resources on all federal lands. While this is not specifically directed in the act it is perhaps indicative of a national will to account for and manage the nations natural heritage in manner that sustains these resources in perpetuity.
Safe Drinking Water Act of 1974	The Safe Drinking Water Act was enacted in 1974 and amended in 1986. This act, implemented by the states, sets national minimum drinking water quality standards and requires regular testing of public drinking water supplies. The National Park Service must comply with state regulations regarding the construction, operation, and monitoring of its public water supplies.
Surface Mining Control and Reclamation Act of 1977	The Surface Mining Control and Reclamation Act establishes a nationwide program to protect the environment from adverse effects of surface coal mining operations, establishes minimum national standards for regulating surface coal mining, assists states in developing and implementing regulatory programs, and promotes reclamation of previously mined areas with inadequate reclamation. Under the Act, the Secretary of the Interior is directed to regulate the conduct of surface coal mining throughout the United States for both federally and non-federally owned rights. The Act establishes the Abandoned Mine Reclamation Fund, which is for the reclamation of land and water affected by coal mining. Eligibility for reclamation under this program requires that the land or water had been mined for coal, or affected by coal mining, and had been inadequately reclaimed prior to the enactment of this act in 1977. Both public and private lands are eligible for funding. Sections 522(e)(1) and 533(e)(3) of the act specifically prohibit surface mining within the National Park Service, National Wildlife Refuge System, National System of Trails, National Wilderness Preservation System, or Wild and Scenic Rivers System. The act also prohibits surface mining that adversely impacts any publicly-owned park or place included in the National Register of Historic Sites. These prohibitions are subject to valid existing rights at the time of the Act, the exact definition of which remains the subject of administrative and legal action. How valid existing rights are ultimately defined will affect the ability of mineral owners to mine in the Recreation Area.

Legislation	Summary Content
Redwood National Park Act of 1978	The Redwood National Park Act amends the General Authorities Act of 1970, and reasserts the system-wide standard of protection prescribed in the original Organic Act. This Act strengthens the Secretary of the Interior's ability to protect park resources, yet qualifies that park protection will "not be exercised in derogation of the values and purposes for which these various areas have been established." Thus, specific provisions in a park's enabling legislation allow park managers to permit certain activities, such as hunting or grazing.
Clean Air Act of 1990 *42 U.S.C. Sec. 7401(c).*	The Clean Air Act provides a legal framework for the National Park Service to preserve and protect parks' air quality related values (AQRVs) from pollution sources emanating from within and outside park boundaries. Because of a perceived need for national and regional air quality research to support state programs, Congress passed its first federal air quality initiative in 1955. In response to increasing harm to public health and welfare and to inadequate controls and enforcement, Congress has slowly but steadily expanded and refined the law, now known as the Clean Air Act, to cover more types of pollutants and emitters; i.e., stationary and mobile sources of pollution. These efforts have culminated in the 1990 amendments to the Clean Air Act, which represent the most comprehensive and detailed set of measures to date to both prevent and curtail air pollution. The declaration of purpose as revised in 1990 states, "A primary goal of this Act is to encourage or otherwise promote reasonable Federal, State, and local government actions, consistent with the provisions of the Act, for pollution prevention."
Government Performance and Results Act of 1993	Passed in 1993, GPRA establishes a performance management system to set goals and track accomplishments within Federal Agencies. In accordance, Park Service-wide strategic plans, annual performance plans, and annual performance reports are prepared and analyzed for management accountability. The strategic plans, developed and updated at all organizational levels, drive budgeting and resource allocation decisions. The superintendent of each park, as well as other program managers, is required to prepare a 5-year strategic plan, an annual performance plan and an annual performance report. The strategic plan and annual performance plan reflect NPS policies and goals stated in the Service-wide Strategic Plan. Annual performance reports for parks and programs show accomplishments or results toward stated goals to evaluate organizational and individual performance. NPS GPRA goals must be consistent with National Park Service Management Policies (2001).
National Parks Omnibus Management Act of 1998	The Omnibus Act is the precursor to the Natural Resource Challenge, the prime directive guiding the NPS I&M Program. The goal of the act is to use state-of-the-art methods of scientific research to improve management decisions within the NPS. This act also made the superintendents of each park unit responsible for the care and condition of the resources within the parks. "The Secretary shall undertake a program of inventory and monitoring of National Park System resources to establish baseline information and to provide information on the long-term trends in the condition of the National Park System." In addition, the act created the Natural Resources Challenge, which provides the funding for the I&M Program and doubles the natural resources staff within the NPS. "The Committee applauds the Service for recognizing that the preservation of the diverse natural elements and the great scenic beauty of America's national parks and other units should be as high a priority in the Service as providing visitor services. A major part of protecting those resources is knowing what they are, where they are, how they interact with their environment and what condition they are in. This involves a serious commitment from the leadership of the National Park Service to insist that the superintendents carry out a systematic, consistent, professional inventory and monitoring program, along with other scientific activities, that is regularly updated to ensure that the Service makes sound resource decisions based on sound scientific data."

Appendix C (continued): Executive Orders

Executive Order	Summary Content
Exotic Organisms *E.O. 11987*	This Order states that government agencies will restrict the introduction of exotic species into natural areas. *"Executive agencies shall, to the extent permitted by law, restrict the introduction of exotic species into the natural ecosystems on lands and waters which they own, lease, or hold for purposes of administration; and, shall encourage the States, local governments, and private citizens to prevent the introduction of exotic species into natural ecosystems of the United States."*
Floodplain Management *E.O. 11988*	Requires all federal agencies to *"reduce the risk of flood loss,... minimize the impacts of floods on human safety, health and welfare, and ... restore and preserve the natural and beneficial values served by flood plains."* To the extent possible, park facilities, such as campgrounds and rest areas, should be located outside floodplain areas. Executive Order 11988 is implemented in the National Park Service through the *Floodplain Management Guidelines*. It is the policy of the National Park Service to 1) restore and preserve natural floodplain values; 2) to the extent possible, avoid environmental impacts to the floodplain by discouraging floodplain development; 3) minimize the risks to life and property when structures and facilities must be located on a floodplain; and, 4) encourage nonstructural over structural methods of flood hazard mitigation.
Off-Road Vehicle Use *E.O. 11989*	If the enabling legislation allows the use of off-road vehicles, NPS is required to designate specific areas for off-road vehicle use. These areas must be *"located to minimize damage to soil, watershed, vegetation, or other resources"* (Section (3)(a)(1)). If it is determined that such use is adverse to resources, the NPS is to immediately close such areas or trails until the impacts have been corrected.
Protection of Wetlands *E.O. 11990*	Requires all federal agencies to *"minimize the destruction, loss, or degradation of wetlands, and preserve and enhance the natural and beneficial values of wetlands*." Unless no practical alternative exists, federal agencies must avoid any activities that have the potential to adversely affect wetland ecosystem integrity. NPS guidance pertaining to this Executive Order is stated in *Floodplain and Wetland Protection Guidelines*.
Federal Compliance with Pollution Control Standards *E.O. 12088*	Requires all federal agencies to prevent, control, and abate environmental pollution from federal facilities and activities and to comply with all applicable pollution control standards, including the Federal Water Pollution Control Act.
Coral Reef Protection *E.O. 13089*	To preserve and protect the biodiversity, health, heritage, and social and economic value of U.S. coral reef ecosystems and the marine environment by coral reef mapping and monitoring; research; conservation, mitigation, and restoration; and international cooperation.
Invasive Species Management *E.O. 13112*	The goal of the Invasive Species Management E.O. is to prevent the introduction of invasive species and provide for their control and to minimize the economic, ecological, and human health impacts that invasive species cause. Among other things, this Executive Order It established the National Invasive Species Council and required the preparation of a National Invasive Species Management Plan to recommend specific, performance-oriented goals and objectives and specific measures of success for Federal agency efforts concerning invasive species.
Protection of Migratory Birds *E.O. 13186*	This Order provides additional protection for migratory birds, such that Federal agencies should "design migratory bird habitat and population conservation principles, measures, and practices, into agency plans and planning processes (natural resource, land management, and environmental quality planning, including, but not limited to, forest and rangeland planning, coastal management planning, watershed planning, etc.) as practicable, and coordinate with other agencies and nonfederal partners in planning efforts."

Appendix C (continued): NPS Polices and Guidance

NPS Policy/Guidance	Summary Content
NPS Management Policies 2001 (NPS Directives System)	This is the basic NPS service-wide policy document. It is the highest of three levels of guidance documents in the NPS Directives System. The Directives System is designed to provide NPS management and status. with clear and continuously updated information on NPS policy and required and/or recommended actions, as well as any other information that will help them manage parks and programs effectively.
NPS Directors Orders	Second level of NPS Directives System. Directors Orders serve as a vehicle to clarify or supplement Management Policies to meet the needs of NPS managers. Relevant Directors Orders: DO-2.1 Resource Management Planning, DO-12 Environmental Impact Assessment, DO-14 Resource Damage Assessment & Restoration, DO-24 Museum Collections Management, DO-41 Wilderness Preservation & Management, DO-47 Sound Preservation & Noise Management, DO-77 Natural Resource Protection.
NPS Handbooks and Reference Manuals	This is the third tier in the NPS Directives System. These documents are issued by Associate Directors. These documents provide NPS field employees with a compilation of legal references, operating policies, standards, procedures, general information, recommendations and examples to assist them in carrying out Management Policies and Director's Orders. Level 3 documents may not impose any new service-wide requirements, unless the Director has specifically authorized them to do so. Relevant Handbooks and Reference Manuals: NPS-75 Natural Resources Inventory & Monitoring, NPS-77 Natural Resources Management Guidelines, NPS Guide to Federal Advisory Committee Act Website: Monitoring Natural Resources in our National Parks, http://science.nature.nps.gov/im/.

Appendix C (continued): Enabling Legislation

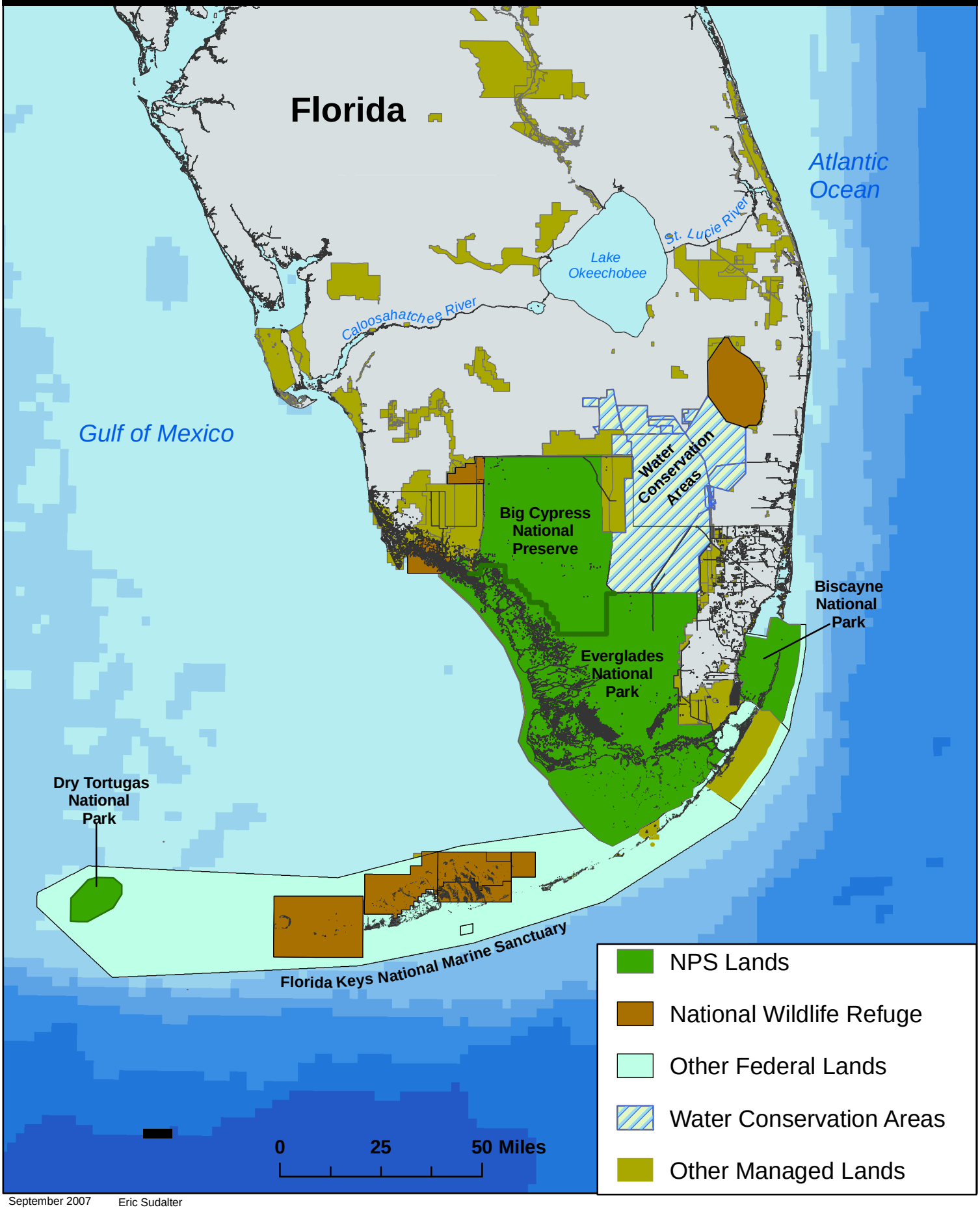
Park	Summary Content
Big Cypress National Preserve	*Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,* That in order to assure the preservation, conservation, and protection of the natural, scenic, hydrologic, floral and faunal, and recreational values of the Big Cypress Watershed in the State of Florida and to provide for the enhancement and public enjoyment thereof, the Big Cypress National Preserve is hereby established.
Biscayne National Park	In order to preserve and protect for the education, inspiration, recreation, and enjoyment of present and future generations a rare combination of terrestrial, marine, and amphibious life in a tropical setting of great natural beauty, there is hereby established the Biscayne National Park in the State of Florida.
Buck Island Reef National Monument	WHEREAS Buck Island and Its adjoining shoals, rocks, and undersea coral reef formations possess one of the finest marine gardens In the Caribbean Sea; and WHEREAS these lands and their related features are of great scientific interest and educational value to students of the sea and to the public; and WHEREAS this unique natural area and the rare marine life which are dependent upon it are subject to constant threat of commercial exploitation and destruction; and WHEREAS the Advisory Board on National Parks, Historic Sites, Buildings and Monuments, established pursuant to the act of August 21, 1935, 49 Stat. see (15 U.S-C- 4g3). Impressed by the caliber and scientific importance of the coral reefs of Buck Island, had urged their prompt protection to prevent further despoliation.
Dry Tortugas National Park	In order to preserve and protect for the education, inspiration, and enjoyment of present and future generations nationally significant natural, historic, scenic, marine, and scientific values in South Florida, there is hereby established the Dry Tortugas National Park.
Everglades National Park	When title to all the lands within boundaries to be determined by the Secretary of the Interior within the area of approximately two thousand square miles in the region of the Everglades of Dade, Monroe, and Collier Counties, in the State of Florida, recommended by said Secretary, in his report to Congress of December 3, 1930, pursuant to the Act of March 1, 1929 (45 Stat. 1443), shall have been vested in the United States, said lands shall be, and are, established, dedicated, and set apart as a public park for the benefit and enjoyment of the people and shall be known as the Everglades National Park
Salt River Bay National Historical Park and Ecological Preserve	In order to preserve, protect, and interpret for the benefit of present and future generations certain nationally significant historical, cultural, and natural sites and resources in the Virgin Islands, there is established the Salt River Bay National Historical Park and Ecological Preserve at St. Croix, Virgin Islands.
Virgin Islands National Park	A portion of the Virgin Islands of the United States, containing outstanding scenic and other features of national significance, shall be established, as prescribed in section 398a of this title, as the ''Virgin Islands National Park''.

APPENDIX D

REGIONAL MAPS

South Florida Managed Lands

National Park Service
U.S. Department of the Interior



September 2007 Eric Sudalter

St. John Managed Lands

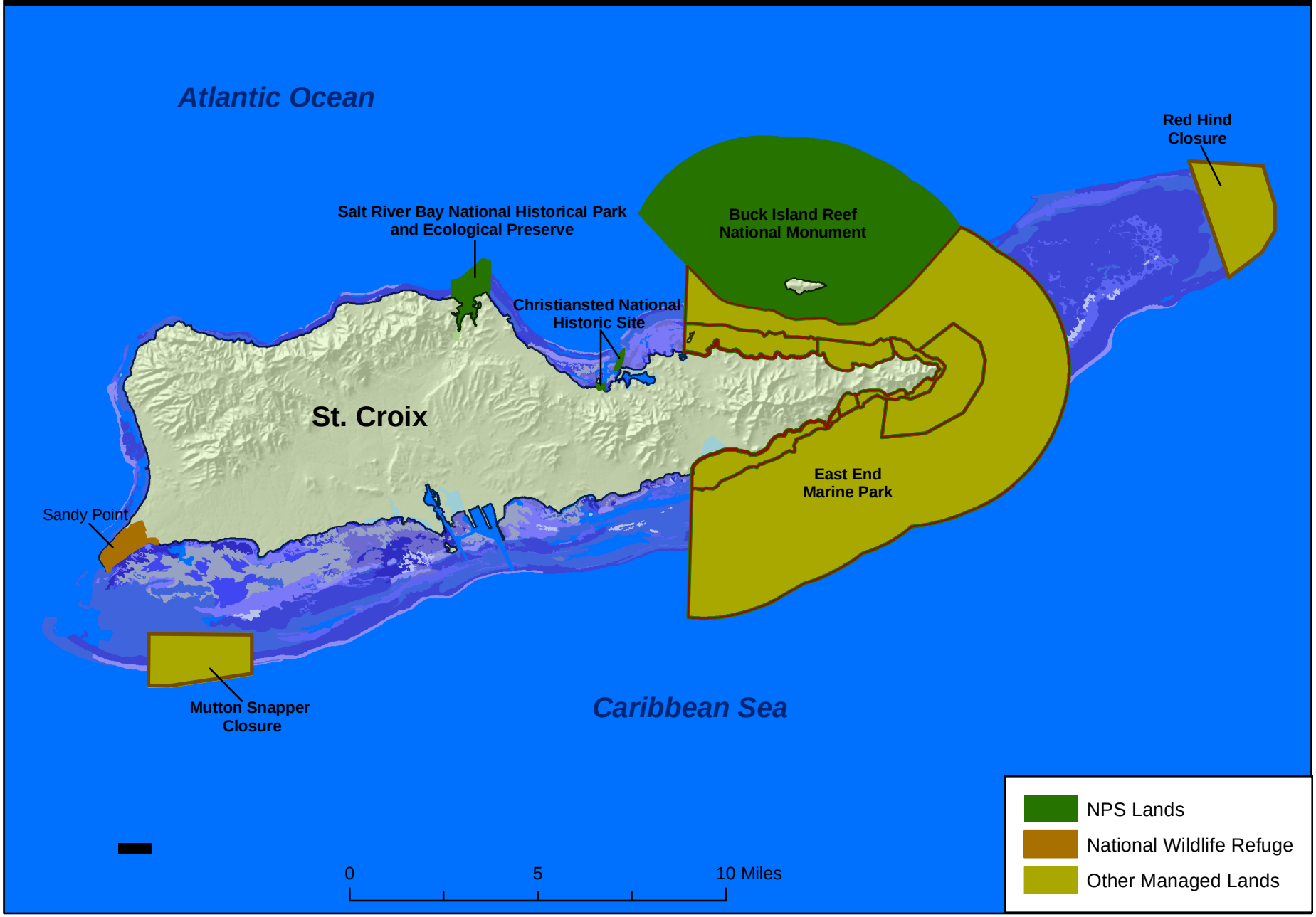
National Park Service
U.S. Department of the Interior



September 2007 Eric Sudalter

St. Croix Managed Lands

National Park Service
U.S. Department of the Interior



September 2007 Eric Sudalter

APPENDIX E

GEOLOGIC RESOURCE MANAGEMENT ISSUES SCOPING SUMMARIES

E.1 Big Cypress National Preserve
E.2 Biscayne National Park
E.3 Buck Island Reef National Monument
E.4 Dry Tortugas National Park
E.5 Everglades National Park
E.6 Salt River Bay National Historic Park and Ecological Preserve
E.7 Virgin Islands National Park and Coral Reef National Monument

APPENDIX E.1

BIG CYPRESS NATIONAL PRESERVE

GEOLOGIC RESOURCE MANAGEMENT ISSUES SCOPING SUMMARY

Trista L. Thornberry-Ehrlich
Colorado State University – Geologic Resource Evaluation
February 13, 2005



Near Sweetwater Strand in Big Cypress National Preserve. Photograph by Trista L. Thornberry-Ehrlich (Colorado State University).

Executive Summary

Followed by a field trip on January 28, 2005, a Geologic Resources Evaluation scoping meeting took place at the preserve headquarters on January 27, 2005. The scoping meeting participants identified the following list of geologic resource management issues.

1. The hydrogeologic system at Big Cypress is a western extension of the Everglades. Surface water flows over the low relief landscape through sloughs and marshes. This flow has been altered by roads, canals, and levees at the preserve.

2. Geologic and topographic mapping when combined with flow patterns would help resource management determine which areas to focus on for restoration.

3. Soils and bedrock depth surveys and measurements are needed at the preserve. This, in addition to soil recovery research, would help resource management deal with ORV damage remediation.

4. Disturbed lands at the preserve include borrow pits and canals dug during the construction of roads and pads for oil and gas drilling. These features disrupt the flow of water and need to be remediated.

5. ORV management is an ongoing process at the park. Implementation of the 2001 ORV Plan is a major management goal. The preserve is trying to designate 644 km (400 miles) of trails to lessen ORV environmental impact.

6. Oil and gas issues include regulating the eight producing wells located within the preserve. Land/mineral ownership rights differ between the surface and subsurface and responsibility for clean-up and remediation is often mislaid.

Introduction

The National Park Service held a Geologic Resource Evaluation scoping meeting for Big Cypress National Preserve at the park headquarters near Everglades City, Florida on Thursday, January 27, 2005. Following this meeting was a field trip on January 28, 2005. The purpose of the meeting was to discuss the status of geologic mapping in the preserve, the associated bibliography, and the geologic issues in the preserve. The products to be derived from the scoping meeting are: (1) Digitized geologic maps covering the preserve; (2) An updated and verified bibliography; (3) Scoping summary (this report); and (4) A Geologic Resource Evaluation Report which brings together all of these products.

Big Cypress National Preserve was established during Gerald Ford's administration on October 11, 1974. Big Cypress covers 720,567 acres of the southwestern corner of Florida. Big Cypress National Preserve was the first national preserve incorporated into the National Park Service. This preserve features incredible biodiversity. The environments protected at the preserve range from sawgrass prairies, mangrove forests, cypress stands and domes, hardwood tree islands, to slow flowing sloughs and marshes. The area covers a large portion of the "western Everglades". The preserve is heavily recreated and contains some of the most productive oil and gas fields in south Florida.

Big Cypress National Preserve identified 37 quadrangles of interest. However, additional coverage of 30 more quadrangles (to the north and west) would add considerably to resource management's understanding of the landscape and watershed at the preserve. The Florida State Geologic Survey (FGS) has digitized a geologic map covering the state from individual county maps at a small scale (~ 1:750,000). This map only displays 5 separate geologic units (Holocene sediments, Pleistocene - Holocene undifferentiated, Miami Limestone, Shell-bearing sediments, Tamiami Formation) for inside the boundaries of the park.

Other geologic maps covering portions of the quadrangles of interest include the FGS MS6/19, MS 6/20, MS 6/21, MS 6/22, MS 6/24, and MS 6/25 (1:24,000, 2000), Geological Society of America (GSA) Memoir 147 (1:79,000, 1977), the FGS OFMS 67 (1:26,720, Dade County), 66/01 (1:126,720, Monroe County), 62 (1:126,720 , Hendry County), 63 and Series 120 (1:126,720, Collier County), 64 (1:126,720, Broward County), 65 (1:126,720, Palm Beach County), USGS 84-4068 and 86-4126 (1:134,000 and 1:136,000, 1985 and 1986, respectively). Additional mapping at a smaller scale will be more helpful for preserve management.

Physiography

South Florida in the area of the Big Cypress is divided into 5 physiographic provinces. The Big Cypress Swamp province defines the western boundary of the Everglades. This area is slightly higher in elevation than the Everglades basin because it is underlain primarily by the coral-rich limestones of the Pliocene Tamiami Formation (3-4 Mya). This formation is exposed in large areas of Big Cypress. Drainage in the province is primarily to the south and southwest.

The Everglades province forms a south dipping, spoon-shaped low-lying area between the Atlantic Coastal Ridge to the east, the Big Cypress Swamp to the west, and the Sandy Flatlands area to the north. The basin has very low relief. The elevation change is only 3.6 to 4.3 m (12-14 ft) from the maximum near Lake Okeechobee to sea level. Prior to anthropogenic alteration, this drainage system flowed slowly from north to south.

Bounding the Everglades province on the east is the Atlantic Coastal Ridge. It is comprised of Pleistocene marine limestones covered by thin quartz sand sheets. The province ranges in elevation from 1.5 to 6 m (5 to 20 ft) in the southernmost portions. The width of the ridge ranges from 16 km (10 miles) in southern Miami-Dade County and narrows to 5 to 8 km (3 – 5 miles) further north. Periodically breaching the southern portions of the ridge are sloughs (transverse glades) oriented perpendicular to the trend of the ridge.

The southern reaches of the Everglades and Big Cypress Swamp provinces transition into the Coastal Marshes and Mangrove Swamp physiographic province. The province covers an area from the northeastern part of Florida Bay, around the southern Florida peninsula, and west, into the Gulf of Mexico up to the Ten Thousand Island region never Everglades City. Bands of swamps and brackish marshes sitting just above sea level characterize this province. Freshwater runoff and tidal fluxes cause the salinity to change dramatically. This is why the mangrove, capable of enduring such salinity changes, thrives in this area.

Geologic History of South Florida

Sediment cores indicate that South Florida has been predominantly an area of carbonate accumulation since the Mesozoic.

Late Paleozoic Era – During the Mississippian, the landmass that would underlie the grand carbonate platform of Florida today was not attached to the North American Craton. It is speculated that it was attached to the northwest portion of the African continent (Condie and Sloan, 1998). However, marine carbonates were being deposited over large portions of the area atop a Paleozoic age crystalline basement high, the Peninsular Arch (Pollastro *et al.,* 2000). In the Pennsylvanian, a collision event, known as the Ouachita orogeny sutured the Florida landmass to the continent as Gondwanaland and North America collided eventually forming the supercontinent Pangaea. The land was still submerged and south Florida was located at the junction of the North American, South American, and African plates. Through the Permian, Pangaea remained intact (Condie and Sloan, 1998).

Early Mesozoic Era – No sooner had Pangaea formed than it began to break up. During the late Triassic, South and Central America and Africa began to rift away from North America. This established the long-standing passive margin of the eastern seaboard that persists today. The Florida and Cuba blocks detached from northwest Africa and the Gulf of Mexico opened (Condie and Sloan, 1998).

Accompanying the rifting of Pangaea was the widespread extrusion of volcanic rocks consistent with mantle plume upwelling due to crustal tension (Heatherington and Mueller, 1991). This continental rifting also opened the Atlantic Ocean basin.

Middle Mesozoic Era - Underlying the south Florida basin are igneous rhyolitic - basaltic rocks (Thomas *et al.,* 1989). These rocks were subaerially exposed and eroded during the late Triassic to middle Jurassic. This caused the formation of redbeds locally. As the Atlantic Ocean continued to develop, deltaic and shallow marine sediments were deposited in the late Jurassic. Restriction of marine circulation at this time resulted in periodic accumulations of evaporites and marine carbonates (Cunningham, 2005). Deposition of Jurassic and Cretaceous sediments was controlled by the south-southeast plunging axis of the Peninsular Arch. Basal sediments onlap and pinch out against the arch (Pollastro *et al.,* 2000).

Late Mesozoic Era – As marine transgression proceeded during the early Cretaceous, the Florida Platform was the site of more widespread deposition of marine limestones and reefs. Further transgression and global warming during the Late Cretaceous established an open marine accumulation of carbonates over the entire Florida Peninsula.

Cenozoic Era – Cenozoic development of the Florida Platform included additional deposition of marine carbonates and deposition of siliciclastics (grains of silicate minerals such as quartz in lieu of carbonates) from northwestern highlands sources and long shore oceanic currents. Tertiary faulting occurred south of Florida as the Cuban block collided with the Antilles arc and carbonate accumulation continued in Florida (Condie and Sloan, 1998). In southern Florida, the open marine setting continued during the Paleocene as more restricted flow to the north resulted in deposits of mixed carbonates and evaporites. Eocene and Oligocene deposition is marked by shallow water carbonates. Intermittent with this deposition were subaerial exposures associated with local oceanic regressions.

Deposition in south Florida during the Miocene changed with the introduction of more widespread siliciclastics from a fluvio-deltaic system prograding down the peninsula. Phosphates and the carbonate ramp of the Arcadia Formation were deposited during the Miocene in south Florida. A Pliocene lowstand caused many of the previous deposits to be reworked and/or eroded. The Tamiami Formation is a Pliocene marine unit comprising a wide range of rock types. These are predominantly fossiliferous sands and clays with limestone.

The Pleistocene era resulted in the conversion from siliciclastic deposition mixed with carbonate accumulation to more widespread carbonate sedimentation (Cunningham, 2005). Global sea-level changes during the intermittent ice ages of the Pleistocene controlled the rate and distribution of carbonate units. At 120 Ka, the last major sea level fall occurred as the mixed carbonate-siliciclastic sediments formed the Fort Thompson Formation. This unit interfingers with the surficial geologic units, the Miami and Key Largo Limestones, and the Anastasia Formation (~130 Ka) (Cunningham, 2005).

At 15-16 Ka sea levels began to rise rapidly and flood southern Florida around 7 or 6 Ka (Shinn *et al.,* 1997). Sea level has continued to rise. Holocene geologic activity in the Big Cypress area consists of the dissolution of carbonate units, the accumulation of carbonate muds, freshwater marls, sand and swamp (organic peat and muck) deposits.

Stratigraphy

Cores drilled in the oil and gas exploration operations help constrain the stratigraphy underlying the preserve. In the oil producing area of Big Cypress, the sedimentary section is 4,572 to 5,182 m (15,000 – 17,000 ft) thick. The first 2,134 to 2,743 m (7,000 – 9,000 ft) are Late Jurassic through Early Cretaceous rocks, the next 914 m (3,000 ft) are Late Cretaceous age rocks, and the remaining 1,676 m (5,500 ft) are of Tertiary age to the present (Pollastro *et al.,* 2000). These rocks fill the South Florida Basin, the center of which is located northwest of the Florida Keys. The basin is bounded on the east by the Paleozoic Peninsular Arch (trending northwest – southeast), the Florida escarpment to the west, the Tampa – Sarasota Arch (trending northeast – southwest) to the north, and the Pine Key arch to the south.

Jurassic age basaltic-rhyolitic rocks underlie all of south Florida. Since the Jurassic, sedimentation has kept pace with overall basin subsidence. Deposition has included carbonates, clastics and evaporites (Pollastro *et al.,* 2000). The earliest sediments, of the Wood River Formation are continental clastics overlain by salt, limestone, anhydrite and brown dolomite. Between the Wood River and the oil producing Sunniland Formation lie the predominantly carbonate-evaporite Bone Island and Pumpkin Bay Formations, and the Glades Group of shales, dolomites, and anhydrites (Faulkner and Applegate, 1986). The Sunniland Formation of Lower Cretaceous age is comprised of anhydrites, thin limestone layers, and dolomites. The Sunniland, along with the anhydrite and limestone of the Lake Trafford Formation and the dolomite, limestone and anhydrite of the Rattlesnake Hammock Formation, comprise the Ocean Reef Group.

The Big Cypress Group and Naples Bay Group overlie the Ocean Reef Group. These are largely dolomites and anhydrites beneath Big Cypress. The Upper Cretaceous Pine Key Formation is composed of chalky limestone and dolomite. It is approximately 914 m (3,000 ft) thick. The Paleocene to present day sedimentary layers lie atop the Pine Key Formation at Big Cypress (Faulkner and Applegate, 1986). Relatively uninterrupted Tertiary deposition amassed the grand carbonate platform of South Florida. These sediments reach great thicknesses of approximately 1,676 m (5,500 ft).

Cores drilled in nearby Everglades National Park help determine the upper stratigraphy at Big Cypress. Eocene to late Oligocene deposition consists of marine carbonates of the Avon Park Formation, the Suwannee Limestone and the Ocala Group, and the Arcadia Formation of ramp setting carbonates with scant quartz contents increasing northward (Cunningham, 2005). A major disconformity marks the boundary between the Arcadia Formation and the overlying Peace River Formation. In other areas of Florida, the Hawthorn Group is between the Arcadia and Peace River Formations. The Peace River Formation contains two distinct units: a lower diatomaceous mudstone, and an upper fine-grained quartz muddy sandstone (Cunningham *et al.,* 1998). Deposited atop the Peace River Formation is the Tertiary age Tamiami Formation. This unit comprises much of the surface outcrop at Big Cypress.

Shallow water limestone of the Fort Thompson Formation underlies the surficial Miami Limestone. This limestone is probably combined with the capping unit of the Miami Limestone. The Fort Thompson is mostly lagoonal facies carbonate with abundant bivalve fossils and some quartz sand. The Miami Limestone is ~125 – 130 Ka and represented deposition during an interglacial period. Two facies exist for the Miami Limestone. The western portion of the unit contains predominantly

the bryozoan facies, the unit then becomes more oolitic eastward (Hoffmeister *et al.,* 1974; Cunningham, 2005).

Overlying the Miami Limestone bedrock are surficial units of freshwater peat and organic muck, freshwater marls, and cyanobacteria mats in the swampy marsh at Big Cypress. The peat and muck typically occurs in low-lying sloughs and solution holes and are dark and fine-grained. During the standing water phase of the wet season, extracellular precipitation of calcium carbonate by cyanobacteria forms fresh limestone marls (Cunningham, 2005).

Significant Geologic Resource Management Issues at Big Cypress National Preserve

1. Hydrogeologic system at Big Cypress

The Big Cypress is really a western extension on the Everglades system. Water is flowing on the surface in marshes and sloughs and below ground in slow flowing aquifers through porous substrate. The present topographic and hydrogeologic information is too coarse and/or inadequate for resource management. More modeling is necessary to understand the true water budget of the preserve.

The flow of water through the preserve has been drastically altered and diverted by the construction of roads, trails, pads, canals, and levees. The state and local pumping policies control a vast portion of water input to Big Cypress. Pumping can control basin dynamics. A major goal of the preserve is the restoration of the original flow ways as best as possible. A focus area is the 9 to 12 m (30 – 40 ft) wide Turner River basin in-channel construction near U.S. Highway 41. Restoration efforts include reconnection flows through canals and roads (building causeways). The Bear Island area is another area to focus restoration efforts. Cooperation is necessary between resource management and local water volume management agencies to coordinate and organize the timing responses of gates and pumps.

Regional models achieve varying degrees of success at Big Cypress. The South Florida Water Management Model (SFWMM) ignores roads and uses an outdated climate. The Natural Systems Model (NSM) uses vegetation patterns to predict an improved pseudotopography. The Across Trophic-Level System Simulation (ATLSS) correlates species with hydrology, hydroperiod, and vegetation. The Everglades Landscape Model (ELM) covers the hydrology of bounded systems of canals and structural control with rain-driven triggers. The Interim Structural and Operational Model (ISOP), which is 2-3 years from implementation, is probably the closest to the concerted water budget management the preserve needs, but still uses core data from the SFWMM model. Cell size and vertical precision vary on these models from 3.2 km (2 miles) to 30 m (100 ft) and 15 to 3 cm (6 to 1 inches), respectively. LIDAR would improve the vertical precision.

Research and monitoring questions and suggestions include: Study how rainfall controls the hydrologic system. Does the depth to bedrock measurement have a significant control on the system? Compare natural and anthropogenic caused hydraulic changes. Monitor hydrologic response to storm events. Try to get LIDAR mapping of sloughs for fine-scale topographic changes. Obtain more hydrologic sampling and install hydrologic monitoring stations in key locations. Determine more stage level measurement points. Monitor stage level. Attempt to align with CERP efforts (Big Cypress is largely overlooked in favor of Everglades restoration). Cooperate with federal, state, and local agencies to monitor and clean up ground and surface water; examples of pollution include creosote (from Copeland sawmill in the 1960s), agricultural runoff (including pesticides from tomato farms). Deep Lake (27 m 90 ft deep) is the southernmost sinkhole in Florida, why? Focus geologic studies on processes rather than just features. Categorize, describe, and model the near-surface, mid- and deep aquifers below Big Cypress National Preserve.

2. Geologic and topographic mapping

The relief at Big Cypress is approximately 6 cm/km (2 inches/mile) or 4.6 m over 145 km (15 ft over 90 miles). This incredibly low relief is the reason the sloughs, swamps, and marshes thrive at Big

Cypress. Water slowly trickles down to the sea from central Florida. High-resolution topographic mapping, when combined with flow patterns would help resource management determine which areas to focus on for restoration.

Research and monitoring questions and suggestions include: Relate small-scale topographic differences with the locations of hammacks and pinelands at the preserve. Map the locations where the Tamiami Limestone is exposed. Focus topography and cross section production on key areas (coordinate with the original flow way restoration efforts). Map karst features in addition to canals and rock pits on maps. Cooperate with slough mapping project through the Audubon Society. Expand upon the Tamiami type section located within the preserve. Are strands and paleochannels related? Why is the boundary between Big Cypress and the Everglades so dramatic? What is the nature of the boundaries between strands? Map rock outcrops at different scales and determine if they have a controlling influence on the location of Cypress stands. Greg Desmond with the USGS is conducting a High-Accuracy Elevation Project with an Airborne Height Finger (AHF), which creates DEMs; support him to obtain better data. Determine original flow ways with DEMs. Suggest more USGS/BLM/NRCS/SFWMD/FLDOT cooperative geologic/mapping projects.

3. Soils and bedrock depth

Soils were identified as an ORV Plan ROD information need. A soil survey is needed at the park as well as research on recovery science. Several unique soil units, such as "deep muck" and "cypress strand" exist in the preserve and should be type localities.

Research and monitoring questions and suggestions: What is the depth of the soils at Big Cypress? Map soil types and depths. Study resiliency of soils. Research possible options to restore damaged soils. Research historical fire data and correlate with soil types. Relate near surface limestone (marine or freshwater) and/or peat with soil distributions.

4. Disturbed lands

Disturbed lands besides the oil and gas exploration affected areas, include borrow pits excavated for the construction of the oil and gas pads and roads built to access remote sites.

Research and monitoring questions and suggestions: Quantitatively identify disturbed sites and explore remediation to restore natural water flow. Remove Bear Islands closed oilfield roads. Work on finding ways to build bridges and reculvert established road areas to improve flow focusing on roads directly perpendicular to flow first.

5. ORV management

More than 409,262 visitors came to the preserve in 2003. These visitors enjoyed the incredible recreational opportunities at Big Cypress. Activities include camping, kayaking, hiking, bird watching, canoeing, hunting, ORV use, and airboat access. The preserve is attempting to concentrate visitor access to reduce environmental impact.

Raised roadbeds across south Florida have dammed the natural, low relief, slow moving sheet-flow from Lake Okeechobee to Florida Bay. ORV use at Big Cypress has caused major damage to the hydrology and soils. Soil resiliency at the preserve is not well understood. Buggies and other ORVs destroy algae (terraphytes) populations in the soils. The entire ecosystem is based on these

microorganisms that lie dormant in dry conditions. When they are churned up and buried, the landscape resembles a soil desert. An ORV management plan, completed in 2001, calls for a designation of 644 km (400 miles) of trails in the preserve. It is estimated that at least 22,000 miles of trails currently exist. For a park the size of the state of Rhode Island, the ranger on duty has difficulty patrolling the ORV activity. Unauthorized airboat use is also a resource management issue affecting water quality, noise levels, and soils.

Research and monitoring questions and suggestions include: Determine the best sites for a designated trails system. Perform a preserve-wide soils survey to establish baseline conditions for trail planning.

6. Oil and gas issues

Oil and gas exploration began in the Big Cypress area in 1923. Most of the active drilling was in the mid 1970's. The main producing geologic unit is the Sunniland Formation. Approximately 450 wells have been drilled along the northwest – southeast oriented Sunniland Trend. Oil and gas activity in the preserve is rapidly declining. As of September 2004, there are 18 wells producing from only eight fields. Eight of these producing wells are located within the preserve. The oil and gas reservoir rocks are porous (10-30% porosity). They are composed of carbonate grainstones and dolomites sealed by evaporites and/or nonporous carbonates. Based on 2D seismic surveys, gravity and magnetics data, the overall drilling success rate has been about 3% (Norby, 2005).

Most of the oil and gas rights under the preserve are of private ownership, established prior to the designation of the preserve. Ninety-nine percent of the land at the preserve is "split estate" meaning the surface and subsurface ownership is different. The pads and roads left behind when a well is closed leave a large scar on the landscape and affect the hydrologic system at Big Cypress. Roads are built of borrow pit material 1.2 m (4 ft) higher than the surrounding drainage. Culverts are thinly spaced and many are falling into rusty disrepair. The responsibility for monitoring, compliance with regulations, restoration and remediation is often unclear and pipes, wells, and structures are still at abandoned pads.

Research and monitoring questions and suggestions: Explore making a depth to bedrock measurement mandatory per shot hole for oil and gas exploration. Obtain seismic information per township on a grid pattern. Use road and pad fill for trail construction and other remediation work. Work with corers to obtain more stratigraphic data. Attempt to update the Minerals Management Plan to have stronger surficial protection regulations.

Scoping Meeting Participants

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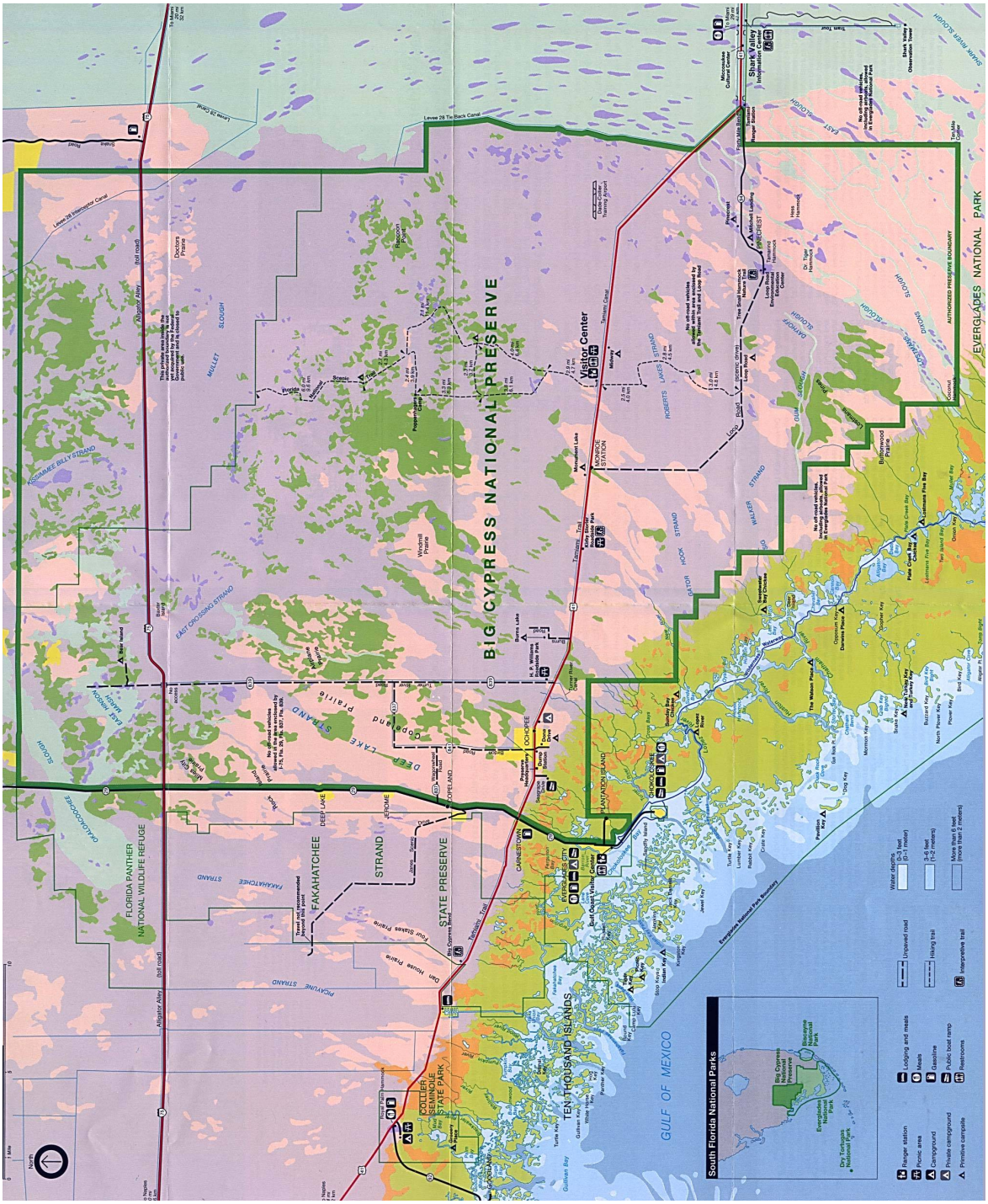
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Map of Big Cypress National Preserve



APPENDIX E.2

BISCAYNE NATIONAL PARK

GEOLOGIC RESOURCE MANAGEMENT ISSUES SCOPING SUMMARY

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Microkarst on Elliot Key's eastern shore, in Biscayne National Park. Photograph by Trista L. Thornberry-Ehrlich (Colorado State University).

Executive Summary

Following a field trip on January 25, 2005, a Geologic Resources Evaluation scoping meeting took place at the park headquarters on January 26, 2005. The scoping meeting participants identified the following list of geologic resource management issues. These topics are discussed in detail on pages 11 - 18.

1. Hydrogeologic system of Biscayne Bay
2. Benthic habitats at Biscayne National Park
3. Inundation history and paleoconditions
4. Sediment transport and erosion
5. Karst activity
6. Sea level rise
7. Disturbed lands
8. Active reefs and coral mapping
9. Recreation demands and resource restoration
10. Sediment thickness
11. Urban development concerns
12. Soil characterization
13. Paleontologic inventory

Introduction

The National Park Service held a Geologic Resource Evaluation scoping meeting for Biscayne National Park at the park headquarters near Homestead, Florida on Wednesday, January 26, 2005. This meeting followed a field trip on January 25, 2005. The purpose of the meeting was to discuss the status of geologic mapping in the park, the associated bibliography, and the geologic issues in the park. The products to be derived from the scoping meeting are: (1) Digitized geologic maps covering the park; (2) An updated and verified bibliography; (3) Scoping summary (this report); and (4) A Geologic Resource Evaluation Report which brings together all of these products.

Biscayne National Monument was established during Lyndon B. Johnson's administration on October 18, 1968. The boundaries were expanded in 1974 to include Swan and Gold Keys. On June 28, 1980, Biscayne was redesignated as a national park. Biscayne covers 172,924 acres along the southeastern Florida coast, 95% of which is underwater (72,000 acres of coral reefs). Biscayne National Park is the largest marine park in North America. The environments protected at the park vary from mangrove forest to the shallow waters of Biscayne Bay, from the northern most islands of the Florida Keys chain to the beginning of the third-largest coral reef tract in the world. The area covers a large portion of the Intercoastal Waterway, a large boating channel running along the Florida coast. The park contains some of the most pristine and unique marine habitat in the continental United States.

Biscayne National Park identified 19 quadrangles of interest. The Florida State Geologic Survey (FGS) has digitized a geologic map covering the state from individual county maps at a small scale (~ 1:750,000). This map only displays 3 separate geologic units (Holocene sediments, Key Largo Limestone, Miami Limestone) for inside the boundaries of the park.

Other geologic maps covering portions of the quadrangles of interest include the USGS I-2505 (1:24,000, 1997), the benthic habitat map published by NOAA CSC (1:48,000, 1999), Geological Society of America (GSA) Memoir 147 (1:79,000, 1977), the FGS OFMS 83/01-07 (1:100,000, 1995), 83/08-12 (1:100,000, 1996), USGS OF-97-526 (1:120,000, 1997),), FGS OFMS 83/08-12 (1:100,000, 1995), 67 (1:126,720, Dade County), 66/01 and 66/02 (1:126,720, Monroe County), USGS OF 97-526 (1:120,000, 1997) and 86-4126 (1:136,000, 1986). Additional mapping at a smaller scale will be more helpful for park management. For Biscayne National Park, where most of the park is underwater, mapping needs extend beyond the shoreline.

Physiography

South Florida in the area of the Biscayne is divided into 5 physiographic provinces. These are called the Atlantic Coastal Ridge, Coastal Marshes and Mangrove Swamp, Everglades, Big Cypress Swamp, and Sandy Flatlands provinces. The Everglades province forms the central south dipping, spoon-shaped low-lying area between the Atlantic Coastal Ridge to the east, the Big Cypress Swamp to the west, the Coastal Marshes and Mangrove Swamp to the south, and the Sandy Flatlands area to the north.

Part of Biscayne National Park lies within the Atlantic Coastal Ridge province. It is comprised of Pleistocene marine limestones covered by thin quartz sand sheets. The province ranges in elevation from 1.5 to 6 m (5 to 20 ft) in the southernmost portions. The width of the ridge ranges from 16 km (10 miles) in southern Miami-Dade County and narrows to 5 to 8 km (3 – 5 miles) further north. Periodically breaching the southern portions of the ridge are sloughs (transverse glades) oriented perpendicular to the trend of the ridge.

The rest of Biscayne National Park is composed of islands and marine/bay environments. The reefs of Biscayne National Park are part of a 241 km (150 miles) long chain of coral reefs extending roughly southwestward down through the lower Florida Keys and into the Caribbean. The Florida Keys are divided into three distinct sections: the upper. middle, and lower Keys. These divisions correspond to their orientation, morphology, water depth, and composition. The upper Keys (including Biscayne) are oriented almost north-south and buttress against the east-southeast winds. The middle Keys are oriented northeast-southwest and face directly into the east-southeast winds. The lower Keys are oriented nearly parallel to the winds and trend nearly east-west (Shinn *et al.,* 1997).

Elliot Key in Biscayne National Park is the parks largest island and is considered the northernmost true coral rock Florida Key. There are 42 islands in Biscayne National Park, which form a protective barrier for Biscayne Bay and south Florida. These islands display the transition from coral rock keys from the south to the sand barrier islands in the north. The islands north of Elliott Key, from Sands Key to Soldier Key, are examples of transitional islands. A transitional island contains features of both hard rock coral keys and sand barrier islands.

Geologic History of South Florida

Sediment cores indicate that South Florida has been predominantly an area of carbonate accumulation since the Mesozoic.

Late Paleozoic Era – During the Mississippian, the landmass that would underlie the grand carbonate platform of Florida today was not attached to the North American Craton. It is speculated that it was attached to the northwest portion of the African continent (Condie and Sloan, 1998). However, marine carbonates were being deposited over large portions of the area atop a Paleozoic age crystalline basement high, the Peninsular Arch (Pollastro *et al.,* 2000). In the Pennsylvanian, a collision event, known as the Ouachita orogeny sutured the Florida landmass to the continent as Gondwanaland and North America collided eventually forming the supercontinent Pangaea. The land was still submerged and south Florida was located at the junction of the North American, South American, and African plates. Through the Permian, Pangaea remained intact (Condie and Sloan, 1998).

Early Mesozoic Era – No sooner had Pangaea formed than it began to break up. During the late Triassic, South and Central America and Africa began to rift away from North America. This established the long-standing passive margin of the eastern seaboard that persists today. The Florida and Cuba blocks detached from northwest Africa and the Gulf of Mexico opened (Condie and Sloan, 1998).

Accompanying the rifting of Pangaea was the widespread extrusion of volcanic rocks consistent with mantle plume upwelling due to crustal tension (Heatherington and Mueller, 1991). This continental rifting also opened the Atlantic Ocean basin.

Middle Mesozoic Era - Underlying the south Florida basin are igneous rhyolitic - basaltic rocks (Thomas *et al.,* 1989). These rocks were subaerially exposed and eroded during the late Triassic to middle Jurassic. This caused the formation of redbeds locally. As the Atlantic Ocean continued to develop, deltaic and shallow marine sediments were deposited in the late Jurassic. Restriction of marine circulation at this time resulted in periodic accumulations of evaporites and marine carbonates (Cunningham, 2005). Deposition of Jurassic and Cretaceous sediments was controlled by the south-southeast plunging axis of the Peninsular Arch. Basal sediments onlap and pinch out against the arch (Pollastro *et al.,* 2000).

Late Mesozoic Era – As marine transgression proceeded during the early Cretaceous, the Florida Platform was the site of more widespread deposition of marine limestones and reefs. Further transgression and global warming during the Late Cretaceous established an open marine accumulation of carbonates over the entire Florida Peninsula.

Cenozoic Era – Cenozoic development of the Florida Platform included additional deposition of marine carbonates and deposition of siliciclastics (grains of silicate minerals such as quartz in lieu of carbonates) from northwestern highlands sources and long shore oceanic currents. Tertiary faulting occurred south of Florida as the Cuban block collided with the Antilles arc and carbonate accumulation continued in Florida (Condie and Sloan, 1998). In southern Florida, the open marine setting continued during the Paleocene as more restricted flow to the north resulted in deposits of mixed carbonates and evaporites. Eocene and Oligocene deposition is marked by shallow water

carbonates. Intermittent with this deposition were subaerial exposures associated with local oceanic regressions.

Deposition in south Florida during the Miocene changed with the introduction of more widespread siliciclastics from a fluvio-deltaic system prograding down the peninsula. Phosphates and the carbonate ramp of the Arcadia Formation were deposited during the Miocene in south Florida. A Pliocene lowstand caused many of the previous deposits to be reworked and/or eroded. The Florida Keys area was active as a thick pile of sand that was being transported south to eventually form the Long Key Formation (Guertin *et al.,* 1999; Cunningham, 2005). Continued carbonate accumulation in the Florida Keys during the Pliocene built the Stock Island Formation (Cunningham *et al.,* 1998).

The Pleistocene era resulted in the conversion from siliciclastic deposition mixed with carbonate accumulation to more widespread carbonate sedimentation (Cunningham, 2005). Global sea-level changes during the intermittent ice ages of the Pleistocene controlled the rate and distribution of carbonate units. At 120 Ka, the last major sea level fall occurred as the reefs and the oolite facies were accumulating to become the Miami and Key Largo Limestones. The Pleistocene Key Largo Limestone (130 Ka) underlies the Florida Keys to its northernmost extent at Soldier Key (Shinn *et al.,* 1997). The Miami Limestone (Upper Pleistocene oolite and bryozoan facies) underlies the southeastern portion of the Florida mainland including Biscayne Bay.

At 15-16 Ka sea levels began to rise rapidly and flood southern Florida around 7 or 6 Ka (Shinn *et al.,* 1997). Sea level has continued to rise. Holocene geologic activity at Biscayne area consists of the accumulation of coral reefs, sand deposits and carbonate muds. These deposits directly overlie the Pleistocene Key Largo and Miami Limestones. Reef distribution at Biscayne is controlled by geologic and climatic factors such as the timing and rate of sea level rise, sediment facies, and underlying bedrock. At present, anthropogenic activity is probably the most prevalent source of reef change in south Florida.

Stratigraphy

Cores such as the deep, continuous core near the Everglades National Park Research Center (W-17232), those of the South Florida Drilling Project (Florida Geological Survey, University of Miami, Florida Department of Transportation), and the USGS help constrain the stratigraphy at depth underlying the park.

The lowest unit penetrated by the core in the Everglades is the Arcadia Formation (top surface at 147 m, 482 ft). This formation consists of ramp setting carbonates with scant quartz contents increasing northward (~20% quartz grains at W-17232) (Cunningham, 2005). A major disconformity marks the boundary between the Arcadia Formation and the overlying Peace River Formation. The Peace River Formation is absent south of the Everglades and pinches out west of Biscayne National Park.

Beneath Biscayne National Park, the Long Key Formation overlies the Arcadia Formation. This new unit, proposed by Cunningham *et al.* (1998) is composed of subsurface siliciclastics underlying the southernmost reaches Florida (from core W-17156 on Long Key). This unit is coeval with the Stock Island Formation of the lower Florida Keys (Guertin *et al.,* 1999). The top of the Long Key Formation beneath the park is ~145 m (475 ft) below the surface. The siliciclastics of the unit were deposited in at least 3 pulses (late Miocene, early Pliocene, and latest Pliocene/earliest Pleistocene). They are present in a channelized morphology of coarse-grained sands (>1mm) (Warzeski *et al.,* 1996).

The Miami Limestone is ~125 – 130 Ka and represented deposition during an interglacial period. Two facies, the oolitic facies and the bryozoan facies are more or less combined in most of the outcrops at east of Biscayne National Park (Hoffmeister *et al.,* 1974; Cunningham, 2005). Further east, towards Biscayne Bay and the upper Keys, the coralline Key Largo Limestone is exposed as far north as Soldier Key (Shinn *et al.,* 1997). The deposition of the Miami and Key Largo Limestones was contemporaneous.

Overlying the Miami and Key Largo Limestones bedrock are surficial units of sands and carbonate muds, coral rubble and reef, as well as local peat and organic material on the islands.

Significant Geologic Resource Management Issues in Biscayne National Park

1. Hydrogeologic system of Biscayne Bay

The resource managers need to understand how water is moving through the hydrogeologic system into, under, and from the park. Two aquifers, the Biscayne (upper) and Florida (lower) aquifers, plus an intermediate aquifer underlie the park. Knowledge is limited about the amount of flow and partitioning between them. Their depths are associated with the five unconformities (Q1 – Q5) in the Fort Thompson – Miami Limestone transition. Porosity is estimated at 40%, but little modeling exists for the system. The USGS has monitoring wells in the park including four seepage wells. These would be useful to perform a tracer study to see how quickly and in what direction water is moving through the system.

Management also needs to understand how the water table might change over time. The Biscayne aquifer is surficial in the Everglades and deepens towards the east. This aquifer provides water for the urban development stretching along the eastern Florida coast. Eight million gallons/day of waste are pumped into deep injection wells from Miami. This waste goes down gradient to the Florida Straights and washes up in the park. Because of Biscayne's location (jutting into the Florida Straights), an understanding of how the water currents and geology interact is vital to understanding contaminant flow through the park.

The interaction between groundwater flow and the overall fresh water and marine ecological quality must be quantitatively determined at Biscayne. Visitor uses and surrounding development are increasing the levels of certain substances in the water at the park. Nutrients from waste are causing algal blooms.

Research and monitoring questions and suggestions include: How many wells are necessary to model the hydrogeologic system at the park? Examine the salt wedge characteristics versus the surface water. How would an increase in hydraulic head affect the local spring activity? Characterize the groundwater interface between the salt and fresh water boundaries. Determine the fresh water discharge into Biscayne Bay. How does a change in hydraulic head affect fresh water discharge into the bay? To what extent does the substrate buffer contaminants in the water flowing into Biscayne Bay? Obtain more cores beneath the park to quantify the characteristics of the Biscayne aquifers location, permeability, porosity, etc. Relate tidal pumping to water movement in the park. Locate the drill log for a 457 m (1,500 ft) well in the center of Elliot Key and use for resource management (possibly located in Denver Service Center?). Access the Harold Hudson Collection of cores at the USGS in St. Petersburg, FL. Measure stable Sr isotopes in ground water as well as ephemeral salinity changes in the Bay to better understand water movement through the hydrogeologic system. Perform mass balance calculations and stable isotope measurements to determine the freshwater inputs and their proportions from rainfall, canal discharge, and groundwater. Map depressions to find freshwater discharge points. Is there a blue hole just outside the park associated with cave openings? Are upwellings in the bay tidal or hydraulic head driven?

2. Benthic habitats at Biscayne National Park

The features in the bay are strongly related to minute changes in elevation. Environments can change within centimeters of topographic relief. Given the coverage of mapping at the park, normal surficial maps are not sufficient for complex management decisions at Biscayne. An interdisciplinary

approach to mapping is critical to producing a useful product for resource management. Anthropogenic, supratidal, intertidal, subtidal, and coastal features would all be helpful. This holistic ecosystem approach integrates biological, physical, cultural, and oceanographic variables.

LIDAR surveys in addition to satellite imagery, multibeam mapping, bathymetry data, water quality and circulation, shoreline change data, pre/post storm comparisons, oceanographic data (waves, tides, currents, turbidity, temperature salinity, sediment transport patterns, coral larvae and other species distributions), etc. are essential for resource management at Biscayne National Park. Research and monitoring questions and suggestions include: What is the minimum mapping unit relevant to resource management? What are the flow dynamics in the bay?

3. Inundation history and paleoconditions

Knowledge of the location and characteristics of paleoshorelines at Biscayne will deepen the understanding of the evolution of the landscape as well as increase predictability of future responses to changing sea level. Any paleoshoreline exposed in the park needs to be dated and mapped. In addition to understanding the paleoshorelines at the park, knowledge of the areas paleodrainages will connect with the archaeology of the area. Approximately 5,000-8,000 years ago, indigenous people were concentrated along shorelines, creeks and other drainages. Any anthropological sites should be protected, preserved, and/or excavated. These will add to the cultural value of the park. Knowledge of how the drainage and shoreline have changed through time should help with this process.

Research and monitoring questions and suggestions include: Use LIDAR (penetrates unconsolidated Holocene sediments) and DEMs to determine the paleotopography, locations of drowned reefs and paleochannels flooded off Elliot Key that lie atop Pleistocene bedrock.

4. Sediment transport and erosion

Biscayne National Park straddles the transition between barrier islands to the north and hard rock islands (keys) to the south. Longshore drift processes end at Key Biscayne and Soldier Key. The "Safety Valve" is a large sand bar that allows water in and out, lessening the effects of storm surges. This dynamic feature has been stable for 100 years.

Shifting muds and sands, and carbonate dissolution continually alter the shape and profile of the shoreline. Sand and mud erode from one beach and deposit elsewhere in the course of a single storm event. Focus also needs to be on understanding the sediment transport dynamics at the park. The hydrogeologic system in the area around the park was altered with the construction of canals, roads, and levees.

Research and monitoring questions and suggestions include: How much beach renourishment/degradation is occurring in the park? By what processes are beaches changing? What effect will rising seas have on the Safety Valve? Does longshore drift stabilize or destabilize the Safety Valve?

5. Karst activity

Karst features are not obvious on the landscape at Biscayne. Microkarst appears on the eastern shores of Elliot and other Keys and numerous holes and caves are located beneath the waters of

Biscayne Bay. Their distribution, characteristics, depths, and interconnectedness need to be systematically mapped and described.

Research and monitoring questions and suggestions include: How are karst features affecting water quality at Biscayne? How do karst features affect the hydrogeologic regime including retention time, hydraulic head, and water storage? How much of the surface is karst-related collapsed features? What steps should be taken to model water flow in the park regarding karst features? Could aerial photography be used to map sinkholes? Map historic and active sinkholes and other karst features in the bay, especially where it might pose a geohazard to visitors. Relate karst topography with sea grass distribution.

6. Sea level rise

Sea level rise is affecting all of South Florida. Local levels of sea level rise are estimated at 23 cm/year (9 inches/year). Given the low relief of the 42 islands at Biscayne National Park, rising seas will quickly submerge the lower islands and shoals. While slowing the rate of sea level rise is beyond the resources of the park, monitoring sea level change and evaluating/predicting impacts on the park's landscape is a valid management issue. Increases in turbidity with rising seas are causing large seagrass dieoffs and increased carbonate material suspension. Baseline data and conditions are needed first, and then monitoring can proceed.

Research and monitoring questions and suggestions include: Is there any way to save the subaerial habitat from rising seas? What is the exact local rate of sea level rise? Looking at the affects of storm surges, how will the buttonwood/mangrove zones respond to the rising water? Monitor and measure the relationship between water level flux and elevations to determine an exposure/submergence index (i.e. 100% of the time exposed versus 0% of the time exposed). Quantitatively define the terms subtidal, supratidal, and intertidal units to use for future predictions and relate these to the local elevations and annual regime of water fluctuations. How fast will the park be submerged? How should facilities be sited in light of sea level rise? Determine the vulnerability index of the shorelines at Biscayne to sea level rise. Are coral growth rates keeping up with sea level rise?

7. Disturbed lands

Several oil and gas exploration wells are located within the quadrangles of interest for the park. These are all dry wells. In addition to these wells, canals (such as L31 canal), levees, and quarries (18 m, 60 ft deep canal along Road 107) are disturbed lands in the Biscayne area. Five canals open to the bay within park boundaries.

Research and monitoring questions and suggestions include: Obtain GPS locations of quarry sites. How do quarries and canals affect groundwater flow?

8. Active reefs and coral mapping

Coral reefs are an essential resource to preserve and protect at Biscayne National Park. They are also one of the most fragile features of the park. At least forty-two different benthic types are present in the park. These are associated with small-scale topographic peaks and valleys. There are approximately six types of reefs in the park separated based on their morphology and relief. The reef

character changes further north to become smaller and rounder. Older corals are concentrated on the northwest corner of the reef for unknown reasons.

The USGS is using spectral color imaging and LIDAR to produce high-resolution maps of coral reefs in the Biscayne area. This in addition to hand measurements and specific transects with acoustic arrays (measures roughness and hardness of substrate) greatly increases the understanding of the production and calcification of corals, and of the overall health of the benthic ecosystem.

The NOAA Coral Ecosystem Mapping Team is starting an initiative to form a coral reef task force of federal and state agencies to coordinate data rich programs. The desired products are high-resolution benthic maps that will be used to develop a hierarchical benthic habitat/structure classification scheme. Some of the information required for this project includes high-resolution imagery, LIDAR, GPS measurements, seafloor habitat characterization, and an agreed upon minimum mapping unit based on the technology and accuracy requirements. The National Park Service hopes to cooperate with this program to increase the understanding of the coral reefs at Biscayne National Park.

Research and monitoring questions and suggestions: Which reefs are part of an actual Pleistocene complex and which have been moved as chunks during storm events? Accurately map and characterize the reefs and the reef edge. Use LIDAR and DEMs to determine the locations of lagoonal patch reefs, storm blowouts, drowned reefs, and patch reef cores for resource management. What is the geologic connection with coral distribution? How many reefs are there at Biscayne? What are the controls on reef shape? Research alternatives to concrete for reef restoration (concrete does not dissolve enough). Why have reefs changed in the past (look at fossil record in the Key Largo Limestone)? Characterize reef structure. Determine which coral species is the reef builder (branching or stony corals). How quickly does reef form pavement? Should damaged areas of the reef be filled? If so, how long will it take to stabilize? What are the causes and nature of the barrier island - key transition?

9. Recreation demands and resource restoration

In 2003, Biscayne National Park hosted 490,178 recreation visits. This number does not include the thousands of boats that pass through Biscayne Bay every week. Primary visitor activities in the park include recreational (and commercial) fishing, diving, snorkeling, camping, picnicking, and hiking. Visitors are placing increasing demands on the limited resources and fragile ecosystem of the park. The Sands Cut area (a shallow sand flat) attracts particular attention from boaters who pull up onto the flats to recreate.

Commercial fishing, spear fishing, lobster trapping, etc. all have profound effects on the resources at Biscayne. Vessel groundings can destroy a reef that took thousands of years to build. Shrimp trawlers crush baby corals. Storms toss traps around the sea floor, causing more damage to the bottom. More than 200 vessel groundings are reported per year at Biscayne National Park. Many more are assumed to occur by park management. Ninety percent of these groundings are in the shallow seagrass beds (~2 m, 6.5 ft deep), 9-10% are on coral reefs, and occasionally mangrove groundings occur.

Sea grasses grow in shoals and channels in the park. There are three levels of severity for groundings based on the depth of impact. Deeper cuts often fill with drift algae. Restoration options for the seagrass beds include resedimentation, sediment stabilization, transplanting, and bird stakes (fertilization and seed distribution from droppings). Groundings on reefs are also categorized by the

severity of the damage. Results include a fractured substrate, altered topography, and rubble production. Restoration of the reefs can include natural recovery, seal/fill fractures, recolonizing the population, reattaching substrate, removing rubble, capping fractures, promoting natural deposition, and abating erosion.

Research and monitoring questions and suggestions: Are visitors affecting sediment transport and the hydrologic system at the park? Should visit limitations be instigated by the park to reduce anthropogenic erosion and sea grass dieoff? Are seagrasses successional species? How are visitors at Sand Cut affecting sediment thickness there? Develop an interpretive exhibit specific to the geology of the park for visitor information.

10. Sediment thickness

The sedimentary cover over the Pleistocene bedrock is only a thin veneer approximately 1.2 to 4.6 m (4 – 15 ft) thick. This veneer is easily disturbed by devegetation and vessel groundings. Understanding the distribution of sediment thickness is vital to determining viable habitat for sea grass. Storm events and hurricanes have a pronounced and often catastrophic effect on the landscape of south Florida. Baseline conditions must be determined and studied for the resource management to predict the environmental response.

Research and monitoring questions and suggestions include: Develop a response protocol in cooperation with other local agencies to determine the geochemical effects of storm surges. Establish baselines for comparison and prediction of future events. Map sedimentary thickness to see differences across the bay as well as solution haloes that form around islands because of organic acids produced by mangrove peats. Monitor changes in sediment distribution because of vessel groundings. How does the clay layer at depth under the sand waves affect sand ripples? How should this clay layer be managed?

11. Urban development concerns

Dominating the western skyline at Biscayne National Park are the Turkey Point nuclear power plant and the Dade County landfill (the highest point in south Florida). The U.S. Air Force Base at Homestead is growing and increasing the local population west of the park (18,000 new home permits in Homestead). Five canals enter the park and inevitably have an effect on overall water quality. Local agriculture increases the phosphorous and nitrate concentrations by more than 100 times the baseline levels.

The power plant has 217 km (135 miles) of cooling canals which prevent thoroughgoing groundwater movement. The fuel delivery channel to the power plant receives barges approximately 300 days/year (55,000 barrels/day). These barges commonly ground in the shallow water near Biscayne National Park. The potential for a toxic spill is high.

Surrounding canals, including the five that directly enter the park, affect sediment transport, increase turbidity, change water chemistry, and form sediment plumes. The Black Point sewage treatment plant, leachate from the Dade County landfill, as well as contaminated water injected into the Florida aquifer are threatening the water quality of the park. Plans are in place to deepen Miami harbor by 9 m (30 ft) which would cause huge amounts of toxic materials now trapped in sediments to be released. The Intercoastal Waterway that runs through the long axis of the park is on the verge of being dredged.

As local population increases, so does the number of vessel groundings at the park. Florida requires no special license to operate a boat, thus inexperienced boaters are often stranded on shoals, reefs, and sand bars. Buoys and low speed zones are an attempt to reduce the severity of the situation, but monitoring and patrolling boat activity (cooperation with the U.S. Coast Guard) is difficult in the large park. Markers also affect the viewshed of the park. Recovering costs of restoration from responsible parties is very difficult. Park staff needs to join forces with NOAA, FKNMS, DEP, and other state agencies to research the cumulative effects of this boating activity and help restore some of the damage caused by vessel groundings.

Research and monitoring questions and suggestions include: What contaminants are attached to sediments emanating from canals? How can the park cooperate with federal, state, and local agencies to remediate threats to water quality at Biscayne? Discuss alternatives to the fuel barge with the authorities of the Turkey Point nuclear power plant.

12. Soil characterization

Soils need to be mapped and characterized on the 42 islands at Biscayne. Locations of the fresh and saltwater peats in Biscayne Bay are of particular importance to determine the inundation history.

13. Paleontologic inventory

Biscayne National Park contains the fossil remnants of a great Pleistocene reef that forms the foundation for the Florida Keys. These fossilized remains have much to correlate with the modern system, but have to be inventoried, mapped, and described.

Research and monitoring questions and suggestions include: Inventory the Pleistocene fossil corals at Biscayne National Park. Attempt to locate and catalogue specimens previously removed from the park for public/private collections. Create an interpretive exhibit for the fossil resources on Winley Key.

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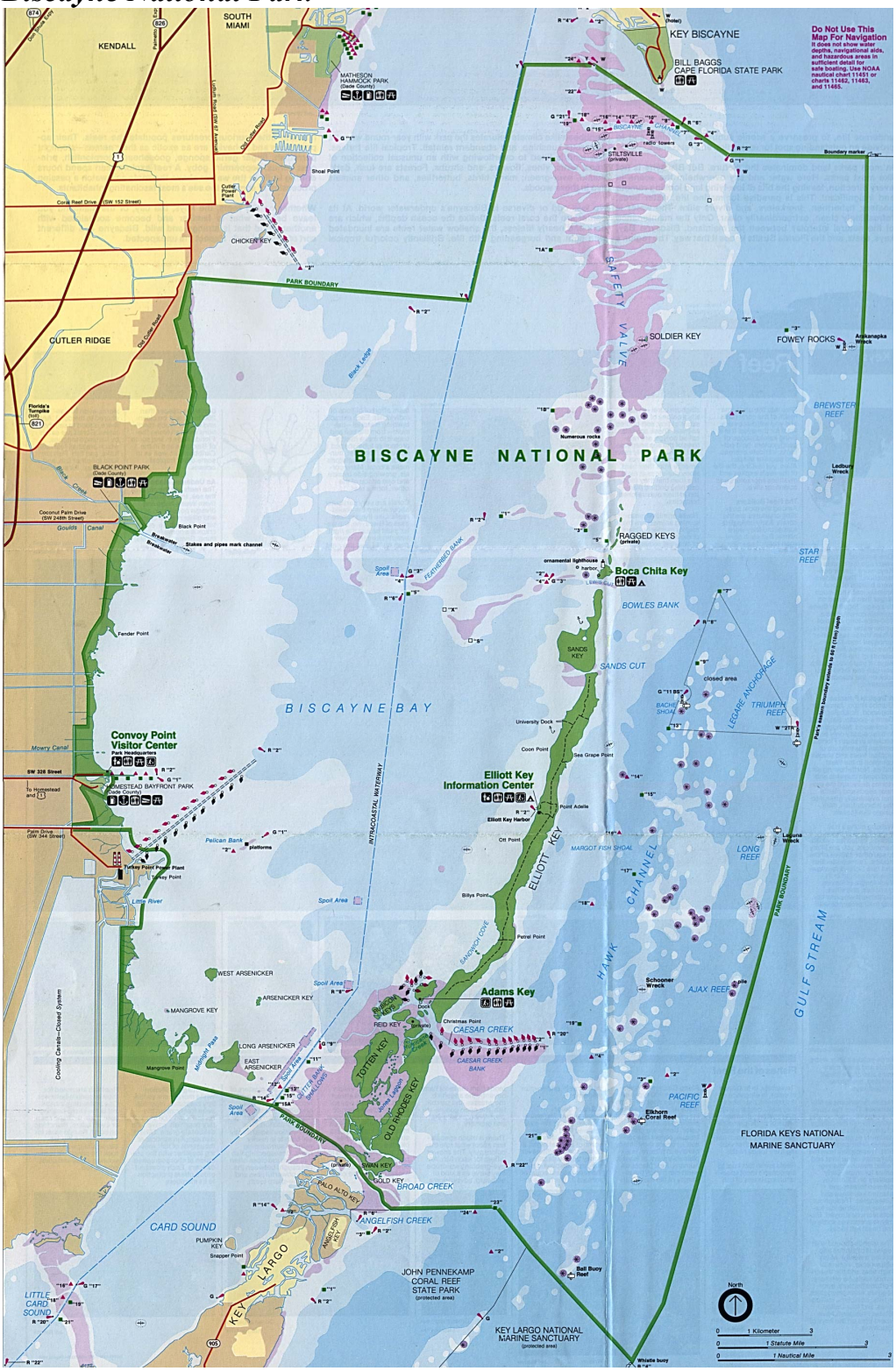
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Map of Biscayne National Park



APPENDIX E.3

BUCK ISLAND REEF NATIONAL MONUMENT

GEOLOGIC RESOURCE MANAGEMENT ISSUES SCOPING SUMMARY



K. N. Hall
Geologic Resource Evaluation
September 1, 2005

EXECUTIVE SUMMARY

A Geologic Resources Evaluation scoping meeting was held for Buck Island Reef National Monument (BUIS) on April 5, 2004. The scoping meeting participants identified the following as the most significant geologic resources management issues:

1. Inventory and monitor coastal and marine processes and resources such as sediment transport, sediment thickness, coral reef populations (i.e. health, location, species), and other benthic habitats.

2. Monitor BUIS hiking trails for a significant increase in erosion.

3. Investigate the possible effects of windblown particulates (i.e. Saharan dust, Montserrat dust) on park resources.

4. Monitor seismic activity in the Puerto Rico Trench and the Anegada Trough for earthquakes and tsunamis.

INTRODUCTION

The National Park Service conducted a Geologic Resources Evaluation scooping meeting at Buck Island Reef National Monument on April 5, 2004. The purpose of the meeting was to discuss the status of geologic mapping in the park, the associated bibliography, and the geologic issues in the park. The products to be derived from the scoping meeting are: (1) Digitized geologic maps covering the park; (2) An updated and verified bibliography; (3) Scoping summary; and (4) A Geologic Resource Evaluation Report which brings together all of these products.

Buck Island was originally designated a protected area by the Municipal Government of St. Croix in 1948. In 1961, Buck Island Reef National Monument was established by President Kennedy in order to protect and preserve "one of the finest marine gardens in the Caribbean Sea." The park included the 176- acre island and approximately 700 acres of submerged lands. In 2001, President Clinton expanded the park to include an additional 18,135 acres of submerged resources. To date, the park contains a total of 19,015 acres (FY2005).

BUIS MAPPING PRODUCTS

Buck Island Reef National Monument has "quadrangles of interest" (or "QOI's") at the 7.5'x7.5'- *(1:24,000)* scale. It is desired to obtain DIGITAL geologic map coverage for all identified 7.5' qoi's. (Figures 1,2 and 3).

While numerous "paper" maps at suitable scale have been published for this park, complete DIGITAL geologic map coverage is not available. It is hoped that through the scoping meetings and discussions with park staff , the USGS and state geological surveys that gaps in DIGITAL coverage can be resolved for areas not currently known to have digitized geologic maps. These meetings lay the foundation for a plan to accomplish this task

The contents of this document reflect what is known regarding published geology as of September 6, 2005, from searches done by NPS-GRD staff as discerned from the USGS on-line geologic maps database found at: *http://ngmdb.usgs.gov/ngmdb/ngm_compsearch.html*

In short, it appears a few maps do give coverage for the island of Saint Croix as follows:

- NOAA Benthic Habitats map

- Whetten, J.T., 1966, Geology of St. Croix, U.S. Virgin Islands, Geological Society of America, Memoir 98, 1:31,680 scale

During the scoping sessions held in April 2004, for Buck Island Reef National Monument (BUIS), Salt River Bay National Historical Park and Ecological Preserve (SARI) and Christiansted National Historic Site (CHRI), it was decided that the Whetten map would be the best available source to give the bedrock geology of the island of Saint Croix, as it would also encompass all three NPS areas on the island of St. Croix (Figures 1 and 2) . NPS-GRE staff will acquire the original map and convert it into a digital, user-friendly GIS product.

The NOAA benthic habitat maps will accompany the bedrock map of the island and is already available digitally. NPS-GRE staff will incorporate it as well into a final geologic map of the island. A summary table follows along with explanatory graphics.

Extent of Coverage	**Published Map Citation**	**Paper**	***Digital***	***GRE Plan***
Entire island of Saint Croix	Whetten, J.T., 1966, Geology of St. Croix, U.S. Virgin Islands, Geological Society of America, Memoir 98, 1:31680 scale	yes	Unknown	Acquire paper copy and convert to digital
Entire island of Saint Croix	Kendall, M.S., M.E. Monaco, K.R. Buja, J.D. Christensen, C.R. Kruer, and M. Finkbeiner, R.A. Warner, 1999, Benthic Habitat Maps of the U.S. Virgin Islands-St. Croix; Prepared by Visual Interpretation from Remote Sensing Imagery Collected by NOAA in 1999, 1:6000 scale	Unknown	Yes, from NOAA	Convert NOAA digital version to NPS format

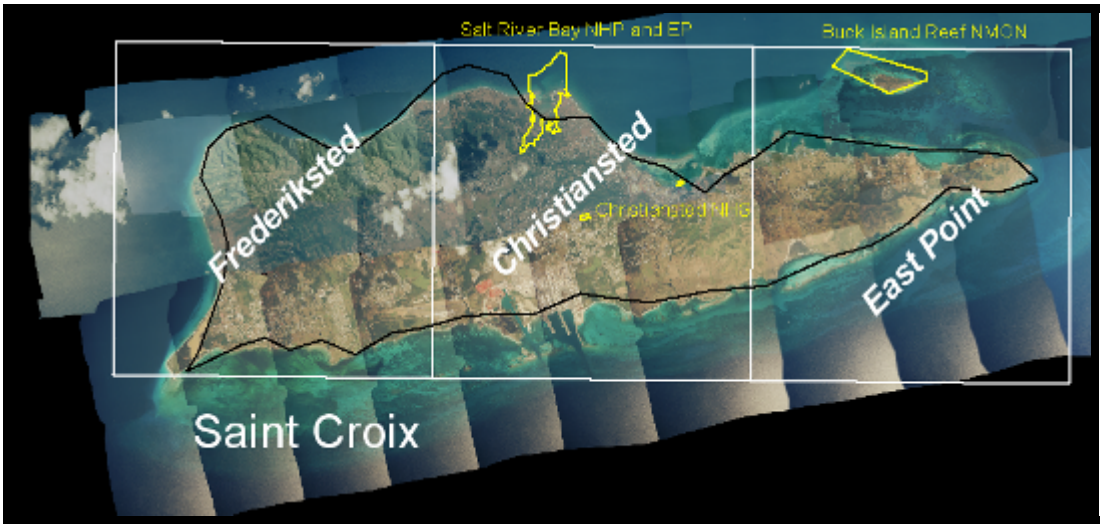


Figure 1: Quadrangles of Interest (QOI's) for BUIS, SARI, and CHRI (7.5' shown in white outline; park boundaries in yellow outline; MrSID image of Island of Saint Croix as background).

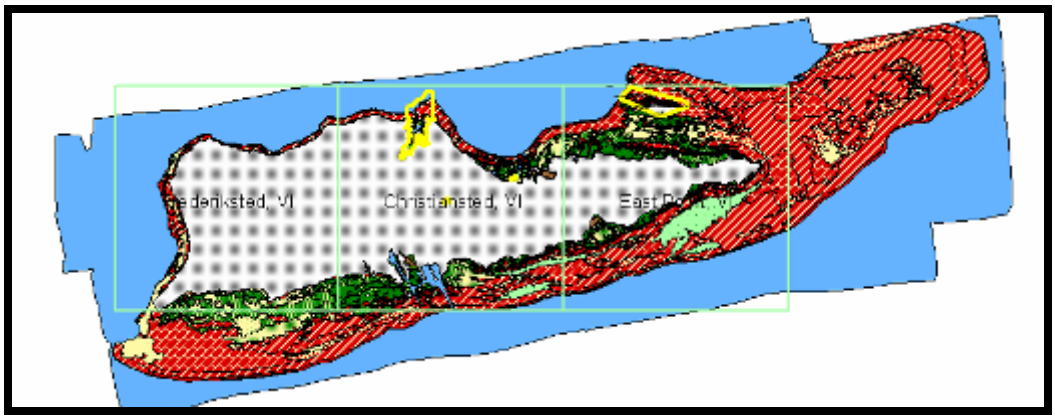


Figure 2: NOAA Benthic Habitats of Saint Croix Island

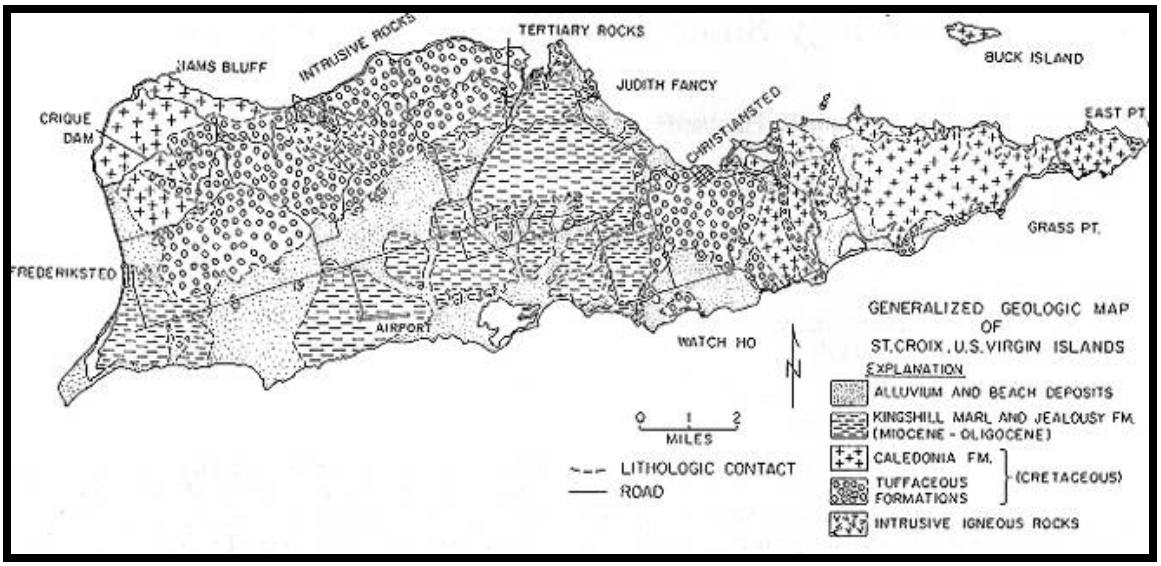


Figure 3: Scan of Generalized Geologic Map of Saint Croix (after Whetten 1974, in Hubbard SP8)

GEOLOGY OF BUCK ISLAND REEF NATIONAL MONUMENT
Taken from Bythell *et al*., 1989

Buck Island Reef National Monument lies approximately 2 km north of St. Croix. The park's modern carbonate environment is composed primarily of the elkhorn coral, *Acropora palmata*. The only non-carbonate exposures are found in a narrow band of Caledonia Formation volcaniclastics (~100 my). This band rings the island and is exposed on the entire shoreline of BUIS with the exception of the west shore. Holocene beachrock also fringes much of the island. (Whetten, 1966: Bythell *et al*., 1989)

The east end of Buck Island is encompassed by a massive bank barrier reef that encloses a 200-300 m. wide, and 2-4 m deep, lagoon. This bank-barrier reef trends from southeast to the northwest and represents one of the largest stands of elkhorn coral on St. Croix. The north side of the island is dominated by isolated patch reefs, both within the lagoon and seaward of the bank barrier reef. The seaward patch reefs, known as haystacks, are composed of almost 100% dead *Acropora palmata.*

Although many of the corals found at BUIS have been decimated by White Band disease, living stands of corals on the windward reefs may grow at the high rate of ~15 meters per 1000 years. This high growth rate, combined with high population densities, result in high levels of carbonate production for Buck Island Reef National Monument. (Gladfelter *et al*., 1977: Gladfelter and Gladfelter, 1979: Bythell *et al*., 1989)

SIGNIFICANT MANAGEMENT ISSUES
The scoping participants identified the following as the most significant geologic issues at Buck Island Reef National Monument:

1. Coastal and Marine Features and Processes

1. Sediment characteristics – sediment thickness, type, and grain size should be integrated into park maps. Available information on sediment distribution, budget, and sources and sinks should be available to park managers for a variety of reasons including, but not limited to, buoy placement and maintenance, boat anchoring, and erosion hotspots. An understanding of the system's sediment supply is critical for monitoring coastal areas and predicting shoreline change.

2. Boating Hazards – boat anchoring and vessel groundings may damage coral reefs. Although anchoring is permissible in certain areas, illegal anchoring and anchor dragging may destroy marine habitat throughout the park. In addition, vessel groundings due to inexperienced boating and storm events may critically damage large sections of coral reefs.

3. Oceanographic Variables – relative sea level rise, temperature and salinity patterns, currents, and tidal regimes should be monitored for Buck Island Reef National Monument. These variables may aid in identifying sediment transport patterns within the park. In addition, knowledge of currents at headlands and in channels may reduce visitor injuries.

4. Benthic habitat mapping – Buck Island Reef National Monument is working in cooperation with NOAA to complete benthic habitat mapping for the park. Benthic habitats including coral reefs and submerged aquatic vegetation will be included in coastal mapping products. These features influence the hydrodynamic regimes within

their localized areas, thereby determining sedimentation patterns. The location of marine habitats should be known in order to determine the impacts that coastal development and visitor use may have on their health and survival.

2. Recreational Impacts

Buck Island Reef National Monument is experiencing significant erosion on its hiking trails. Further studies are needed because even small increases in sedimentation can negatively affect adjacent marine habitats including coral reefs and seagrass beds.

3. Windblown Features and Processes

Currently, the park is investigating the effects of Saharan dust on park resources. It is believed that imported particulates could have harmful effects on fragile marine habitats such as coral reefs and seagrass beds, by carrying fungi and dust-borne pathogens. Dust from alternate sources such as the Montserrat eruption of 1995 could also have negative impacts on park resources.

4. Seismic Activity

The Virgin Islands are situated on an active plate boundary zone between the Caribbean Plate and the North American Plate. Periodic seismic activity, including earthquakes, submarine landslides, submarine volcanic eruptions, subaerial pyroclastic flows, and tsunamis are common throughout the region. The active fault zone lies approximately 100 miles north of Buck Island Reef National Monument in the Puerto Rico Trench. (Olcott, 1999) In addition, the Anegada Trough lies between St. Thomas and St. Croix. In 1867, a 7.5 magnitude earthquake generated two large tsunamis. These tsunamis produced waves in excess of 23 feet, causing loss of life and structural damage on St. Croix.

Currently, A U.S. Geological Survey (USGS) seismic station in Puerto Rico monitors earthquake activity in the U.S. Virgin Islands.

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APPENDIX E.4

DRY TORTUGAS NATIONAL PARK

GEOLOGIC RESOURCE MANAGEMENT ISSUES SCOPING SUMMARY

Trista L. Thornberry-Ehrlich
Colorado State University – Geologic Resource Evaluation
January 31, 2005



Fort Jefferson and moat at Dry Tortugas National Park. Photograph by Trista L. Thornberry-Ehrlich (Colorado State University).

Executive Summary

Following a field trip on January 23, 2005, a Geologic Resources Evaluation scoping meeting took place in Homestead, Florida on January 24, 2005. The scoping meeting participants identified the following geologic resource management issues.

1. Coral reef framework rehabilitation and restoration is needed in response to anthropogenic degradation and disease. Vessel groundings are of particular concern.

2. Sea level rise is a concern for all of South Florida. Further research and monitoring is needed to determine how the environments at Dry Tortugas will respond to rising seas.

3. Benthic ecosystems need to be mapped at a large scale in the park using a multidisciplinary approach for resource management.

4. Island geomorphic processes and stability of Fort Jefferson are closely linked. Resource management must understand the nature of the underlying sediments to attempt to stabilize the crumbling fort. Modeling of sediment transport patterns and rates will help to predict shoreline evolution.

5. Groundwater flow dynamics, dictated by the hydrogeologic system, need to be modeled to predict nutrient/contaminant flow paths and to monitor water quality at the park.

6. Recreation and other use (including commercial fishing boats) threaten the reefs and sea grass beds at the Dry Tortugas. Remediation of the anchorage at the park is being considered.

Introduction

Following a daylong field trip on January 23, 2005, the National Park Service held a Geologic Resource Evaluation scoping meeting for Dry Tortugas National Park at the Krome Center in Homestead, Florida on Monday, January 24, 2005. The purpose of the meeting was to discuss the status of geologic mapping in the park, the associated bibliography, and the geologic issues in the park. The products to be derived from the scoping meeting are: (1) Digitized geologic maps covering the park; (2) An updated and verified bibliography; (3) Scoping summary (this report); and (4) A Geologic Resource Evaluation Report which brings together all of these products.

Dry Tortugas National Monument was established under Franklin D. Roosevelt's administration on January 4, 1935. On October 26, 1992, the monument was redesignated a national park. Dry Tortugas covers 64,701 acres and is located 112.9 km (70 miles) west of Key West. Over 99% of the park is under water. Seven keys, (Loggerhead, Garden, Bush, Long, Hospital, Middle, and East Keys) comprise the only subaerial exposures. The area covers a large portion of the outermost Florida Keys, a long tract of paleoreefs that stretch from Biscayne National Park to Dry Tortugas, some 193 km (120 miles). The park contains some of the most pristine marine habitat in the continental United States. Its isolated location attracts nesting birds and turtles to its shores. The strategic location also attracted military attention leading to the construction of the defensive Fort Jefferson on Garden Key.

Dry Tortugas National Park is covered by four quadrangles of interest (Dry Tortugas OE, Dry Tortugas OE E, Dry Tortugas OE S, and Dry Tortugas OE SE). However, additional coverage is required for underwater mapping in surrounding quadrangles. The Florida State Geologic Survey has digitized a geologic map covering the state at a small scale (~ 1:750,000). This map only displays one geologic unit for the park. Additional mapping at a smaller scale will be more helpful for park management.

Physiography

The Florida Keys are divided into three distinct sections: the upper. middle, and lower Keys (including Dry Tortugas). These divisions correspond to their orientation, morphology, water depth, and composition. The upper Keys are oriented almost north-south and buttress against the east-southeast winds. The middle Keys are oriented northeast-southwest and face directly into the east-southeast winds. The upper and middle Keys are composed of coralline limestone. The lower Keys are oriented nearly parallel to the winds and trend nearly east-west and are composed of oolite (preserved tidal-bar deposits?). Water depth is at a maximum in the middle Keys. As a result, the coral reef development is greatest in the shallower waters of the upper and lower Keys (Shinn *et al.,* 1997).

East of Dry Tortugas is an area of extensive sand waves that are current-swept into crests as high as 3 m (9 ft), called the Quicksands. Sand accumulations are as thick as 12 m (40 ft). The reefs at Dry Tortugas are thick, as much as 17 m (55 ft). They form an elevated atoll-like rim. The sand islands are located around the atoll and are as much as 14 m (45 ft) thick (Loggerhead Key). The Holocene sediments at Dry Tortugas are mostly uncemented and the mixture of paleocorals and sands proved an unstable foundation for the construction of Fort Jefferson on Garden Key.

Geologic History of South Florida

Sediment cores (southwest of the Marquesas Keys, penetrated 4,500 m (15,000 ft) indicate that South Florida has been predominantly an area of carbonate accumulation since the Mesozoic.

Late Paleozoic Era – During the Mississippian, the landmass that would underlie the grand carbonate platform of Florida today was not attached to the North American Craton. It is speculated that it was attached to the northwest portion of the African continent (Condie and Sloan, 1998). However, marine carbonates were being deposited over large portions of the area atop a Paleozoic age crystalline basement high, the Peninsular Arch (Pollastro *et al.,* 2000). In the Pennsylvanian, a collision event, known as the Ouachita orogeny sutured the Florida landmass to the continent as Gondwanaland and North America collided eventually forming the supercontinent Pangaea. The land was still submerged and south Florida was located at the junction of the North American, South American, and African plates. Through the Permian, Pangaea remained intact (Condie and Sloan, 1998).

Early Mesozoic Era – No sooner had Pangaea formed than it began to break up. During the late Triassic, South and Central America and Africa began to rift away from North America. This established the long-standing passive margin of the eastern seaboard that persists today. The Florida and Cuba blocks detached from northwest Africa and the Gulf of Mexico opened (Condie and Sloan, 1998).

Accompanying the rifting of Pangaea was the widespread extrusion of volcanic rocks consistent with mantle plume upwelling due to crustal tension (Heatherington and Mueller, 1991). This continental rifting also opened the Atlantic Ocean basin.

Middle Mesozoic Era - Underlying the south Florida basin are igneous rhyolitic - basaltic rocks (Thomas *et al.,* 1989). These rocks were subaerially exposed and eroded during the late Triassic to middle Jurassic. This caused the formation of redbeds locally. As the Atlantic Ocean continued to develop, deltaic and shallow marine sediments were deposited in the late Jurassic. Restriction of marine circulation at this time resulted in periodic accumulations of evaporites and marine carbonates (Cunningham, 2005). Deposition of Jurassic and Cretaceous sediments was controlled by the south-southeast plunging axis of the Peninsular Arch. Basal sediments onlap and pinch out against the arch (Pollastro *et al.,* 2000).

Late Mesozoic Era – As marine transgression proceeded during the early Cretaceous, the Florida Platform was the site of more widespread deposition of marine limestones and reefs. Further transgression and global warming during the Late Cretaceous established an open marine accumulation of carbonates over the entire Florida Peninsula.

Cenozoic Era – Cenozoic development of the Florida Platform included additional deposition of marine carbonates and deposition of siliciclastics (grains of silicate minerals such as quartz in lieu of carbonates) from northwestern highlands sources and long shore oceanic currents. Tertiary faulting occurred south of Florida as the Cuban block collided with the Antilles arc and carbonate accumulation continued in Florida (Condie and Sloan, 1998). In southern Florida, the open marine setting continued during the Paleocene as more restricted flow to the north resulted in deposits of mixed carbonates and evaporites. Eocene and Oligocene deposition is marked by shallow water

carbonates. Intermittent with this deposition were subaerial exposures associated with local oceanic regressions.

Deposition in south Florida during the Miocene changed with the introduction of more widespread siliciclastics from a fluvio-deltaic system prograding down the peninsula. Phosphates and the carbonate ramp of the Arcadia Formation were deposited during the Miocene in south Florida. A Pliocene lowstand caused many of the previous deposits to be reworked and/or eroded. The Florida Keys area was active as a thick pile of sand that was being transported south to eventually form the Long Key Formation (Guertin *et al.,* 1999; Cunningham, 2005). Continued carbonate accumulation in the Florida Keys during the Pliocene built the Stock Island Formation (Cunningham *et al.,* 1998).

The Pleistocene era resulted in the conversion from siliciclastic deposition mixed with carbonate accumulation to more widespread carbonate sedimentation (Cunningham, 2005). Global sea-level changes during the intermittent ice ages of the Pleistocene controlled the rate and distribution of carbonate units. At 120 Ka, the last major sea level fall occurred as the reefs and the oolite facies were accumulating to become the Key Largo Limestone. Locally, the Pleistocene Key Largo Limestone (130 Ka) underlies the lower Keys including the Dry Tortugas. The Pleistocene section is south Florida is more than 61 m (200 ft) thick at Big Pine Key (Shinn *et al.,* 1997).

At 15-16 Ka sea level began to rise rapidly and flood southern Florida around 7 or 6 Ka (Shinn *et al.,* 1997). Sea level has continued to rise. Holocene geologic activity in the Dry Tortugas area consists of the accumulation of coral reefs, sand deposits and carbonate muds. These deposits directly overlie the Pleistocene Key Largo Limestone. Reef distribution at Dry Tortugas is controlled by geologic and climatic factors such as the timing and rate of sea level rise, sediment facies, oceanic currents, and underlying bedrock (topography).

Stratigraphy

The USGS has installed monitoring wells at Garden Key of Dry Tortugas National Park. Cores from these wells reveal the upper 1 m (3 ft) to consist of sand and other anthropogenic debris. *Halimeda* is the most abundant biogenic sediment grain (Davis, Jr., and O'Neill, 1979). In the core, the next 15 m (50 ft) is Holocene limestone including head corals and numerous sand pockets, below the Holocene units is the Pleistocene Key Largo Limestone (fossilized patch reef complex and oolites) that underlies much of the South Florida Keys (Shinn *et al.,* 1979).

The Pleistocene section is of varying thickness and may contain as many as five separate facies units. In the lower keys (Big Pine Key), the section is more than 18 m (60 ft) thick. A Pleistocene coral facies (*Montastraea annularis*) underlies modern Holocene reefs. Pleistocene biogenic (*Halimeda*) underlies Holocene carbonate sands (Shinn *et al.,* 1997). The mixed stratigraphy from the Holocene caused the initial subsidence of Fort Jefferson. Differential subsidence continues to this day between the unconsolidated sand pockets and the limestones.

Marine units at Dry Tortugas include sandy shoals, lagoons, algal mats, patch reefs, bank barrier/fringing reefs, staghorn reefs, beach rock, hard bottom, and bare sand and rubble (Davis, 1979; Meeder, 1979; Ginsburg, 1979).

Significant Geologic Resource Management Issues in Dry Tortugas National Park

1. Coral reef framework rehabilitation and restoration

Due in part to its isolated location, Dry Tortugas protects pristine and unique coral communities with pinnacles, staghorn and elkhorn corals. Historically, the shallow shoals and reefs have caused numerous shipwrecks (Windjammer, Little Africa, Brick, etc). Today, the reefs and accompanying sea grass beds are under constant threat of degradation from vessel groundings and overuse. Private and public vessels as well as those from the local fishing industry (shrimpers) are all permitted safe harbor at the park and the high traffic in the area increases the likelihood of groundings and damage.

Given that coral growth rates are very slow, restoring a coral bank after a vessel grounding is more than just a matter of patching a hole, care must be given to the type of material used (i.e. concrete, fossil corals) and the encouragement of regrowth. To protect the environment, the banks must be restored before restoring damaged sea grass beds. Monitoring and research questions include: What is the best way to encourage growth on the reefs? What affect does loss of sea grass beds have on the marine environment? Should the number of permitted boat moorings be limited? How?

2. Sea level rise

Sea level rise is affecting all of South Florida. While slowing the rate of sea level rise is beyond the resources of the park, monitoring sea level change and evaluating/predicting impacts on the park's landscape is a valid management issue. The seven islands of Dry Tortugas are under constant threat of inundation by the sea. Several of the islands disappear seasonally due to rising seas including Middle Key. Bird Key has disappeared altogether. Given the low relief of the islands, this rise will destroy the bird and turtle nesting habitats protected at the park. The USGS and NOAA are working to determine the coastal vulnerability index (CVI) of the park.

Park management must continually balance 1) the aim to let natural processes take their course at Dry Tortugas, with 2) the preservation/restoration of the cultural resources present (Fort Jefferson and Loggerhead Key Lighthouse). Research and monitoring questions include: What is the best way to preserve the structure of Fort Jefferson from rising seas? Is there any way to save the subaerial habitat from rising seas? Will coral growth rates be able to change in response? What is the local rate of sea level rise? Looking at the affects of storm surges, how will the islands respond to the rising water?

3. Island geomorphic processes and stability of Fort Jefferson

The very nature of the landscape at Dry Tortugas is one of change. Shifting sands continually alter the shape and profile of the islands. Sand erodes from one beach and is deposited elsewhere in the course of a single storm event (including two deposits in the fort's moat on the west and northeast sides). Focus also needs to be placed on understanding the sediment transport dynamics at the park. A relatively deep channel separated Garden Key and Bush Key until a large storm event joined them with a sand bridge. This sand bridge widens and recedes, but remains a persistent feature of the landscape. The anchorage at the park, to the south of Garden Key is being filled in. This affects access to the park as well as the safe harbor provided by the park. Dredging this area could have devastating effects on the local ecosystem.

Fort Jefferson is the largest of the 19th century coastal fortifications in America. Construction began on Fort Jefferson in 1846, but was never finished due to uneven subsidence in the foundations on Garden Key. This subsidence was rapid at first and cracked the freshwater cisterns making it necessary to distill seawater or import water to the fort. Ongoing efforts are attempting to stabilize the fort and preserve this historical resource. Research and monitoring questions include: Should the channel between Garden and Bush Key be dredged to encourage circulation around the islands? Should the anchorage area be dredged? What effects would dredging have on the benthic/marine environments at the park? How will further stabilization of the fort affect the environment?

4. Benthic ecosystems

Benthic habitats comprise more than 99% of Dry Tortugas National Park. Environments can change within centimeters of topographic relief. Given the coverage of mapping at the park, normal surficial maps are not sufficient for complex management decisions at Dry Tortugas. An interdisciplinary approach to mapping is critical to producing a useful product for resource management. Anthropogenic, supratidal, intertidal, subtidal, and coastal features would all be helpful. This holistic ecosystem approach integrates biological, physical, cultural, and oceanographic variables.

USGS LIDAR surveys are adding detail to the elevation and geomorphic profiles at Dry Tortugas. These in addition to satellite imagery, multibeam mapping, bathymetry data, water quality and circulation, shoreline change data, pre/post storm comparisons, oceanographic data (waves, tides, currents, turbidity, temperature salinity, sediment transport patterns, coral larvae and other species distributions) are essential for resource management at Dry Tortugas National Park. Research and monitoring questions include: What is the minimum mapping unit relevant to resource management? Would banded maps of vulnerability patterns be useful? Could video be employed to monitor shoreline change at the park?

5. Groundwater flow dynamics

The interaction between groundwater flow and the overall marine ecological quality must be quantitatively determined at Dry Tortugas. Visitor uses as well as other boats are increasing the levels of certain substances in the water at the park. This is affecting corals, including the last stand of elkhorn coral near Bush and Long Keys). Nutrients from waste are causing algal blooms. The USGS has drilled a series of monitoring wells at the park, both inside and outside the fort to monitor water chemistry. A sand overflow into the fort's moat along the western wall from Hurricane Charlie in 2004 inundated one well.

Research and monitoring questions include: How many wells are necessary to model the hydrogeologic system at the park? What are the affects of the numerous boats moored in the anchorage of the park on water quality? How has the sediment transport affected groundwater flow patterns (i.e. the sand bridge between Garden and Bush Keys)?

6. Recreation and other use demands

In 2003, Dry Tortugas National Park hosted 74,576 recreation visits. These in addition to the boat moorings (public, private, and industry) are placing increasing demands on the limited resources and fragile ecosystems of the park. The most common visitor activities include snorkeling, the self-guided tour of the fort, camping, and swimming at the beach. Visitors access Dry Tortugas by Ferry (69%), seaplane (11%), commercial charter (10%), private sailboat (7%), private motor boat (2%),

commercial dive boat (1%), and other (4%) (Ye and Littlejohn, 2003). These all have an impact on the parks benthic environments, viewshed, air and water quality, and noise levels.

Research and monitoring questions: Should the park restrict access to the islands? Would a guided boat tour decrease the environmental impact of visitation? Are visitors affecting sediment transport?

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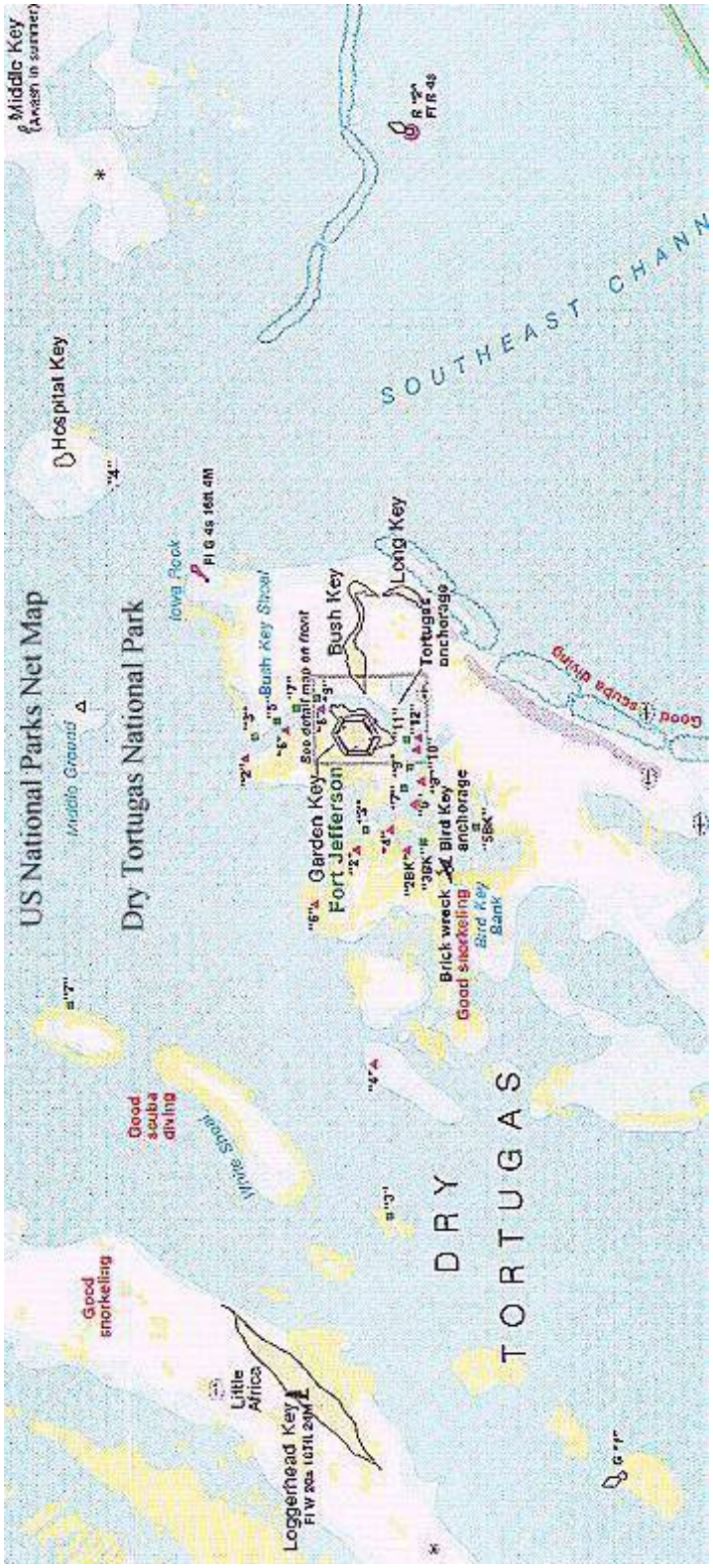
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Map of Dry Tortugas National Park

APPENDIX E.5

EVERGLADES NATIONAL PARK

GEOLOGIC RESOURCE MANAGEMENT ISSUES SCOPING SUMMARY

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February 4, 2005



Rock Reef Pass in Everglades National Park. Photograph by Trista L. Thornberry-Ehrlich (Colorado State University).

Executive Summary

A Geologic Resources Evaluation scoping meeting took place in Homestead, Florida on January 24, 2005. The meeting was followed by a field trip on January 25, 2005. The scoping meeting participants identified the following list of geologic resource management issues. These topics are discussed in detail on pages 10 - 16.

1. The Florida Bay mud banks elevation and stability
2. Mangrove zone topography and buttonwood ridge height
3. Whitewater Bay and Gulf Coast estuaries
4. Solution holes
5. Aquifer characteristics and groundwater flow dynamics
6. Recreation and other use demands
7. Earthen and failed dams, canals, and sheet piling
8. Sediment transport and resuspension at Lake Ingraham
9. Sinkholes and karst features
10. Paleoclimates
11. Sea level rise
12. Geologic changes due to storms and hurricanes
13. Atmospheric deposition of African dust
14. “Lake Belt” management
15. Tree islands and hardwood hammacks
16. Archaeological sites

Introduction

The National Park Service held a Geologic Resource Evaluation scoping meeting for Everglades National Park at the Krome Center in Homestead, Florida on Monday, January 24, 2005, followed by a field trip the next day. The purpose of the meeting was to discuss the status of geologic mapping in the park, the associated bibliography, and the geologic issues in the park. The products to be derived from the scoping meeting are: (1) Digitized geologic maps covering the park; (2) An updated and verified bibliography; (3) Scoping summary (this report); and (4) A Geologic Resource Evaluation Report which brings together all of these products.

Everglades National Park was established under Harry S. Truman's administration on December 6, 1947. On October 26, 1976, the park was designated as an International Biosphere Reserve. The park attained its Wilderness Designation on November 10, 1978. It was made a world heritage site on October 24, 1979, and was named a Wetland of International Importance on June 4, 1987. Everglades covers 1,508,537 acres spanning the southern tip of the Florida peninsula and most of Florida Bay between the peninsula and the Florida Keys. The Everglades is the only subtropical preserve in North America. The environments at the park vary from mangrove and cypress swamps, marine and estuarine environments, pinelands and hardwood hammocks, sawgrass prairies and rock ridges. The area covers a large portion of the Florida Bay, a large carbonate mud bank. The park contains some of the most pristine and unique marshland habitat in the continental United States.

Everglades National Park identified 385 quadrangles of interest. The Florida State Geologic Survey (FGS) has digitized a geologic map covering the state from individual county maps at a small scale (~ 1:750,000). This map only displays 4 separate geologic units (Holocene sediments, Key Largo Limestone, Miami Limestone, Tamiami Formation) for inside the boundaries of the park. Located within the quadrangles of interest are 11 additional geologic map units.

Other geologic maps covering portions of the park itself include the FGS MS6/22 (1:24,000, 2000), the benthic habitat map published by NOAA CSC (1:48,000, 1999), Geological Society of America (GSA) Memoir 147 (1:79,000, 1977), the FGS OFMS 83/01-07 (1:100,000, 1996), 83/08-12 (1:100,000, 1995), 67 (1:26,720, Dade County), 66/01 (1:26,720, Monroe County), 63 and Series 120 (1:26,720, Collier County), USGS OF 97-526 (1:120,000, 1997) and 86-4126 (1:136,000, 1986).
Additional mapping at a smaller scale will be more helpful for park management.

Physiography

South Florida in the area of the Everglades is divided into 5 physiographic provinces. The Everglades province forms a south dipping, spoon-shaped low-lying area between the Atlantic Coastal Ridge to the east, the Big Cypress Swamp to the west, and the Sandy Flatlands area to the north. The basin has very low relief. The elevation change is only 3.6 to 4.3 m (12-14 ft) from the maximum near Lake Okeechobee to sea level. Prior to anthropogenic alteration, this drainage system flowed slowly from north to south.

Bounding the Everglades province on the east is the Atlantic Coastal Ridge. It is comprised of Pleistocene marine limestones covered by thin quartz sand sheets. The province ranges in elevation from 1.5 to 6 m (5 to 20 ft) in the southernmost portions. The width of the ridge ranges from 16 km (10 miles) in southern Miami-Dade County and narrows to 5 to 8 km (3 – 5 miles) further north. Periodically breaching the southern portions of the ridge are sloughs (transverse glades) oriented perpendicular to the trend of the ridge.

The southern reaches of the Everglades and Big Cypress Swamp provinces transition into the Coastal Marshes and Mangrove Swamp physiographic province. The province covers an area from the northeastern part of Florida Bay, around the southern Florida peninsula, and west, into the Gulf of Mexico up to the Ten Thousand Island region never Everglades City. Bands of swamps and brackish marshes sitting just above sea level characterize this province. Freshwater runoff and tidal fluxes cause the salinity to change dramatically. This is why the mangrove, capable of enduring such salinity changes, thrives in this area.

The Big Cypress Swamp province defines the western boundary of the Everglades. This area is slightly higher in elevation than the Everglades basin because it is underlain primarily by the coral-rich limestones of the Pliocene Tamiami Formation (3-4 Ma). This formation is exposed in large areas of Big Cypress. Drainage in the province is primarily to the south and southwest.

Geologic History of South Florida

Sediment cores indicate that South Florida has been predominantly an area of carbonate accumulation since the Mesozoic.

Late Paleozoic Era – During the Mississippian, the landmass that would underlie the grand carbonate platform of Florida today was not attached to the North American Craton. It is speculated that it was attached to the northwest portion of the African continent (Condie and Sloan, 1998). However, marine carbonates were being deposited over large portions of the area atop a Paleozoic age crystalline basement high, the Peninsular Arch (Pollastro *et al.,* 2000). In the Pennsylvanian, a collision event, known as the Ouachita orogeny sutured the Florida landmass to the continent as Gondwanaland and North America collided eventually forming the supercontinent Pangaea. The land was still submerged and south Florida was located at the junction of the North American, South American, and African plates. Through the Permian, Pangaea remained intact (Condie and Sloan, 1998).

Early Mesozoic Era – No sooner had Pangaea formed than it began to break up. During the late Triassic, South and Central America and Africa began to rift away from North America. This established the long-standing passive margin of the eastern seaboard that persists today. The Florida and Cuba blocks detached from northwest Africa and the Gulf of Mexico opened (Condie and Sloan, 1998).

Accompanying the rifting of Pangaea was the widespread extrusion of volcanic rocks consistent with mantle plume upwelling due to crustal tension (Heatherington and Mueller, 1991). This continental rifting also opened the Atlantic Ocean basin.

Middle Mesozoic Era - Underlying the south Florida basin are igneous rhyolitic - basaltic rocks (Thomas *et al*., 1989). These rocks were subaerially exposed and eroded during the late Triassic to middle Jurassic. This caused the formation of redbeds locally. As the Atlantic Ocean continued to develop, deltaic and shallow marine sediments were deposited in the late Jurassic. Restriction of marine circulation at this time resulted in periodic accumulations of evaporites and marine carbonates (Cunningham, 2005). Deposition of Jurassic and Cretaceous sediments was controlled by the south-southeast plunging axis of the Peninsular Arch. Basal sediments onlap and pinch out against the arch (Pollastro *et al.,* 2000).

Late Mesozoic Era – As marine transgression proceeded during the early Cretaceous, the Florida Platform was the site of more widespread deposition of marine limestones and reefs. Further transgression and global warming during the Late Cretaceous established an open marine accumulation of carbonates over the entire Florida Peninsula.

Cenozoic Era – Cenozoic development of the Florida Platform included additional deposition of marine carbonates and deposition of siliciclastics (grains of silicate minerals such as quartz in lieu of carbonates) from northwestern highlands sources and long shore oceanic currents. Tertiary faulting occurred south of Florida as the Cuban block collided with the Antilles arc and carbonate accumulation continued in Florida (Condie and Sloan, 1998). In southern Florida, the open marine setting continued during the Paleocene as more restricted flow to the north resulted in deposits of mixed carbonates and evaporites. Eocene and Oligocene

deposition is marked by shallow water carbonates. Intermittent with this deposition were subaerial exposures associated with local oceanic regressions.

Deposition in south Florida during the Miocene changed with the introduction of more widespread siliciclastics from a fluvio-deltaic system prograding down the peninsula. Phosphates and the carbonate ramp of the Arcadia Formation were deposited during the Miocene in south Florida. A Pliocene lowstand caused many of the previous deposits to be reworked and/or eroded. The Everglades area was the deposition area of a thick pile of sand that was being transported south to eventually form the Long Key Formation (Guertin *et al.,* 1999; Cunningham, 2005).

The Pleistocene era resulted in the conversion from siliciclastic deposition mixed with carbonate accumulation to more widespread carbonate sedimentation (Cunningham, 2005). Global sea-level changes during the intermittent ice ages of the Pleistocene controlled the rate and distribution of carbonate units. At 120 Ka, the last major sea level fall occurred as the mixed carbonate-siliciclastic sediments formed the Fort Thompson Formation. This unit interfingers with the surficial geologic units, the Miami and Key Largo Limestones, and the Anastasia Formation (~130 Ka) (Cunningham, 2005).

At 15-16 Ka sea level began to rise rapidly and flood southern Florida around 7 or 6 Ka (Shinn *et al.,* 1997). Sea level has continued to rise. Holocene geologic activity in the Everglades area consists of the dissolution of carbonate units, the accumulation of carbonate muds, marine and freshwater marls, sand and swamp deposits.

Stratigraphy

Cores such as the deep, continuous core near the Everglades National Park Research Center (W-17232), those of the South Florida Drilling Project (Florida Geological Survey, University of Miami, Florida Department of Transportation), and the USGS help constrain the stratigraphy underlying the park.

The lowest unit penetrated by the core in the park is the Arcadia Formation (top surface at 147 m, 482 ft). This formation consists of ramp setting carbonates with scant quartz contents increasing northward (~20% quartz grains at W-17232) (Cunningham, 2005). A major disconformity marks the boundary between the Arcadia Formation and the overlying Peace River Formation. The Peace River Formation is absent south of the Everglades. It contains two distinct units: a lower diatomaceous mudstone, and an upper fine-grained quartz muddy sandstone (Cunningham *et al.,* 1998). The top of the Peace River Formation is 98.8 m (324 ft) below the surface at W-17232 (McNeill *et al.,* 1996).

Cunningham *et al*. (1998) proposed a new unit, the Long Key Formation, for subsurface siliciclastics underlying the southernmost reaches Florida (from core W-17156 on Long Key). This unit is coeval with the Stock Island Formation of the lower Florida Keys (Guertin *et al.,* 1999). The top of the Long Key Formation in the park is 17.4 m (57 ft) below the surface. The siliciclastics of the unit were deposited in at least three pulses (late Miocene, early Pliocene, and latest Pliocene/earliest Pleistocene). They are present in a channelized morphology of coarse-grained sands (>1mm) (Warzeski *et al.,* 1996).

Shallow water limestone of the Fort Thompson Formation comprises the uppermost 17 m of cored section in the Everglades. This limestone is probably combined with the capping unit of the Miami Limestone. The Fort Thompson is mostly lagoonal facies carbonate with abundant bivalve fossils and some quartz sand. The Miami Limestone is ~125 – 130 Ka and represented deposition during an interglacial period. Two facies, the oolitic facies and the bryozoan facies are more or less combined in most of the outcrops at Everglades National Park (Hoffmeister *et al.,* 1974; Cunningham, 2005).

Overlying the Miami Limestone bedrock are surficial units of freshwater peat and organic muck, freshwater and marine marls, and cyanobacteria mats. The peat and muck typically occurs in low-lying sloughs and solution holes and are dark and fine-grained. During the standing water phase of the wet season, extracellular precipitation of calcium carbonate by cyanobacteria forms fresh and marine limestone marls. The marine marls (Flamingo Marl) are dominated by aragonitic mud, and shell deposits that form a sort of coastal levee around the southern rim of the park (Cunningham, 2005).

Significant Geologic Resource Management Issues in Everglades National Park

1. The Florida Bay mud banks elevation and stability

The Florida Bay is covered by an extensive system of supra- and subtidal carbonate mud banks, coastal marl ridges, coastal carbonate mud ridges, mangrove peat deposits, and mollusk deposits. There is a strong resource management need to understand how water moves around the bay and what buttressing effect, if any, the mud and marl ridges have on the flow of water. Another concern is gaining an understanding of the nature of landscape evolution during late Holocene sea level rise (23 cm, 9 inches rise in sea level in 70 years). Many of the freshwater marshes behind the ridges are changing to super saline marine lagoons.

The features in the bay are strongly related to minute changes in elevation. Environments can change within centimeters of topographic relief. Given the coverage of mapping at the park, normal surficial maps are not sufficient for complex management decisions at the Everglades. An interdisciplinary approach to mapping is critical to producing a useful product for resource management. Anthropogenic, supratidal, intertidal, subtidal, and coastal features would all be helpful. This holistic ecosystem approach integrates biological, physical, cultural, and oceanographic variables.

LIDAR surveys in addition to satellite imagery, multibeam mapping, bathymetry data, water quality and circulation, shoreline change data, pre/post storm comparisons, oceanographic data (waves, tides, currents, turbidity, temperature salinity, sediment transport patterns, coral larvae and other species distributions), etc. are essential for resource management at Everglades National Park. Research and monitoring questions and suggestions include: What is the relationship between coastal marl and carbonate mud ridges and the buttonwood distribution? What is the minimum mapping unit relevant to resource management? What are the flow dynamics (especially related to salinity) in the bay? What controls the distribution of the mud banks? Is there any remediation possible for the hypersaline environment in the central portion of the bay? Why does the basin and bank character of the Florida Bay resemble hexagonal mudcracks?

2. Mangrove zone topography and buttonwood ridge height

The mangroves thrive in oscillating fresh-saline water conditions. In a sense, they define the water level. A baseline needs to be established regarding sea level rise to determine its effect on the mangrove areas. Detailed topography would help manage this resource. The scale of inches is important for the low banks and ridges where the tides and wind expose the entire western basins.

3. Whitewater Bay and Gulf Coast estuaries

Whitewater Bay sits behind Cape Sable and is fed by the Shark, Broad, and Harney Rivers. It is bound by a buttonwood embankment growing as a natural berm on a storm beach made of mud.

Research and monitoring questions and suggestions include: What is the relationship between the diversion of water through canals and the buttonwood distribution? What is the nature of the Shark Slough-Taylor Slough divide?

4. Solution holes

Solution holes are an element of the karst topography at the park. They provide essential habitat for fish and other wildlife during the dry winter months at the Everglades. Solution holes occur throughout the park (especially in the eastern half) and need to be systematically located, mapped, and described for resource management.

Research and monitoring questions and suggestions include: How are solution holes and other karst features affecting water quality at the Everglades? Are solution holes sources of phosphorus input? How do solution holes affect the hydrogeologic regime including retention time, hydraulic head, and water storage?

5. Aquifer characteristics and groundwater flow dynamics

The interaction between groundwater flow and the overall fresh water and marine ecological quality must be quantitatively determined at the Everglades. Visitor uses and surrounding development are increasing the levels of certain substances in the water at the park. Nutrients from waste are causing algal blooms. Salinity levels are dependent on seasonal freshwater input and tidal circulation in the Florida Bay.

Research and monitoring questions and suggestions include: How many wells are necessary to model the hydrogeologic system at the park? Model the porosity and permeability of the Fort Thompson layer. Examine the salt wedge characteristics versus the surface water. Is increasing the hydraulic head at the Everglades a good idea? How would an increase in hydraulic head affect the local spring activity?

6. Recreation and other use demands

In 2003, Everglades National Park hosted 1,031,888 recreation visits. These in are placing increasing demands on the limited resources and fragile ecosystem of the park. Motorized boat access and fishing motors are restricted in the wilderness areas of the park.

Research and monitoring questions and suggestions: Are visitors affecting sediment transport and the hydrologic system at the park?

7. Earthen and failed dams, canals, and sheet piling

Dams and other earth works in the park pose a serious threat to the safety of visitors and park resources. During the 1930's a series of canals and levees were constructed (including East Cape canal, Homestead canal, Slegel's ditch, Houseman's ditch, and Middle Cape canal) to divert the water away from the "prime" real estate around Cape Sable. The real estate venture failed and the land was later included in the park boundaries. The remediation of the canals and earth works is a park responsibility.

Canals throughout south Florida divert water away from the natural flow between Lake Okeechobee and the Everglades. Locally, near Cape Sable and Lake Ingraham, the flow is disrupted and sediment transport patterns have changed. Fresh water marshes behind the cape are being salinated due to the overall lack of fresh water input.

8. Sediment transport and resuspension at Cape Sable and Lake Ingraham

The very nature of the landscape at the Everglades is one of change. Shifting muds and sands continually alter the shape and profile of the shoreline. Sand and mud erode from one beach and are deposited elsewhere in the course of a single storm event. Focus also needs to be on understanding the sediment transport dynamics at the park. The hydrogeologic system in the area around Lake Ingraham was altered with the construction of canals, roads, and levees. As a result, sediments scouring through the canals are being deposited in the lake basin (6-30 cm/year, 2.4-11.8 inches/year) and the lake levels are very low and are often exposed at low tide. The delta emanating from the Middle Cape Canal is expanding and increasing the sediment influx for the Florida Bay. Salinity is increasing as 80 high tides a year are cresting the low marl ridges. Higher salinity waters are encroaching on the fresh water areas. This leads to a decline in marsh, mangrove, and prairie areas.

Research and monitoring questions and suggestions: Are declines in mangrove, marsh, and prairie areas due to the canal system or sea level rise around Lake Ingraham? USGS survey points are too far apart for proper monitoring of landscape response to sea level rise (~400 m, 1,312 ft apart). Can the number of these points be increased? Should fill dams be destroyed or reestablished? What remediation can be done on the eroded canal openings (erosion rate is 0.6-1.2 m/year, 2-4 ft/year)? What is the rate of change in sediment transport around Cape Sable? How much sediment is being lost through canal scouring? What would be the effects of replugging the Middle Cape Canal?

9. Sinkholes and karst features

The Fort Thompson limestone is a very permeable unit. Borrow pits and canals intersect this unit in many locations of the park. This is affecting water flow. Approximately 50 sinkholes have been located in the park. These serve as vital habitat during the dry season. However, their distribution, characteristics, depths, and interconnectedness need to be systematically mapped and described.

Research and monitoring questions and suggestions: What steps should be taken to model water flow in the park regarding karst features? Could aerial photography be used to map sinkholes? What is the relationship, if any, between solution holes and other karst features and the distribution of hardwood hammacks and tree islands at the park?

10. Paleoclimates

Cores in Florida and Biscayne Bays, and numerous sloughs in the park show peat and pollen as indicators of past climates. The spatial coverage for the cores is not at an adequate resolution to determine the temporal relationships and make interpolations between points. Bioturbation and other ground disturbances (railroad infill effects) distort the subsurface features.

Research and monitoring questions and suggestions: Perform more coring operations to increase coverage at the park. Identify pollen species and correlate with paleoclimate.

11. Sea level rise

Sea level rise is affecting all of South Florida. While slowing the rate of sea level rise is beyond the resources of the park, monitoring sea level change and evaluating/predicting impacts on the park's landscape is a valid management issue. The fresh water marshes and brackish estuaries are under constant threat of inundation by the sea. Given the low relief of the park, this rise will destroy much of the marsh landscape protected at the park. Sea level rise is also causing beach erosion near Cape Sable and Lake Ingraham. Increases in turbidity with rising seas are causing large seagrass dieoffs and increased carbonate material suspension.

Research and monitoring questions and suggestions include: Is there any way to save the subaerial habitat from rising seas? What is the local rate of sea level rise? Looking at the affects of storm surges, how will the buttonwood/mangrove zones respond to the rising water? What direction should future planning proceed in light of the current restoration effort? Monitor and measure the relationship between water level flux and elevations to determine an exposure/submergence index (i.e. 100% of the time exposed versus 0% of the time exposed). Quantitatively define the terms subtidal, intertidal, and supratidal to use for future predictions and relate these to the local elevations and annual regime of water fluctuations.

12. Geologic changes due to storms and hurricanes

Storm events and hurricanes have a pronounced and often catastrophic effect on the landscape of south Florida. Baseline conditions must be determined and studied for the resource management to predict the environmental response. Hurricane Donna in 1960 evacuated water from the bay by about 1 m (3 ft), then the water rushed back in to a depth of 2.1 m (7 ft). This resulted in mud deposition on the south side of the mud ridges and a high-energy shell layer deposit on the north side. Hurricane Andrew blew the highland beach area near the Ross River away. Geochemical changes resulting from the influx of storm water went unmeasured in the panic and cleanup by local agencies.

Research and monitoring questions and suggestions include: Develop a response protocol in cooperation with other local agencies to determine the geochemical effects of storm surges. What are the recovery rates of mangroves after large storm events? Establish baselines for comparison and prediction of future events.

13. Atmospheric deposition of African dust

Dust has been blowing across the Atlantic Ocean and depositing in south Florida for thousands of years. Paleosols and reddish (oxidized) layers atop the Miami Limestone attest to these airborne inputs. The process continues today, but modern development has introduced nutrients, elements, microbes, pesticides, soot, organics, bacteria, viruses, and other contaminants to the dust. The dust diminishes air water visibility. A peak of dust fall in the 1980s coincided with a sea urchin disease and other benthic system killoffs. Lead,

arsenic, phosphate, copper, iron, and mercury concentrations in the surface sediments in the middle of Florida Bay are highest in low tidal flux areas.

Research and monitoring questions and suggestions include: There are 9.1 m (30 ft) monitoring wells in the bay; these could be expanded and utilized (contact Gene Shinn). Did the combination of dust and hypersalinity kill sea grass and cause algal blooms in Florida Bay? Monitor dust levels and attempt to correlate with environmental responses. Are dieoffs caused by African dust or by the transport of sediments, nutrients, and organics transported out during rising seas and storms?

14. "Lake Belt" management

The term "Lake Belt" refers to a series of quarries near the park. These features are supposed to supply water to the park as part of a restoration effort. There is some concern about how these features are affecting groundwater movement. Some USGS monitoring wells are located near levees, but more wells would increase the understanding of the local hydrogeologic system. Local agriculture introduces sulphates, phosphorus, and other contaminants into the groundwater near these lakes that, given the permeable, conduit-rich bedrock, would easily contaminate the water in the quarries and affect the ecosystem of the park.

15. Tree islands and hardwood hammacks

Tree islands and hardwood hammacks are prevalent features at the Everglades. They dot the sawgrass prairies throughout the park. They appear to be oriented in linear trends. There is discussion as to whether the islands and hammacks are located in bedrock highs or lows. They could be located in peat depressions, or perhaps on a laminated duracrust formed by phosphorus from evaporites pulled up by the trees in the groundwater.

Rock ridges, such as that at Rock Reef Pass, are subtle, enigmatic linear features on the landscape at the Everglades. There are approximately 20 rock ridges in south Florida. The amount of relief associated with these ridges is small, approximately 0.9 to 1.5 m (3-5 ft), but the vegetation changes across them and makes them appear more pronounced. Many theories abound as to why these features exist. Are they paleoshores, results of Pleistocene wrench faulting, developed fractures, concentrations of shells in oolite, paleo mudbanks, or the result of differential compaction and fracturing?

Research and monitoring questions and suggestions include: There are numerous theories as to why these features exist. Can hydrogeochemistry determine if the bedrock is a source of phosphorous for these trees? How did the tree islands and hardwood hammacks form? What is the geologic control on their distribution? Are their linear trends related to elongated paleoflows? Obtain more cores in a transect through a rock ridge to help determine why they exist. Core tree islands to bedrock to determine the nature of their formation. Install a monitoring well into the tree islands to look at differences in local groundwater chemistry.

16. Archaeological sites

There are several sites, approximately 12,000 years old, along ancient coastlines that contain artifacts from the local indigenous populations. Mapping and/or reconstructing these sites

would add to the cultural value of the park and help reconstruct the paleoshoreline in the Ten Thousand lakes, and Cape Sable areas especially.

Scoping Meeting Participants

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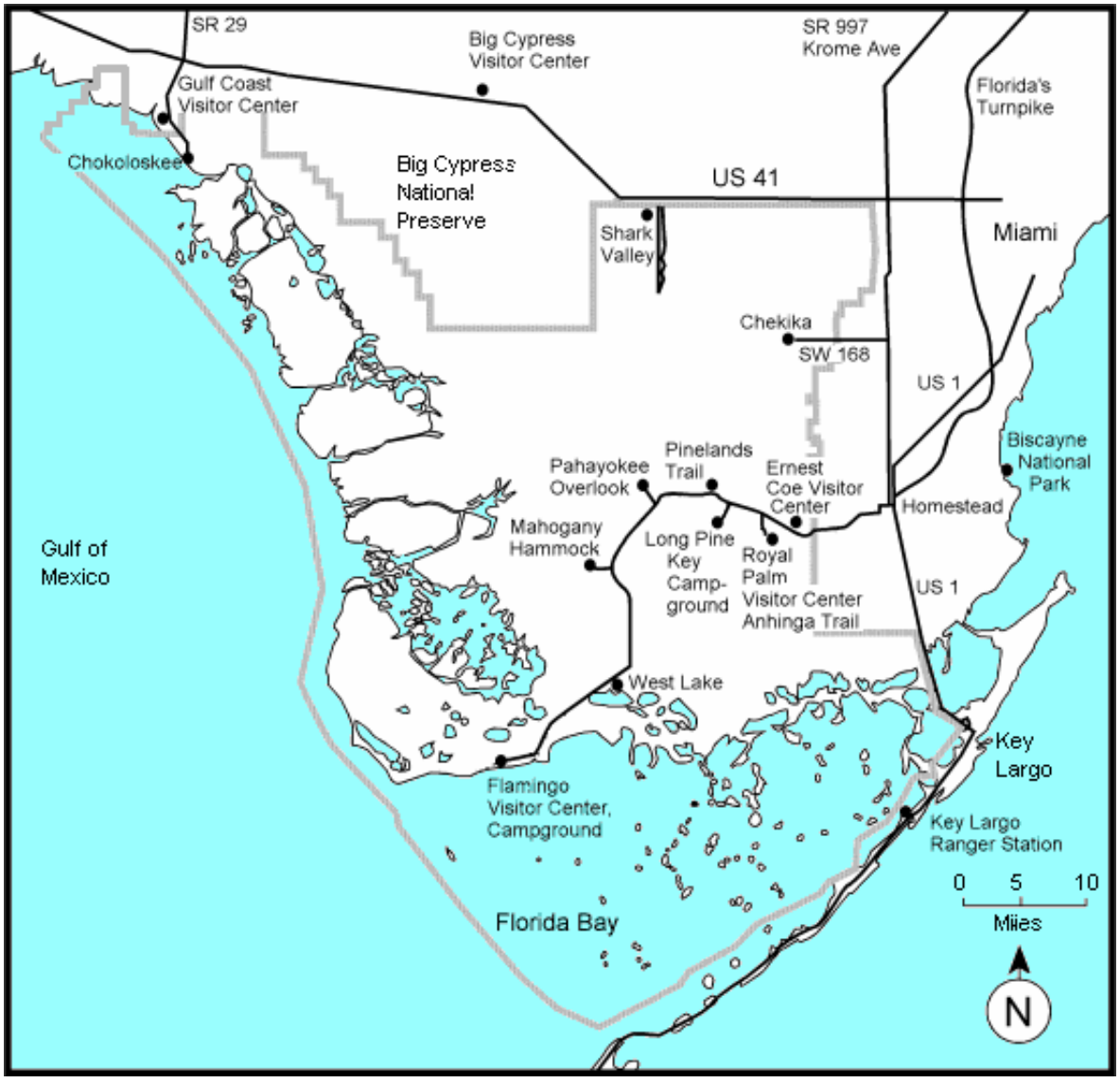
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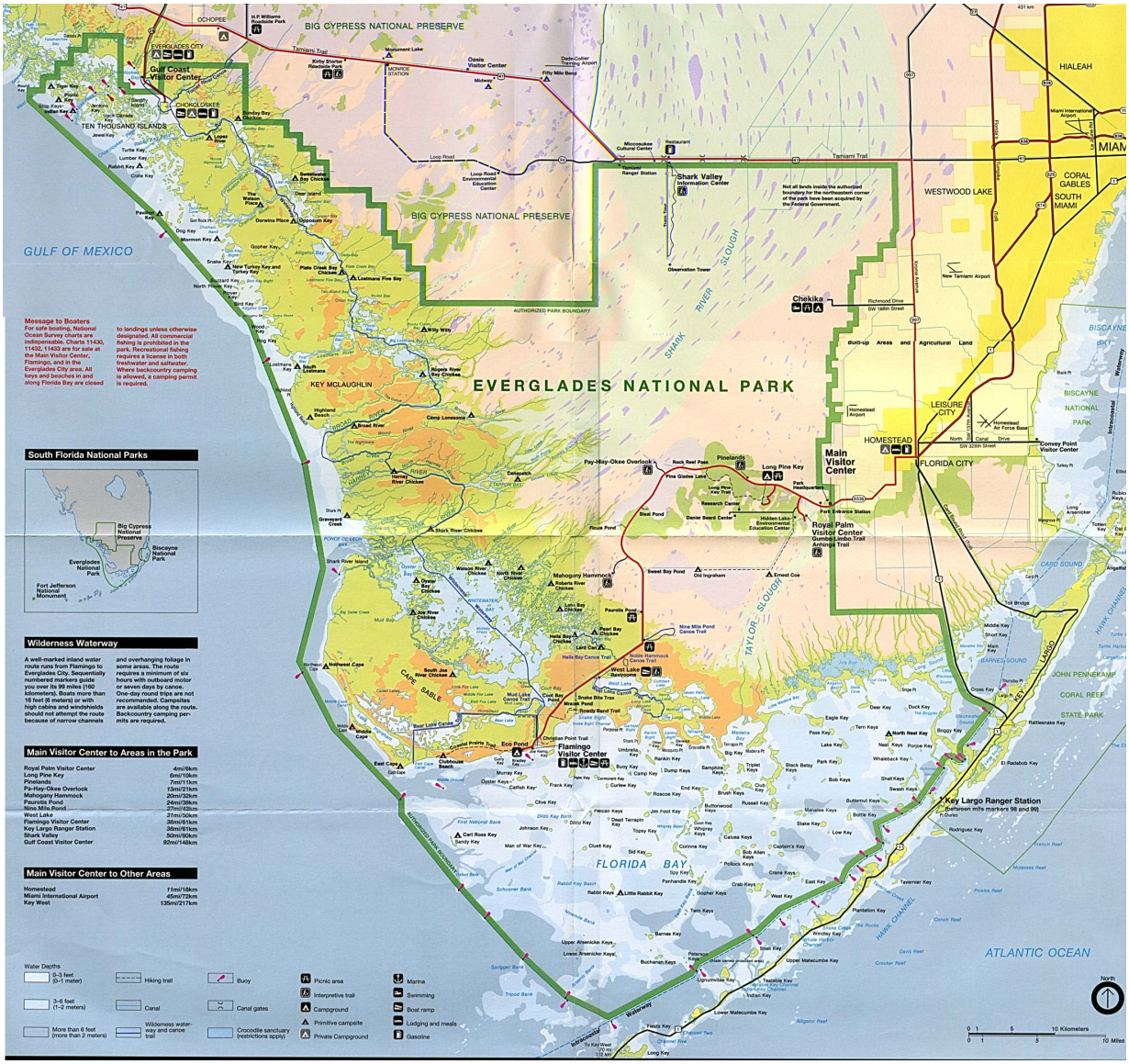
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Maps of Everglades National Park




EVERGLADES NATIONAL PARK
BIG CYPRESS NATIONAL PRESERVE
GULF OF MEXICO
FLORIDA BAY
ATLANTIC OCEAN
Message to Boaters
South Florida National Parks
Wilderness Waterway
Main Visitor Center to Areas in the Park
Main Visitor Center to Other Areas
Water Depths
Flamingo Visitor Center
Royal Palm Visitor Center
Main Visitor Center
Shark Valley Information Center
Key Largo Ranger Station
Gulf Coast Visitor Center
Chekika
TEN THOUSAND ISLANDS
KEY MCLAUGHLIN
HOMESTEAD
FLORIDA CITY
LEISURE CITY
WESTWOOD LAKE
CORAL GABLES
SOUTH MIAMI
HIALEAH
MIAMI

APPENDIX E.6

SALT RIVER BAY NATIONAL HISTORIC PARK AND ECOLOGICAL PRESERVE

GEOLOGIC RESOURCE MANAGEMENT ISSUES SCOPING SUMMARY



Kimberly N. Hall
Geologic Resource Evaluation
September 1, 2005

INTRODUCTION

The National Park Service conducted a Geologic Resources Evaluation scooping meeting at Salt River Bay National Historic Park and Ecological Preserve (SARI) on April 6, 2004. The purpose of the meeting was to discuss the status of geologic mapping in the park, the associated bibliography, and the geologic issues in the park. The products to be derived from the scoping meeting are: (1) Digitized geologic maps covering the park; (2) An updated and verified bibliography; (3) Scoping summary (this report); and (4) A Geologic Resource Evaluation Report which brings together all of these products.

Salt River Bay National Historic Park and Ecological Preserve (SARI) was established by Congress on February 24, 1992 to protect and preserve an astounding array of natural and cultural resources. The park includes fragile coral reefs, a submarine canyon, and the largest remaining mangrove forest found in the Virgin Islands. The National Park Service and the Government of the U.S. Virgin Islands jointly manage this 1,015 acre park and preserve.

Salt River Bay National Historic Park and Ecological Preserve is not identified as an inventory and monitoring park, and therefore, significant time was not spent addressing the geologic inventory and monitoring needs. However, the scoping meeting participants identified the following as the most significant geologic resources management issue at the park:

Complete structure and bedrock maps to compliment existing benthic habitat maps.

SARI MAPPING PRODUCTS

Salt River Bay National Historic Park and Ecological Preserve has "quadrangles of interest" (or "QOI's") at the 7.5'x7.5'- *(1:24,000) scale.* It is desired to obtain DIGITAL geologic map coverage for all identified 7.5' qoi's. (Figures 1,2 and 3).

While numerous "paper" maps at suitable scale have been published for this park, complete DIGITAL geologic map coverage is not known. It is hoped that through the scoping meetings and discussions with park staff , the USGS and state geological surveys that gaps in DIGITAL coverage can be resolved for areas not currently known to have digitized geologic maps. These meetings lay the foundation for a plan to accomplish this task

The contents of this document reflect what is known regarding published geology as of September 6, 2005 from searches done by NPS-GRD staff as discerned from the USGS on-line geologic maps database found at: *http://ngmdb.usgs.gov/ngmdb/ngm_compsearch.html*

In short, it appears a few maps do give coverage for the island of Saint Croix as follows:

- NOAA Benthic Habitats map

- Whetten, J.T., 1966, Geology of St. Croix, U.S. Virgin Islands, Geological Society of America, Memoir 98, 1:31,680 scale

During the scoping sessions held in April 2004 for Buck Island Reef National Monument (BUIS), SARI and Christiansted National Historic Site (CHRI), it was decided that the Whetten map would be the best available source to give the bedrock geology of the island of Saint Croix, as it would also encompass all three NPS areas on the island of St. Croix (Figures 1 and 2) . NPS-GRE staff will acquire the original map and convert it into a digital, user-friendly GIS product.

The NOAA benthic habitat maps will accompany the bedrock map of the island and is already available digitally. NPS-GRE staff will incorporate it as well into a final geologic map of the island. A summary table follows along with explanatory graphics.

Extent of Coverage	Published Map Citation	Paper	Digital	GRE Plan
Entire island of Saint Croix	Whetten, J.T., 1966, Geology of St. Croix, U.S. Virgin Islands, Geological Society of America, Memoir 98, 1:31680 scale	yes	Unknown	Acquire paper copy and convert to digtal
Entire island of Saint Croix	Kendall, M.S., M.E. Monaco, K.R. Buja, J.D. Christensen, C.R. Kruer, and M. Finkbeiner, R.A. Warner, 1999, Benthic Habitat Maps of the U.S. Virgin Islands-St. Croix; Prepared by Visual Interpretation from Remote Sensing Imagery Collected by NOAA in 1999, 1:6000 scale	Unknown	Yes, from NOAA	Convert NOAA digital version to NPS format

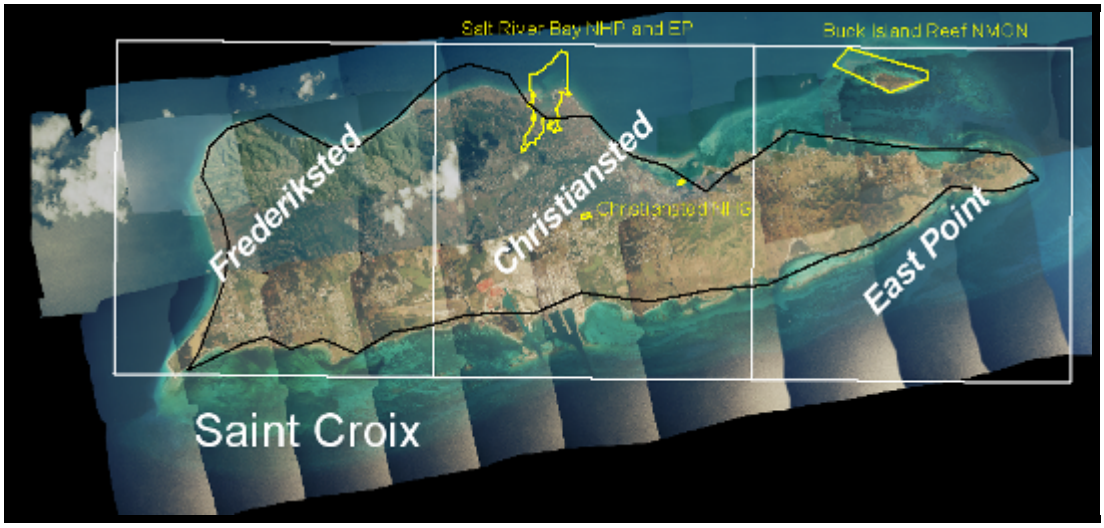


Figure 1: Quadrangles of Interest (QOI's) for BUIS, SARI, and CHRI (7.5' shown in white outline; park boundaries in yellow outline; MrSID image of Island of Saint Croix as background).

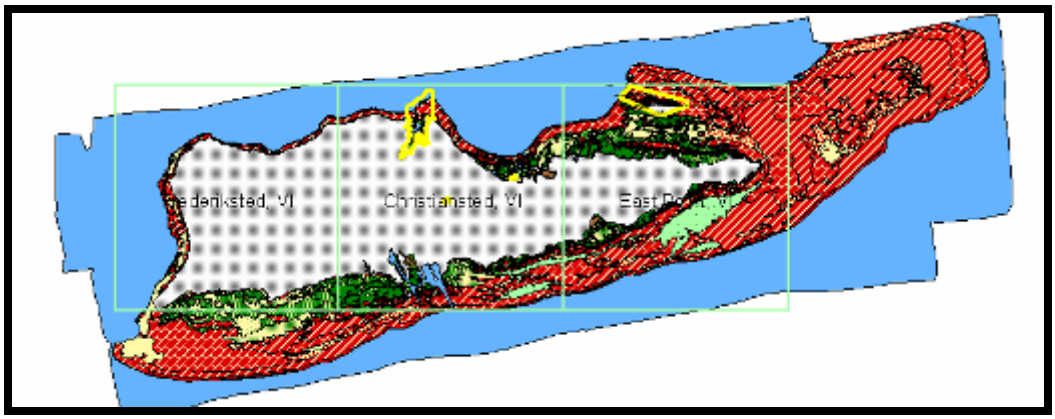


Figure 2: NOAA Benthic Habitats of Saint Croix Island

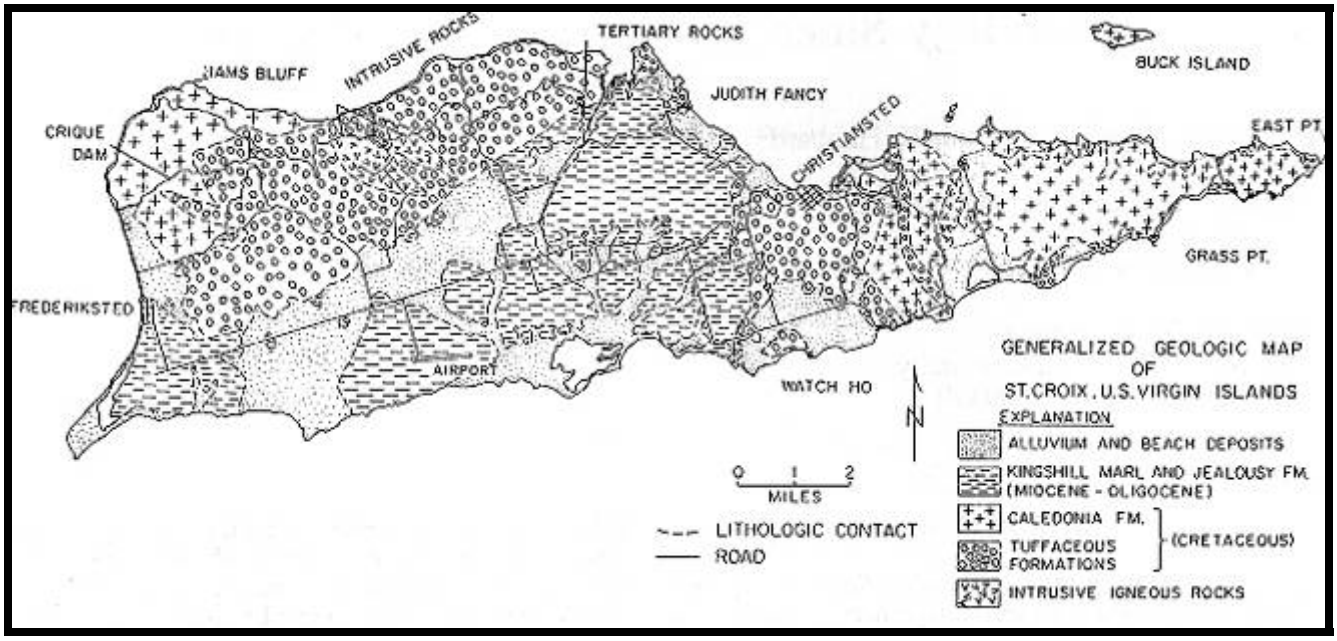


Figure 3: Scan of Generalized Geologic Map of Saint Croix (after Whetten 1974, in Hubbard SP8)

GEOLOGY AND STRATIGRAPHY OF SARI

Salt River Bay consists primarily of two geologic units - the Miocene Kingshill Formation and the Cretaceous Judith's Fancy Formation (Justus *et al.*, 1975: Gill *et al.*, 2002a: Gill *et al.*, 2002b: Kendall *et al.*, 2005). The Kingshill Formation is predominantly composed of limestone. This unit underlies much of the Salt River drainage basin and the area south of the park. The northern portion of the basin and the exposed bedrock around Salt River Bay are composed of the Judith's Fancy Formation. This unit consists of volcaniclastics, sandstone, mudstones, and a few small gabbro and diorite intrusions (Kendall *et al.*, 2005).

The Salt River Bay National Historic Park and Ecological Preserve encompasses an estuary and a submarine canyon that are separated by a narrow coral reef. The estuary is divided into three embayments including Sugar, Triton and Salt River Bays. Sediment cores taken within the park demonstrate a fining-upward in estuarine deposition, most likely reflecting the gradual enclosure of the estuary due to reef accretion, and the corresponding decrease in open marine conditions (Hubbard, 1989).

The accretionary reef at Salt River Bay has effectively created a depositional barrier between the estuary and submarine canyon. Sediments within the upper estuary are terrigenous, containing mollusk and *Halimeda* fragments. Seaward of the reef, sediments rapidly coarsen and reef components become increasingly important. Sediments within the canyon are almost exclusively carbonate in composition due to bioerosion. The canyon floor is composed primarily of medium- to coarse- grained carbonate sands (0.27 – 0.99 mm), becoming increasingly finer down canyon (Kendall *et al.*, 2005).

Salt River Canyon is believed to be related to a previous lowstand of sea level. The Salt River Canyon extends to a depth of 80-100 meters at its seaward edge. Due to sedimentary deposition and reef accretion, the canyon is in a constant state of transition and is most likely different from its original topography.

Currents within Salt River Canyon rarely exceed 10-15 cm/sec. However, currents greater than 50 cm/sec were observed down canyon during storm events (Hubbard, 1989). In addition, suspended sediment loads within the canyon are normally high, and increase dramatically during storm events. It is estimated that 66,000 kg of sediment enter the canyon annually, with approximately one third of the total introduced during storm events. In contrast, only ~18,000 kg of sediment are removed from the system each year, creating a gradual net increase within the canyon. The long term build up of sediments is periodically purged during storm events and hurricanes (Hubbard 1989; Kendall *et al.*, 2005).

In general sediments move from east to west on the shelf adjacent to the submarine canyon. This movement creates highly different characteristics on the east and west canyon walls. The eastern wall is characterized by a gradual slope, covered in cobbles and sparse corals. Organisms that can tolerate high sediment influx and scouring such as gorgonians and sponges are dominant. In contrast, the western canyon wall is steep with many overhangs and caves. Numerous grooves and tributaries cut into the canyon wall, and abundant fracturing and slumping are evident. Primary organisms found on the western wall include antipatharians, scleractineans corals and plexaurids. The most common corals include *Mantastrea annularis*, *Siderastrea* sp. and *Agaricia* sp. (Hubbard 1989).

SIGNIFICANT MANAGEMENT ISSUES

Salt River Bay National Historic Park and Ecological Preserve is not identified as an inventory and monitoring park, and therefore, significant time was not spent addressing the geologic inventory and monitoring needs. However, it was discussed that if possible, structure and bedrock mapping should be completed to compliment existing benthic habitat maps. Once complete, the geologic framework may help park managers to understand modern coastal dynamics and morphology by defining which areas are predisposed for more rapid change and/or evolution. Surface and subsurface lithology should be included.

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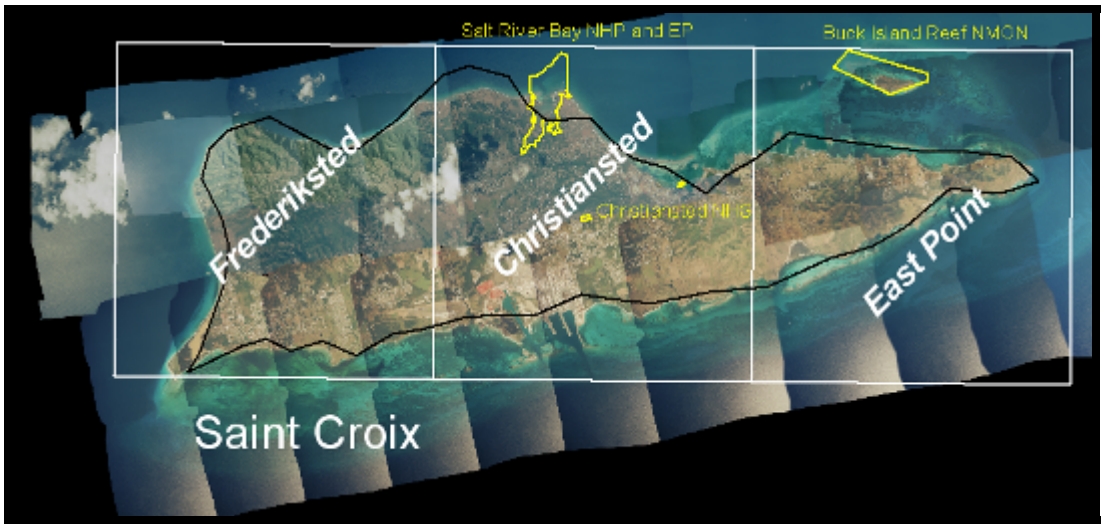
All comments and suggestions to improve this understanding are most welcome at this time and will be summarized in a summary report following from this meeting.
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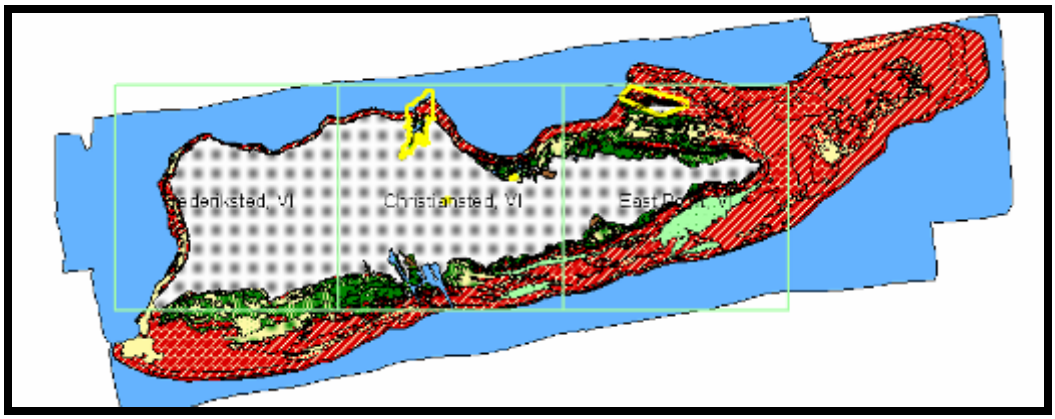
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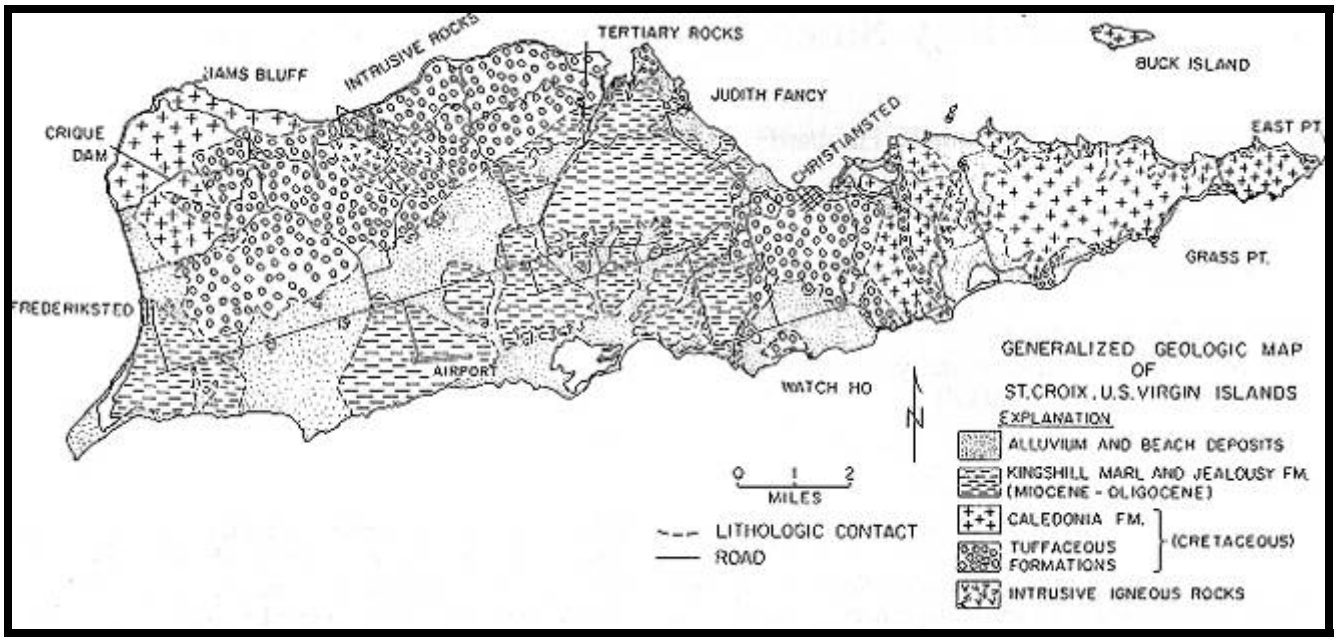
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NOAA Benthic Habitats of Saint Croix Island



Scan of Generalized Geologic Map of Saint Croix (after Whetten 1974, in Hubbard SP8)

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SIGNIFICANT MANAGEMENT ISSUES

Salt River Bay National Historic Park and Ecological Preserve was not identified as an inventory and monitoring park at the time of the April 6, 2004 meeting, and therefore, significant time was not spent addressing the geologic inventory and monitoring needs. However, it was discussed that if possible, structure and bedrock mapping should be completed to compliment existing benthic habitat maps. Once complete, the geologic framework may help park managers to understand modern coastal dynamics and morphology by defining which areas are predisposed for more rapid change and/or evolution. Surface and subsurface lithology should be included.

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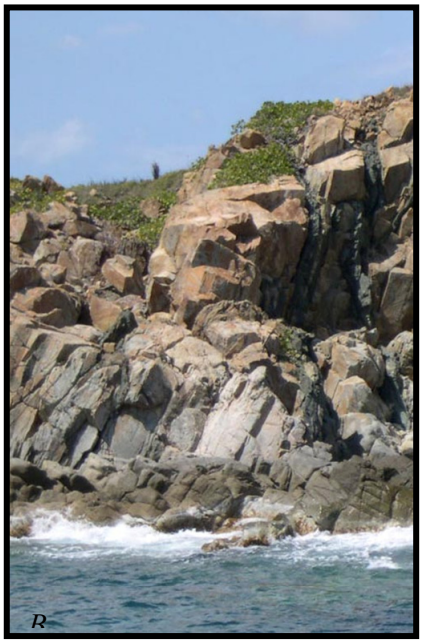
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APPENDIX E.7

VIRGIN ISLANDS NATIONAL PARK
and
CORAL REEF NATIONAL MONUMENT

GEOLOGIC RESOURCE MANAGEMENT ISSUES SCOPING SUMMARY


Kimberly N. Hall
Geologic Resource Evaluation
September 1, 2005

Columnar Jointing on LeDuck Island, USVI. The south shore of St. John is visible in the background.



Hydrothermal alteration in the Water Island Formation, south and central St. John, USVI. The White Cliffs display mineral alteration including copper (green), iron (red), and limonite (yellow). Much of the white coloration is due to the large amount of plagioclase feldspar within the igneous rocks.

Title page:

A) Coastal Erosion at Cinnamon Bay. This Seaside Mahoe was once located in the protected backshore area of the beach. This tree (one of many) died due to continued seawater inundation and coastal erosion. Currently, many important archaeological sites at Cinnamon Bay are threatened due to beach erosion.
Photo: Jack Hopkins

B) Swarming dikes on Ditliff Point, south shore, St. John.

C) Marble Taino trading bead found on Cinnamon Bay, St. John. Scientists question if this bead was created on St. John or imported from an alternate source. This problem demonstrates a clear link between archaeology and geology.

EXECUTIVE SUMMARY

A Geologic Resources Evaluation scoping meeting for Virgin Islands National Park (VIIS)and Virgin Islands Coral Reef National Monument (CRNM) was held at Park headquarters in Cruz Bay, VI on April 7-9, 2004. The scoping meeting participants identified the following as the most significant geologic resource management issues.

1. Minimize the effects of erosion and sedimentation into adjacent marine ecosystems due to land use and grazing.

2. Inventory and monitor coastal resources and processes including beach erosion and accretion due to storm events and recreational demands.

3. Inventory and monitor marine processes and resources such as sediment transport, sediment thickness, coral reef location, and human impacts on benthic habitats.

4. Monitor the possible effects of windblown particulates (i.e. Saharan dust, Monserrat dust) on park resources.

INTRODUCTION

The National Park Service conducted a Geologic Resources Evaluation scooping meeting at Virgin Islands National Park, St. John, USVI, April 7-9, 2004. The purpose of the meeting was to discuss the status of geologic mapping in the park, the associated bibliography, and the geologic issues in the park. The products to be derived from the scoping meeting are: (1) Digitized geologic maps covering the park; (2) An updated and verified bibliography; (3) Scoping summary (this report); and (4) A Geologic Resource Evaluation Report which brings together all of these products.

Virgin Islands National Park (VIIS) was established August 2, 1956, and was declared a Biosphere Reserve by the United Nations in 1976. The park includes slightly more than half of the island of St. John and approximately nine square miles of the surrounding waters. In addition, Virgin Islands National Park includes land in Red Hook, St. Thomas (6 acres), Wintberg Estate, St. Thomas (4 acres), and Hassel Island (135 acres). The total area of VIIS is currently 14,689 acres (FY-2004).

Virgins Islands Coral Reef National Monument (CRNM) was established by President Clinton on January 17, 2001, to protect and preserve the delicate coral resources contained within. This monument contains 12,708 acres of submerged lands adjacent to St. John including Hurricane Hole.

VIIS MAPPING PRODUCTS

Virgin Islands National Park has "quadrangles of interest" (or "QOI's") at the 7.5'x7.5'-*(1:24,000) scale.* It is desired to obtain DIGITAL geologic map coverage for all identified 7.5' qoi's.(Figures 1,2 and 3)

The contents of this document reflect what is known regarding published geology as of September 6, 2005 from searches done by NPS-GRD staff as discerned from the USGS on-line geologic maps database found at *http://ngmdb.usgs.gov/ngmdb/ngm_compsearch.html*

Virgin Islands National Park is covered by the following maps:

- *Rankin, D.W., 2002, Geology of St. John, U.S. Virgin Islands, US Geological Survey, Professional Paper 1631, 1:24000 scale*
- NOAA Benthic Habitats map

During the scoping sessions held in April 2004, for VIIS, it was decided that the Rankin map would be the best available source to give the bedrock geology of the island of Saint John. NPS-GRE staff acquired the original paper map and converted it into a digital user-friendly GIS product that is available on-line at http://science.nature.nps.gov/nrdata/

The NOAA benthic habitat maps will accompany the bedrock map of the island and is already available digitally. NPS-GRE staff will incorporate it as well into a final geologic map of the island. A summary table follows along with explanatory graphics.

Extent of Coverage	Published Map Citation	Paper	Digital	GRE Plan
Entire island of Saint John	Rankin, D.W., 2002, Geology of St. John, U.S. Virgin Islands, US Geological Survey, Professional Paper 1631, 1:24000 scale	yes	Yes	GRE already have digitized this map
Entire islands of Saint John and Saint Thomas	Kendall, M.S., M.E. Monaco, K.R. Buja, J.D. Christensen, C.R. Kruer, and M. Finkbeiner, R.A. Warner, 1999, Benthic Habitat and Zone Maps of St. Thomas and St. John, U.S. Virgin Islands; Prepared by Visual Interpretation from Remote Sensing Imagery Collected by NOAA in 1999, , , 1:6000 scale	Unknown	Yes, from NOAA	Convert NOAA digital version to NPS format

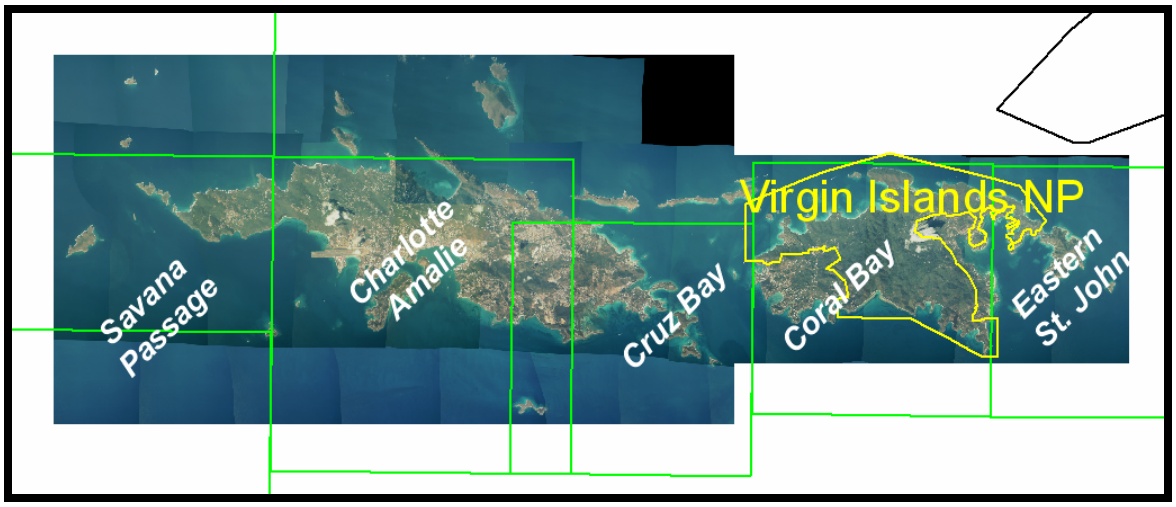


Figure 1:Quadrangles of Interest (QOI's) for VIIS (7.5' shown in light green outline; park boundaries in yellow outline; MrSID image of Islands of Saint John and Saint Thomas as background)

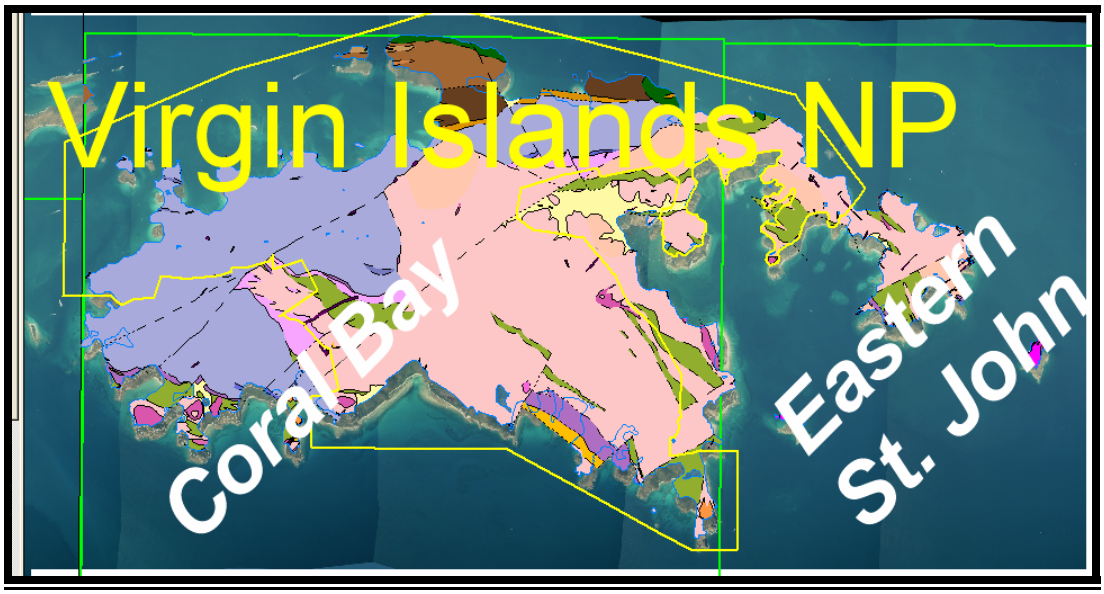


Figure 2:Extent of Rankin, D.W., 2002, Geology of St. John, U.S. Virgin Islands, US Geological Survey, Professional Paper 1631, 1:24000 scale

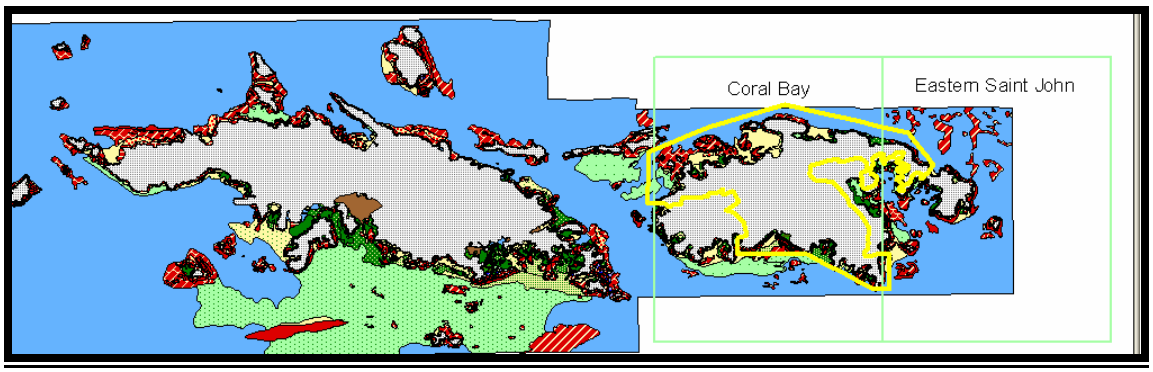


Figure 3: NOAA Benthic Habitats of St John and St Thomas.

GEOLOGY AND STRATIGRAPHY OF ST. JOHN, USVI

The geologic history of St. John began in the Early Cretaceous (~100 my) with the shallow water deposition of the *Water Island Formation*. This unit is composed predominantly of extrusive keratophyres (fine-grained igneous rocks with high Si and K content), basalts, and minor cherts that formed in an extensional oceanic environment (Rankin, 2002). This formation was produced from the same volcanism that formed the Greater Antilles. The Water Island Formation is the oldest unit found on St. John, with exceptional exposures on the south side of the island. The unit is estimated to be at least two kilometers thick (Rankin, 2002), and although the base is not visible, it is presumed to be underlain by oceanic crust (Donnelly, 1989).

Geologic features commonly found within the Water Island Formation include pillow basalts, volcanic wackes and tuffs, amygdaloidal basalts, and nodular keratophyres (high sodium rocks). Internal stratigraphic order has not been observed, although the "attitude of these contacts, along with bedding in the volcanic wacke, flow layering in keratophyres (used cautiously), and "bedding" in pillowed basalt aid in defining the map pattern and overall structure" of the formation (Rankin, 2002). Due to mixed masses of keratophyres and basalts, it is possible that two lava types were extruded concurrently (Rankin, 2002).

Intrusive rocks of the Careen Hill Intrusive Suite are commonly found within the Water Island Formation. The igneous intrusions are primarily the intrusive equivalents of the Water Island Formation. Small dikes and plutons composed of intrusive keratophyres and fine-grained gabbros are found interspersed throughout the Water Island formation. Spectacular features found within the Careen Hill Intrusive Suite include columnar jointing and sheeted dikes. The columnar jointing found on Leduck island is composed of a light colored granite called a trondhjemite. The Water Island Formation and the Careen Hill Intrusive Suite combine to form the Lameshur Volcanic-Intrusive Complex (Rankin, 2002).

The Lameshur Volcanic-Intrusive Complex is overlain by more than 1.5 km of blue andesite ash beds and pyroclastic breccias called the Louisenhoj Formation. This unit was deposited in the Late Cretaceous when explosive subduction-related volcanism occurred in shallow marine waters associated with a developing island arc environment. Graded bedding is evident throughout the formation due to the deposition of volcanic material by submarine slides and slumps. A variety of clast sizes suggest that numerous volcanic vents are located nearby. Geologic features found throughout the Louisenhoj Formation include volcanic conglomerates and wackes, andesite tuff breccias, and bedded, boulder volcanic conglomerates. The Louisenhoj Formation covers the Western half of Saint John, including Cruz Bay and Rendezvous Bay. It is commonly referred to as "Blue Bitch" rock by Saint Johnians.

Following the deposition of the Louisenhoj Formation, St. John experienced a period of reduced volcanism and gradual sea floor subsidence. At that time (L. Cretaceous), approximately 100 m of thinly bedded limestone, referred to as the Outer Brass Limestone, was deposited in a quiet marine environment. It is thought that deposition occurred on moderate slopes a few hundred feet in depth. This formation contains high concentrations of silica tests and thin, interbedded tuffs. Due to contact metamorphism from Tertiary plutons, deposits of white and blue-gray calcitic marble containing plagioclase, epidote, garnets,

diopside, vesuviatnite, and wollastonite are found throughout the formation (Rankin, 2002). This unit forms a discontinuous belt extending from Maho Bay to Brown Bay, with excellent exposures at Mary's Creek on the north shore of the island. It is possible this marble was utilized by native Taino peoples for trading beads and jewelry.

Although the Outer Brass Limestone is a thin, minor unit on St. John, it is a useful tool for separating the conglomeratic Louisenhoj Formation from the lesser conglomeratic Tutu Formation (Rankin, 2002). The Tutu Formation formed by island arc volcanism which resumed in the Late Cretaceous. Most of the material seems to have been deposited by turbidity currents, suggesting deposition on an "unstable slope such as a trench wall leading into an accretionary wedge" (Rankin, 2002).

The Tutu Formation extends from Maho Bay to Leinster Point. This formation is characterized by volcanic wackes, shales, conglomerates, calcareous siltstones, limestones, and rare basalts and andesites (or their metamorphic equivalents) (Rankin, 2002). Volcaniclastic fragments found within the Tutu Formation are generally sand and silt size suggesting the volcanic source was further away than the Louisenhoj vents (Rankin, 2002). Additionally, a distinct fining-upward implies increasingly distant volcanic sources. The extrusive igneous rocks of the Tutu Formation are the last evidence of volcanism on St. John.

The Tertiary Period was marked by intense plutonic activity that produced folding and faulting across the island. Following the intrusion of diabase dikes, north-south compression was created by the collision of the Caribbean plate and the North American plate. The intensity of deformation increases northward on St. John.

The last period of tectonic activity on the island occurred after the late Eocene (post 39 my). At that time a series of strike slip faults occurred due to the spreading of the Cayman Trough. No recent tectonic activity has been recorded.

SIGNIFICANT MANAGEMENT ISSUES

The scoping participants identified the following as the most significant geologic issues at Virgin Islands National Park:

1. Slope stability and erosion

St. John is characterized by rugged terrain with steep, rocky slopes. More than 80% of the island is covered with hillsides in excess of 30% (CH2M Hill, 1979). Slope failure is common during storm events and may have devastating effects on terrestrial, coastal, and marine habitats. Recently, numerous nesting sites of the endangered brown pelican were decimated due to slope instability caused by Tropical Storm Frances (2002). In addition, roads are often impassable during storm events due to rock and mudslides, creating serious hazards to park visitors.

Grazing is another cause of slope failure within the park. Feral goats and hogs negatively impact fragile park resources. Heavy grazing on steep hillsides increase erosion into adjacent coastal and marine ecosystems. Even small increases in sedimentation may have devastating effects on fragile environments including coral reefs and seagrass beds.

2. Coastal Features and Processes

Virgin Islands National Park is known for its beautiful beaches and unique coastal ecosystems. Many of the park's management issues concern the protection and preservation of these valuable resources. Unfortunately, many of these resources are at risk due visitor demands, anthropogenic modifications, and/or natural coastal dynamics. Immediate concerns include, but are not limited to, the following:

1. Beach erosion - Cinnamon Bay contains one of the beaches experiencing rapid erosion in Virgin Islands National Park. This popular tourist beach is the site of numerous archaeological sites, some dating to 900 AD. The Archaeology Center, the oldest remaining active structure on St. John, is at great risk for destruction. Riprap was placed along the shoreline in the 1970s to slow beach erosion. However, this has done little to diminish destructive processes. The loss of shoreline vegetation is an additional management concern associated with beach erosion.

2. Coastal development – coastal development on St. John continues to increase at an alarming rate. Construction increases sedimentation rates into adjacent waters. Sedimentation and runoff may damage fragile marine ecosystems including coral reefs and seagrass beds. Water quality monitoring is performed monthly at numerous locations throughout the park to assess damage from coastal development.

3. Anthropogenic modifications – Modifications have been made to some of St. John's shorelines. For example, docks have been constructed at Lameshur Bay, Caneel Bay, and Cruz Bay. Also, as previously mentioned, the Archaeology Center at Cinnamon Bay is protected by riprap. Any shoreline change will affect shoreline dynamics. Changes in sediment transport, including beach erosion and accretion, should be closely monitored where human structures have been erected.

Dredging is an another concern to park managers. Dredging is often performed in Cruz Bay to benefit shipping, transport and recreation. Coastal dredging increases turbidity and sediment loads, thereby damaging marine resources. Dredging may also interfere with sediment transport and flow dynamics in coastal and marine systems. In addition, dredged sediments may include harmful contaminants and pollutants.

4. Salt pond infilling – the salt ponds found within Virgin Islands National Park are in danger of infilling due to increased sediment loading. High sedimentation rates may be caused by a variety of factors including feral animal grazing, storm events, and/or human activities.

3. Marine Features and Processes

4. Sediment characteristics – sediment thickness, type, and grain size should be integrated into park maps. Available information on sediment distribution,

budget, and sources and sinks should be available to park managers for a variety of reasons including, but not limited to, buoy placement and maintenance, boat anchoring, and erosion hotspots. An understanding of the system's sediment supply is critical for monitoring coastal areas and predicting shoreline change (Nelson, 2002).

5. Recreation Impacts –More than 800,000 guests visit the park each year. Common forms of recreation include boating and fishing- both of which may have detrimental impacts on park resources. Two of the most serious impacts defined at this meeting are:

    A. Boating – anchoring and vessel groundings have seriously damaged many coral reefs, seagrass beds, and mangrove forests in VIIS and CRNM. Although anchoring is permissible in certain areas, illegal anchoring and anchor dragging (usually due to operator ignorance) has destroyed marine habitat throughout the park. In addition, vessel groundings due to inexperienced boating and storm events have critically damaged large sections of coral reefs.

    B. Surfing – Surfing occurs at many locations in the park including Johnson's Reef, Fish Bay, and Cinnamon Bay. Surfing hazards include dangers to both park visitors and park resources. For example, surfing at Johnson's Reef may damage fragile coral habitat. In addition, park visitors have been gravely injured while body surfing at Cinnamon Bay due to the steep break at the shoreline. However, the beaches must remain open due to the Free Beach act.

6. Oceanographic Variables – Relative sea level rise, temperature and salinity patterns, currents, and tidal regimes should be monitored for Virgin Islands National Park. These variables may aid in identifying sediment transport patterns within the park. In addition, knowledge of currents at headlands and in channels may reduce visitor injuries.

7. Benthic habitat mapping – Virgin Islands National Park is working in cooperation with NOAA to complete benthic habitat mapping for the park. Benthic habitats including coral reefs and submerged aquatic vegetation should be included in coastal mapping products. These features influence the hydrodynamic regimes within their localized areas, thereby determining sedimentation patterns. The location of marine habitats should be known in order to determine the impacts that coastal development and visitor use may have on their health and survival (Nelson, 2002).

4. Windblown Features and Processes

Currently, the park is investigating the effects of Saharan dust on park resources. It is believed that imported particulates could have harmful effects on fragile marine habitats such as coral reefs and seagrass beds, by carrying fungi and dust-borne pathogens. Dust from

alternate sources such as the Montserrat eruption of 1995 could also have negative impacts on park resources.

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APPENDIX F

WATER RESOURCES

F.1 303(d) List of Impaired Water Resources within the South Florida / Caribbean Network

F.2 Current Water Quality Findings and Monitoring Programs within the South Florida / Caribbean Network and Review of Regional Hydrology Summaries

APPENDIX F.1

303(d) LIST OF IMPAIRED WATER RESOURCES WITHIN THE SOUTH FLORIDA / CARIBBEAN NETWORK

What is the 303(d) List?

Section 303(d) of the Clean Water Act (CWA) requires states and territories to develop a list of waters not meeting water quality standards or not supporting their designated uses. Total Maximum Daily Loads (TMDLs) are required for the waters determined to be impaired based on these detailed assessments because of technology-based effluent limitations, current effluent limitations required by State or local authority, or other pollution control requirements are not stringent enough to meet current water quality standards.

Background and Sources of information for the 303(d) List

The 303(d) lists are based primarily on the state and territories' 1996 305(b) Water Quality Assessment Report ("305(b) report"), which uses a watershed approach to evaluate the state's surface waters, ground waters, and wetlands. All existing and readily available water quality related data (chemical, physical, and biological) and information were assembled and evaluated in the development of the 305(b) report, including but not limited to data in EPA's STOrage and RETrieval (STORET) database, the Statewide Biological Database (biological assessments), and fish consumption advisory information. The 303(d) lists are re-evaluated and updated about every two years.
Here we report the 303(d) list 2002 update for the National Parks in both Florida and the Virgin Islands. This list was compiled from a number of sources all of which are not in complete agreement. The water bodies listed are either in the park units or in adjacent or upstream locations.

We used the following sources:
http://www.dep.state.fl.us/water/tmdl/index.html
http://www.epa.gov/OWOW/TMDL
http://10.147.158.160/wrd/dui/ (a NPS WASO WRD webpage)
along with direct contact with the state and territorial appropriate environmental departments.

303(d) LIST OF IMPAIRED WATER RESOURCES WITHIN THE SOUTH FLORIDA CARIBBEAN NETWORK

Park	Water Body Name	Water Body type	Parameters	Priority
BICY	L-28 Interceptor	Stream	Dissolved Oxygen, Nutrients, Mercury (Based on Fish Consumption Advisory),	Low
	L-28 Gap	Stream	Dissolved Oxygen	Low
	Tamiami Canal	Stream	Dissolved Oxygen, Mercury (Based on Fish Consumption Advisory), Cadmium	Low
	WCA 3A Center Section	Stream	Dissolved Oxygen, Nutrients, Mercury (Based on Fish Consumption Advisory),	Low
BISC	No water Bodies are listed within park boundary – however Military canal moves water to the park via canals and water control structures.	Stream	Lead, Cadmium, Copper-- Heavy metals potentially from Homestead Air Force Base. Suggested by DEP-Tallahassee	Low
EVER	Florida Bay	Estuary	Dissolved Oxygen, Nutrients, High Salinity	Low
	Area B Tamiami Canal	Stream	Dissolved Oxygen, Nutrients	Low
	Everglades National Park L-67 Culvert	Stream	Dissolved Oxygen, Iron	Low
	Water Conservation Area (WCA) 3B	Stream	Dissolved Oxygen, Mercury (Based on Fish Consumption Advisory)	Low
	Everglades National Park Shark Slough	Stream	Dissolved Oxygen, Iron, Mercury (Based on Fish Consumption Advisory), Nutrients	Low
	C-113	Stream	Dissolved Oxygen, Nutrients	Low
	C-111	Stream	Dissolved Oxygen, Mercury	Low
	Everglades National Park Taylor Slough	Stream	Dissolved Oxygen, Iron	Low
	Transect T3	Stream	Dissolved Oxygen	Low
	Long Sound	Stream	Dissolved Oxygen	Low

Park	Water Body Name	Water Body type	Parameters	Priority
SARI	Salt River Marina	Estuary	Dissolved Oxygen	Medium
	Salt River Estuary	Estuary	Dissolved Oxygen	Medium
	Salt River Bay	Estuary	Dissolved Oxygen	High
VIIS	Caneel Bay	Estuary	Dissolved Oxygen, Turbidity	Medium
	Cruz Bay	Estuary	Dissolved Oxygen, Turbidity	Medium
	Cinnamon Bay	Estuary	Dissolved Oxygen	Low
	Maho Bay / Francis Bay	Estuary	Dissolved Oxygen	Low

APPENDIX F.2

CURRENT WATER QUALITY MONITORING PROGRAMS WITHIN THE SOUTH FLORIDA/CARIBBEAN NETWORK AND REVIEW OF REGIONAL HYDROLOGY SUMMARIES

Table 1. This table summaries the current and on going water quality sampling programs within the SFCN. Listing the Park unit, Agency performing sampling, contact person, frequency of collection, general methodology being used, for the following parameters Temperature (T), Conductivity (C), Dissolved Oxygen (DO), pH, Nitrogen (multiple species N), Phosphorus (multiple speciesP) Water (stage, depth, or flow), Which database the data is stored in (Data), If the data is archived in EPA's STOrage and RETrieval (STORET) database and summary interval (Sum)

Park	Agency	Agency Contact	Freq	Method	T	C	DO	pH	N	P	Water	Data	STORET	Sum
BICY	NPS	Bob Sobzack	Continuous	Datalogger	20						20	DBHYDRO	Yes	Weekly Live Web product From NPS staff
	NPS	Bob Sobzack	Six times per year at 45 day interval from June to Feb	Grab Samples	16	16	16	16	16	16		DBHYDRO	Yes	Annual from NPS staff
BISC	NPS	Sarah Bellmund	Continuous	Datalogger	34	34					34	DBHYDRO	Yes	Annual from NPS staff
	FIU	Joe Boyer	Monthly	Grab Samples	19	19	19		19	19		DBHYDRO	Yes	Annual from FIU
	DERM	Steven Blair	Monthly	Grab Samples	20	20	20	20	20	20	20	DBHYDRO – until 2004	Yes – Florida STORET	Event Driven
	NPS-SFCN	Ben Ruttenberg	Continuous	Datalogger	2							SFCN	NPS STORET	Annual

Table 1. Continue

Park	Agency	Agency Contact	Freq	Method	T	C	DO	pH	N	P	Water	Data	STORET	Sum
BUIS	DRNR/DEP		2 sites for Fecal Coliform	Grab Samples									EPA STORET	Event Driven
	NPS-SFCN	Ben Ruttenberg	Continuous	Datalogger	2								NPS STORET	Annual
DRTO	FIU	Joe Boyer	Monthly – 7 sites in park proper	Grab Samples	15	15	15		15	15		DBHYDRO	Yes	Annual from FIU
	FIO	Joe Fajans	Continuous	Datalogger	1	1					1	Real-time wed page NDBC	No	Real-time wed page NDBC
	NPS-SFCN	Ben Ruttenberg	Continuous	Datalogger	2							SFCN	NPS STORET	Annual
EVER	NPS	Kevin Kotun	Continuous	Datalogger	129						129		No	Event Driven
	NPS	Kevin Kotun		Grab Samples	8	8	8	8	8	8		DBHYDRO	Yes	?
	SFWMD	Kevin Kotun	Continuous	Datalogger							409	DBHYDRO	Yes	Real-time wed page DBHYDRO
	USGS	EVER	Continuous	Datalogger	197	15					197	USGS Real-time wed page	No	USGS Real-time web page
	FIU-LTER	Evelyn Gaiser	Continuous	Datalogger / Grab Samples	6	13	1		13	13	5	FIU-LTER Webpage	No	Event Driven

Table 1. Continue														
Park	**Agency**	**Agency Contact**	**Freq**	**Method**	**T**	**C**	**DO**	**pH**	**N**	**P**	**Water**	**Data**	**STORET**	**Sum**
SARI	DPNR/DEP	?	1 site for Fecal Coliform	Grab Samples									EPA STORET	Event Driven
	NOAA AOML/ ICON/ CREWS	?	Continuous	Datalogger	1	1						NOAA-ICON web page	No	NOAA real-time web page
VIIS	DPNR/DEP	?	1 site for Fecal Coliform	Grab Samples									EPA STORET	Event Driven
	NPS	Christy McManus	Two times per year	Grab Samples	15	15	15	15	15	15			No	No
	NPS-SFCN	Ben Ruttenberg	Continuous	Datalogger	5								NPS STORET	Annual

EPA- Environmental Protection Agency
DERM – Miami-Dade County Department of Environmental Resource Management
DPNR/DEP-Virgin Island Division of Environmental Protection / Department of Planning and Natural Resources Protection
FIU- Florida International University – Southeast Environmental Research Center- Water Quality Monitoring Network www.serc.fiu.edu/wqmnetwork/
FIU-LTER- Florida International University-Long Term Ecological Research http://fcelter.edu
FIO - Florida Institute of Oceanography / Florida Fish and Wildlife Conservation Commission
NDBC – National Data Buoy Center www.ndbc.noaa.gov
NPS – National Park Service
NPS-SFCN – National Park Service South Florida Caribbean Network
SFWMD- South Florida Water Management District
USGS- United States Geological Survey

This appendix summarizes current water quality monitoring programs and trends within the South Florida / Caribbean Network (SFCN). The current and on going water monitoring programs are summarized by park in Table 1. Many of these water quality sampling programs are performed by non-National Park Service (NPS) groups. In the text that follows we have summaries of current programs and discuss recent trends in each of the park units. Additionally, we have a regional section which describes the major water quality programs occurring in the South Florida region (below Lake Okeechobee). This section has been included in order to draw in information from the Everglades restoration efforts. Finally, we have included a review of recent regional hydrology summaries.

Big Cypress National Preserve

Big Cypress National Preserve (BICY) continuously monitors 20 water stations (see figure in supplemental information section, Table1). Station establishment was paid for by the South Florida Water Management District (SFWMD). The routine calibration of the stations is also paid for by SFWMD funds. These stations record water temperature, water depth, rainfall, and conductivity. BICY Hydrologist, Robert (Bob) Sobzack, maintains the stations and calibrates the instrumentation according to a memorandum of understanding with the funding agency SFWMD. The hydrology data is downloaded via radio telemetry to Miami and stored in the DBHYDRO database (glades.sfwmd.gov/pls/dbhydro_pro_plsql/). The rainfall, water depth and input/output flow data is summarized weekly, monthly, and annually. This product is currently a live web product (www.fgcu.edu/bcw/hcu.htm).

Additionally, BICY has a water quality sampling program that collects samples in 16 open-marsh sites. This data is collected only during the wet season (6 times a year). This water quality sampling program is maintained with funds from SFWMD.

The long-term water quality record for BICY was most recently summarized in united States Geological Survey (USGS) open file report *Water Quality in Big Cypress National Preserve and Everglades National Park – Trends and Spatial Characteristics of Selected Constituents* (Miller *et al*. 2004). As the water level decreases due to seasonal cycles there is an increase in the breakdown of organic matter and a build up of organic waste and nutrients. Long-term changes in water quality (1959-2000) in BICY are less pronounced than has been observed in Everglades National Park (EVER). However, BICY generally has higher total phosphorous (> 0.015 mg/L) compared to EVER. This difference has been attributed to higher natural sources of phosphorous in the shallow soils and ground water. BICY has lower sulfate (1 mg/L) and chloride

(20 mg/L) than EVER due to limited canal transport to the preserve (Miller *et al*. 2004).

BICY has low levels of trace elements, pesticides, and other toxic organic compound. Atrazine in the water column, and heptachlor, expoxide, lindane and p,p′-DDE in canal bed sediments exceeded aquatic life criteria in 2 out of 304 samples (1, 2, and 16 % in samples respectively, Miller *et al*. 2004). Miller and McPherson (2001) found that there were different sources of bottom sediment and water contaminants in the Baron River area of the BICY. Specifically, lead, copper and zinc levels (normalized to aluminum) exceeded normal limits. Polynuclear aromatic hydrocarbons and p-cresol (normalized to organic carbon) exceedances are probably related to road traffic or are from an old creosote wood treatment facility.

Biscayne National Park

Biscayne National Park (BISC) currently monitors thirty-four water stations (see station location map in the supplemental information section, Table 1). BISC ecologist Sarah Bellmund is currently uploading records (1988 to present) into the Data ForEVER and DBHYDRO databases (see South Florida Regional Monitoring section). BISC staff plans to evaluate the dataset for outliers and make recommendations about long-term monitoring of some of the stations. The overall goal is to use the long-term data to evaluate model outputs regarding Everglades's restoration on Biscayne Bay. Suggestions may include establishment of more stations on the eastern part of the park to determine water quality issues for reef locations.

The SFCN has two long term reef water temperature sampling sites (established in 2004) in BISC. This data is currently collected and maintained by SFCN staff.

In addition to the NPS, Florida International University Southeast Environmental Research Center (FIU-SERC) maintains 25 stations within Biscayne Bay for SFWMD water quality program (19 of the stations are with BISC, see the South Florida Regional Monitoring section). Also Miami-Dade County Department of Environmental Research (DERM) (Steven Blair (305-372-6853 blairs@miamidade.gov) has 20 grab sample stations within BISC.

SFWMD has summarized DERM's long-term (1979 to 2005) water quality sampling at 13 sites within Biscayne Bay. Within Biscayne Bay which includes parts of BISC, specific water quality targets have been established for ammonia (0.01 mg L-1) and nitrate/nitrite nitrogen (0.05 mg L-1); all other contaminant parameters should have declining long-term trends under the proposed restoration.

Everglades National Park

Three agencies are maintaining approximately 700 water quality stations in and around Everglades National Park as part of the Everglades restoration program (See station location map in the supplemental information section, See Table 1). EVER has a dedicated hydrology staff which maintains stations, perform routine sampling, archive data, check for quality assurance and quality control as well as investigate the trends in the water parameters. A major asset for EVER is the Data ForEVER database established and maintained by Kevin Kotun (Supervisory Physical Hydrologist of the South Florida Natural Resource Center). Additional information is in the South Florida Regional Monitoring section of this report. In addition to the programs mentioned above the Florida Coastal Everglades Long Term Ecological Research site is established within EVER. These sites are areas of intense research by over 50 scientists investigating the role of water quality in the Everglades ecosystem.

The long-term water quality (1959-2000) trend indicates that upstream changes in water management have produced increases in chloride concentrations and specific conductance in the two main drainages of EVER at Shark River Slough and Taylor Slough (Miller, McPherson, Sobczak and Clark 2004). Additional information on the trends in EVER are given in the South Florida Regional Assessments section of this report.

Dry Tortugas National Park

Dry Tortugas National Park (DRTO) water quality monitoring is part of the Florida Keys National Marine Sanctuary (FKNMS) (http://www.fknms.nos.noaa.gov/welcome.html) water quality protection program. Essentially DRTO is used as a pristine site for the coral reef ecosystem that surrounds the Florida Keys. The Dry Tortugas water quality is monitored by the 15 sites which are maintained by FIU-SERC Water Quality Monitoring Network (http://serc.fiu.edu/wqmnetwork/) funded by the Environmental Protection Agency Water Quality Protection Plan. Additionally, the Florida Institute of Oceanography maintains the C-man Station DRYF1 data record from 1992 to September 2005 and has since been replaced by Station PLSF1. The National Oceanic and Atmospheric Administration (NOAA) National Data Buoy Center manages the data (http://www.ndbc.noaa.gov/station_page.php). The SFCN has two long term reef water temperature sampling sites (established in 2004) in DRTO. This data is currently collected and maintained by SFCN staff. Recently, the USGS has established a number of monitoring wells to track Fort Jefferson's waste

water treatment effluent (See station location map in the supplemental information section).

Virgin Islands National Park

There are 15 water quality sites in VIIS (See station location map in the supplemental information section). Monitoring includes surface water samples for temperature, conductivity, pH and dissolved oxygen and nutrient analysis. This data is currently being inputted into one database with the data being checked for errors. A site map is located in the supplement information section. These sites are sampled by Christy McManus. Limited progress has been made towards reviewing the current water quality data trends.

Additionally, there are 5 locations where the SFCN collects reef water temperature. Collection has been continuous from 1988 at some sites. This data is collected and maintained by SFCN staff. The reef temperature data set was critical to investigating the 2005 coral bleaching impact to the reefs of the Virgin Islands (Fig 1).

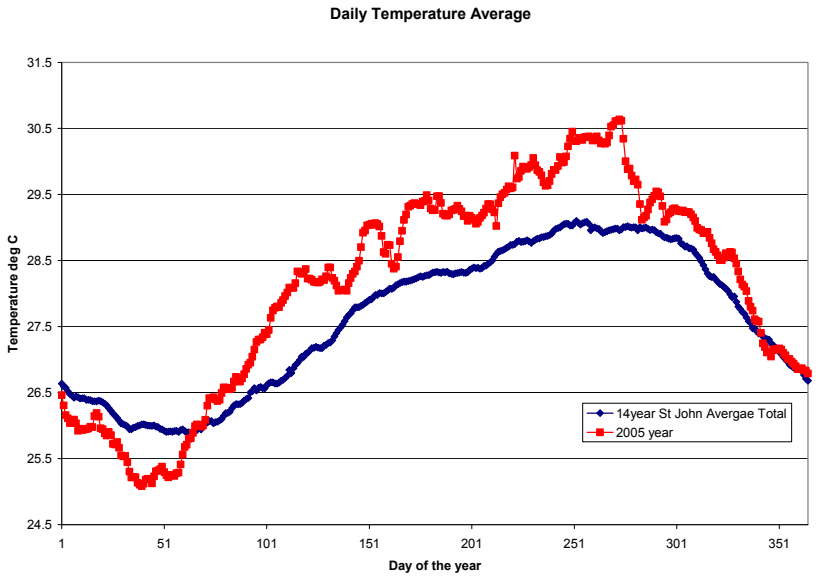


Figure 1. 2005 Daily reef water Temperature compared to the 14- year period of record.

Buck Island Reef and National Monument and Salt River Bay National Historical Park and Ecological Preserve

The territorial government of the Virgin Island Department of Planning and Natural Resources Protection / Division of Environmental Protection (DPNR/DEP) monitors two beach sites and two open water sites at Buck Island Reef and National Monument (BUIS) and one beach site at Salt River Bay National Historical Park and Ecological Preserve (SARI) (See station location

map in the supplemental information section). This monitoring is related to water quality for beach swimming at these sites tracking fecal coliform and *Enterococcus coliform*. The SFCN has two long term reef water temperature sampling sites (established in 2000) in BUIS. This data is currently collected and maintained by SFCN staff.

The South Florida Regional View

A number of regional water initiatives in South Florida relate directly or indirectly to the $10 billion Department of Interior's Comprehensive Everglades Restoration Plan (CERP, http://www.evergladesplan.org/). In this section we first present the monitoring network assets and then some of the regional summary of the hydrology trends within South Florida.

South Florida Regional Monitoring:

The Estuarine Water Quality Monitoring Network was established in 1991 to characterize status and trends in water quality of Florida Bay and has since expanded to cover much of the South Florida region (southwest coast of EVER and Biscayne Bay). It is funded by the SFWMD managed by Dr. Joseph N. Boyer of FIU-SERC. Water quality data is collected from 28 stations in Florida Bay (EVER), 22 stations in Whitewater Bay (EVER), 25 stations in the Ten Thousand Inlands (EVER), 49 stations on the Southwest Florida Shelf (EVER) and 25 stations in Biscayne Bay (BISC). SERC monitors for the following water quality parameters: salinity (practical salinity scale), temperature (°C), dissolved oxygen (DO, mg/L), turbidity (NTU), relative florescence, light attenuation (K_d, m-1), dissolved nutrients nitrate (NO_3^-), nitrite (NO_2^-), ammonium (NH_4^+), dissolved inorganic nitrogen (DIN), soluble reactive phosphate (SRP), total unfiltered concentrations of nitrogen (TN), total organic nitrogen (TON), total organic carbon (TOC), total phosphorous (TP) and silicate ($Si(OH)_4$), chlorophyll *a* (CHLA $\mu g\ l^{-1}$) and alkaline phosphatase activity (APA, $\mu M\ h^{-1}$). This information is readily downloadable at http://serc.fiu.edu/wqmnetwork/.

The Data ForEVER database is a regional water database that covers: EVER, BICY and BISC plus many of the dominant water management control structures in South Florida. The database currently tracks approximately 851 stations covering a large variety of parameters. The Data ForEVER database supports queries by data type, agency supporting station, station name, observation point, aggregation level, validation status, units and output type. The database is populated with stations maintained by: NPS, USGS, and SFWMD. Stage, rain, flow, and salinity are critically important parameters being monitored in the South Florida Everglades (Table 2). Dissolved oxygen and pH are not routinely monitored parameters. This is mainly due to

difficulty in the automation of measuring these parameters. Automation of deployment is important since most of these stations report via telecommunication. Sites have been installed and supported by Federal (NPS, USGS, and NOAA) with 379 stations, State (SFWMD, FIU) with 439 stations and Local (DERM) agencies with 33 stations (Table 3).

Table 2. Number of sites which record the specific parameter of interest.

Parameter	Number of sites recoding the Parameter
Air temperature	32
Bottom temperature	146
Water temperature	296
Salinity	314
Flow	409
Ground water level	32
Head water	270
Rain	614
Stage	795

Table 3. Number of stations by funding Agency.

Agency	Number of sites
DERM – Dade County Environmental Resource Management	33
FIU – Florida International University	30
NOAA – National Oceanic and Atmospheric Administration	7
NPS BICY – Big Cypress National Preserve	18
NPS BISC – Biscayne National Park	20
NPS EVER – Everglades National Park	129
NPS SFWMD – National Park Service / South Florida Water Management District	8
SFWMD - South Florida Water Management District	409
USGS – United States Geological Survey (Both Water Resources Division and Biological Resources Division)	197
Total	**851**

South Florida Regional Assessments:

In addition to the traditional land management role of the National Park Service, EVER, BICY, and BISC have the added role of reviewing proposed restoration plans and alternatives for Comprehensive Everglades Restoration

Plan (CERP http://www.evergladesplan.org/). This role requires extensive analysis of the trends in water quality and physical hydrology found in the South Florida region. The most recent review of the current Everglades restoration process can be found in Ahn *et al.* (2005), "An Assessment of the Interim Operation Plan". The Interim Operational Plan (IOP) report is a compilation of analyses evaluating hydrological and ecological effects of water management practices on the Everglades. This eight chapter report to Congress aims to assess IOP impacts on water quality and make recommendations for future management activities. By analyzing water quality, salinity, and hydrology monitoring data the IOP report assesses the impact of IOP management activities compared to Pre-IOP management of the Everglades ecosystem.

The Interim Structural and Operational Plan (ISOP) and IOP are attempts to improve the ecosystem quality of EVER. Rapid water level decline in the park due to water management actions has negative impacts on all organisms dependent on water depth. Pumps will be used to return seepage from EVER back into the system while maintaining a higher than average water detention level (NPS 2005).

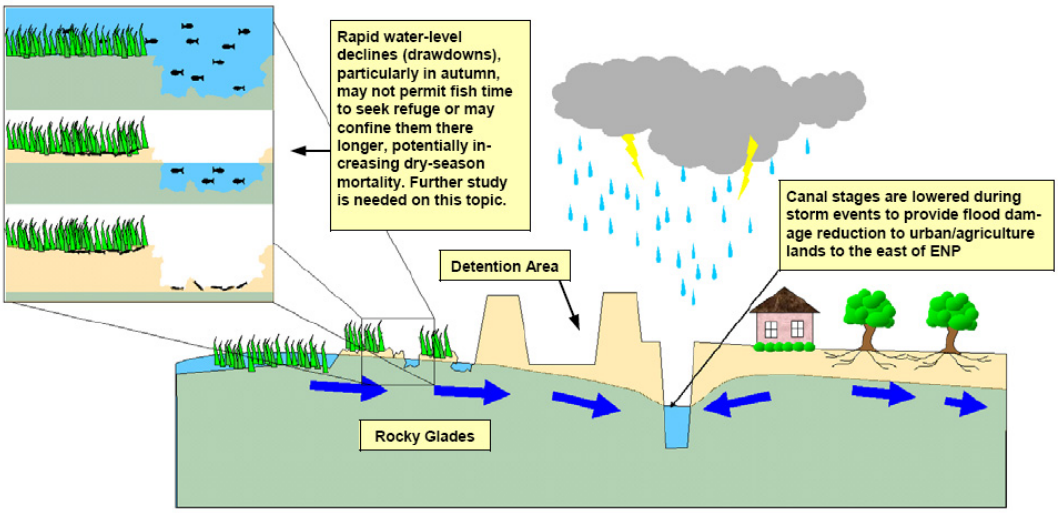


Figure 2. Schematic showing the effects of canal drawdowns. (Taken from IOP report)

Recent assessments have shown that hydrologic conditions beneficial to the Cape Sable Seaside Sparrow habitat are shallower than current trends. The IOP was able to achieve these desired levels in the Central and Western Shark Slough providing an improved opportunity for nesting (Fig 3). The Northeast Shark Slough was unable to provide the necessary benefits to the Cape Sable Seaside Sparrow. The IOP resulted in a slight increase in water depth and reduction in seepage losses in the Rocky Glades. The Upper Taylor Slough showed a more natural timing and distribution of inundation due to the IOP;

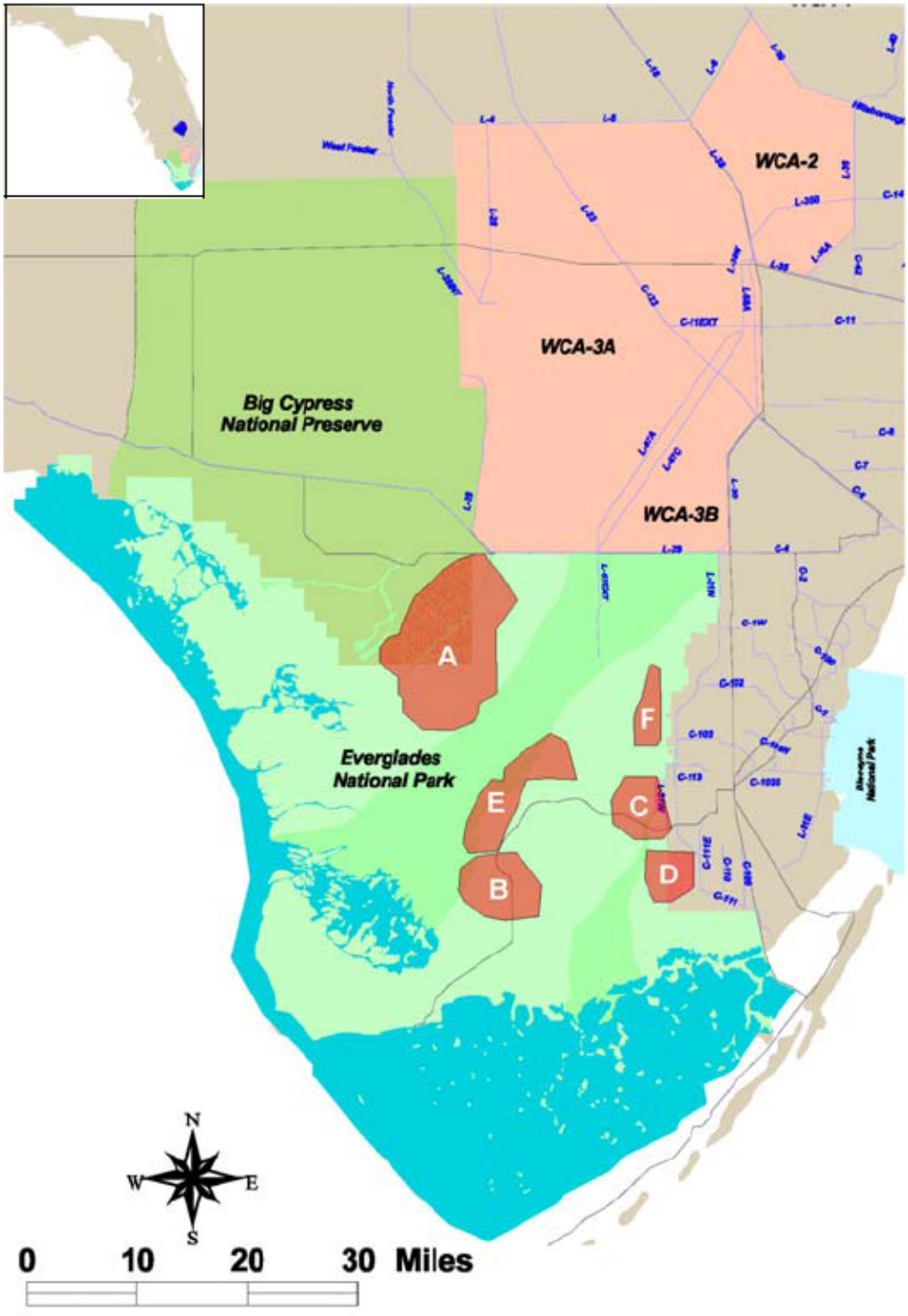


Figure 3. Map showing the location of the areas occupied by the six (A-F) Cape Sable Seaside Sparrow sub-populations. (Taken from IOP report)

however, the Lower Taylor Slough and the Eastern Panhandle experienced no significant change in hydrologic conditions (Ahn *et al*. 2005a).

The IOP allowed for a slight increase in salinity in the Florida Bay and Gulf Coast Estuaries but the change was not statistically significant. Increased salinity is not generally desirable for the health of the Florida Bay ecosystem. Annual salinity increased at Shark River, Little Madeira, Terrapin Bay, North River, Whipray Basin, Duck Key and Butternut Key. Monthly mean salinity decreased during the dry seasons (November-January) and increased during the late dry/early wet season (February-July.) The salinity at Canepatch significantly increased during the month of March (see Fig 10 taken from Ahn *et al*. 2005b, letter codes indicate basin name i.e. LM=Little Madeira). Additionally, salinity was not reduced as a result of the IOP compared to the Test 7I period (1996-1999) in fact the salinity was always slightly higher but not statistically significant (Fig 4)

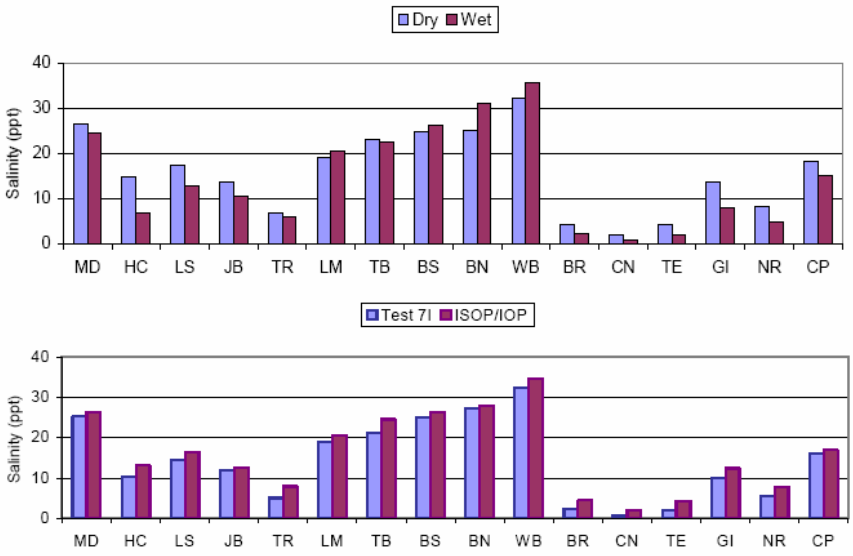


Figure 4. Comparison of historical salinity values: (a) between the wet and dry seasons, and (b) Test 7I and ISOP/IOP periods. (Taken from Figure 10 IOP report.)

In the CERP, hydrological detention areas located outside of the parks are used to reduce total phosphorus (TP) amounts by 5-15% of incoming concentrations (generally in the range of 6-20 ppb). However, the TP concentrations during the IOP implementation increased in the soil and water of EVER. Shark Slough had the largest rise of TP concentrations in its water and is a major concern of the IOP implementation. Until water detention areas have adequate canal plugs and proper flow scheduling, future operational evaluations are needed to control water quality (Kadlec *et al*. 2005).

In addition to the IOP assessment, the Environmental Protection Agency (EPA) has a South Florida Ecosystem Assessment project. The South Florida Ecosystem Assessment Project goal was to provide scientific-based management decisions to the Everglades ecosystem and its restoration. Essentially the Assessment project attempts to relate the four main areas of ecosystem influences: hydropatterns, eutrophication, habitat alteration, and mercury contamination (Fig 5).

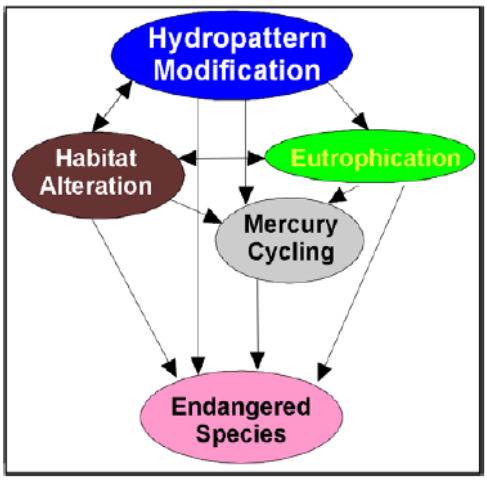


Figure 5 Restoration issues are highly interdependent and must addressed together (Taken from figure 54. Stober et al. 2001).

Hydropatterns

The depth, duration of inundation, and distribution of water has been altered by canal systems and levees built by the US Army Corps of Engineers (Fig 6). Everglades Restoration is currently being implemented with the goal to return the hydrology to a more natural water flow pattern (more information at www.evergladesplan.org).

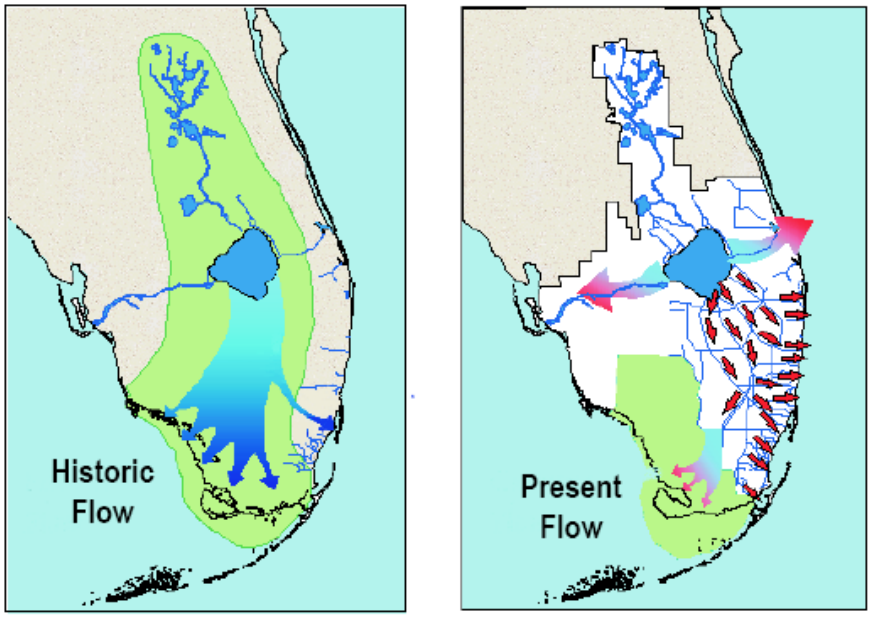


Figure 6 Historic flow pattern (left) and present flow patterns (right) through the South Florida system. Water movement is highly managed through the canals and water control structures (Taken from Figure 7 Stober et al. 2001).

Eutrophication

The Everglades Agricultural Area (EAA) and urban development contribute to nutrient overloading of EVER. Excess nutrients (eutrophication) can result in an increase of oxygen-demanding organic matter which in turn reduces the amount of dissolved oxygen in the water. Waters with low (hypoxia) to no oxygen (anoxia) generally do not support fishes and other macro-invertebrates. Thus, eutrophication reduces the food quality of wading bird habitats and can change the native sawgrass and wet prairie communities. In 1990, all discharges from the EAA were required to be reduced to total phosphorus 50 ppb in an attempt to lessen the eutrophic impacts on the Everglades.

Habitat Alteration

The Everglades has lost over 1 million acres to urban development and agriculture since the beginning of the 20th century. The loss is irreversible and much of the remaining land and its ecosystems are altered from drainage changes/systems. Studies found that four major plant communities: sawgrass (*Cladium jamaicense*); water lily (*Nymphaea odorata*); purple bladderwort (*Utricularia purpurea*); spikerush (*Eleocharis cellulosa*); and cattail (*Typha domingensis*) indicate ecosystem qualities, such as hydroperiod, water depth, soil type and nutrient requirements. As monitoring continues, changes in these indicator species may signal undesirable water quality and habitat alterations.

Mercury Contamination

Consumption advisories exist for over 2 million acres of South Florida waters due to mercury contamination. Methyl-mercury is fat soluble and can be readily absorbed by biological organisms. This allows mercury to accumulate and move through the food chain, increasing in concentration at each level (Fig 7). The Regional Environmental Monitoring and Assessment Program (REMAP) was initiated to address mercury contamination issues in South Florida. Mosquito fish were used as the indicator species to test for mercury contamination (Fig 8). The U.S. Fish and Wildlife Service established a predator protection level of 100 ppb mercury in prey fish to prevent excessive bioaccumulation. Between Alligator Alley and Tamiami Trail, a hot spot was identified as having the highest mercury concentration in South Florida (Stober *et al.* 2001). Mercury poisoning is being investigated for its possible role in impacting Everglades' organisms.

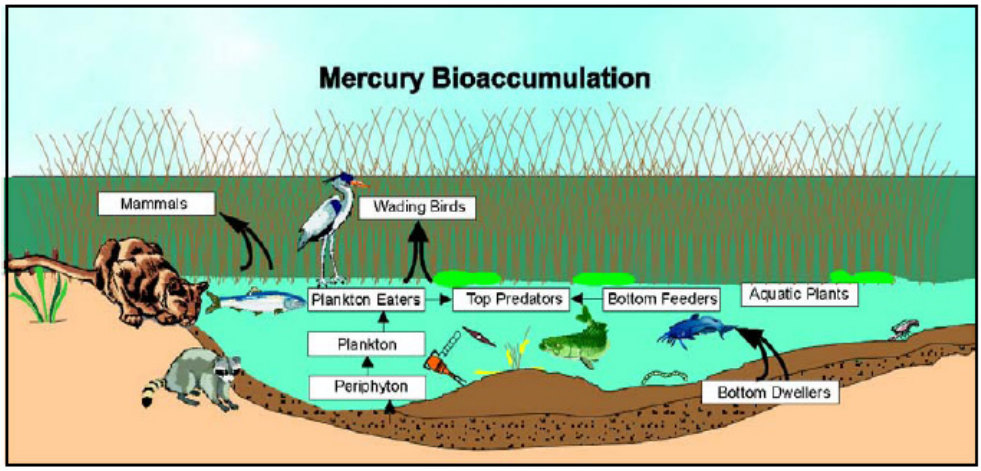


Figure 7 Bioaccumulation of mercury up the food chain from the water to wading birds and the Florida panther. Mercury concentrations in largemouth bass are over 1,000,000 times higher than methylmercury concentrations in water (Taken from Figure 39 Stober et al. 2001).

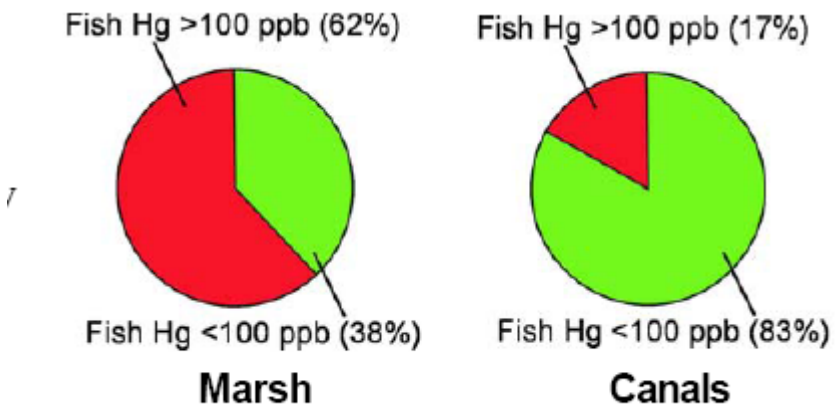


Figure 8 About 62% of the marsh area, compared to 17% of the canal miles. Have mosquitofish with mercury concentrations exceeding the proposed predator protection level of 100 ppb (Taken from Figure 32 Stober et al. 2001).

The Virgin Islands Region View

The territorial government of the Virgin Islands Department of Planning and Natural Resources Protection / Division of Environmental Protection (DPNR/DEP) is the main agency monitoring water quality in VIIS. The DPNR/DEP maintains 135 monitoring stations across St. John, St, Croix, and St Thomas. These stations are sampled quarterly. In addition, there are 145 beach sites which are sampled for near-shore water quality. SFCN has attempted to meet with Chris Crawford of the territorial government to explore water quality issues but direct exchange has not yet occurred.

Summaries generated by the Water Resources Division of the NPS indicate that all three Virgin Island parks have exceeded EPA screening criteria in the past. However, the verified 303(d) listing of water bodies would suggest that VIIS and SARI have greater human impacts than BUIS. This same view has been expressed a number of times by the resource management staff at the respective parks. In general, BUIS water quality is influenced more by the greater Caribbean Sea than by terrestrial sources, whereas, the VIIS and SARI are being influenced by anthropogenic terrestrial sources.

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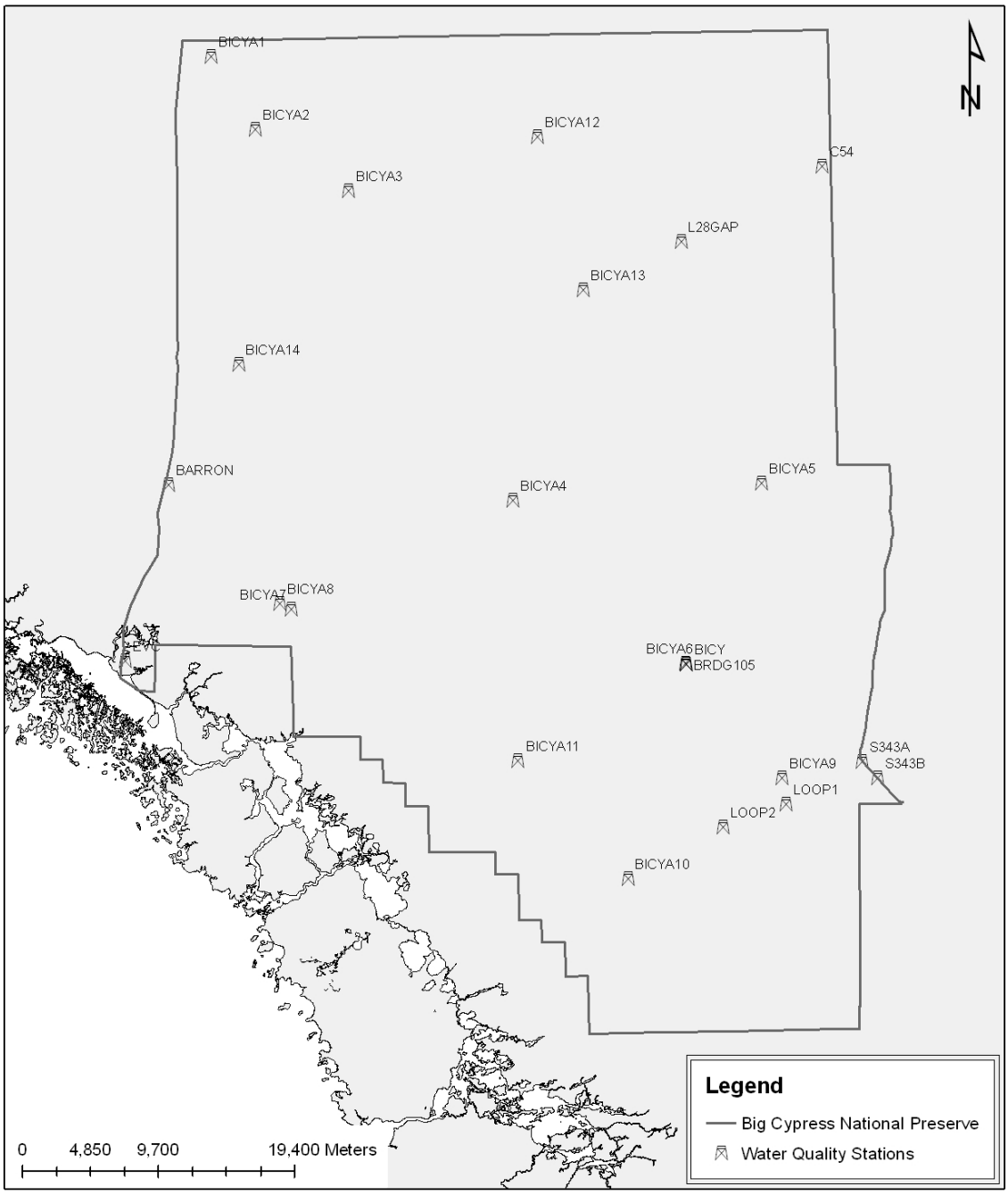
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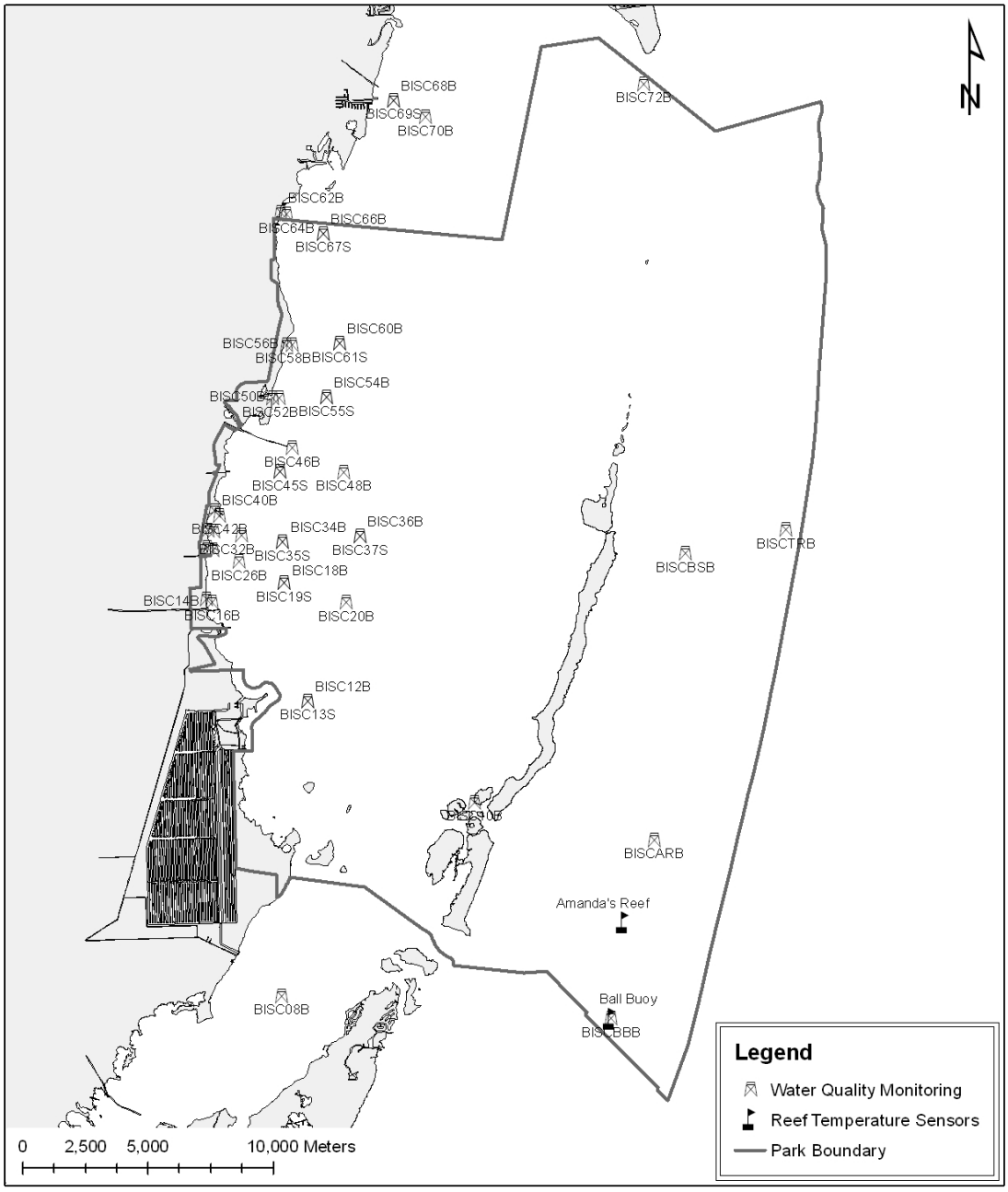
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Supplemental information section

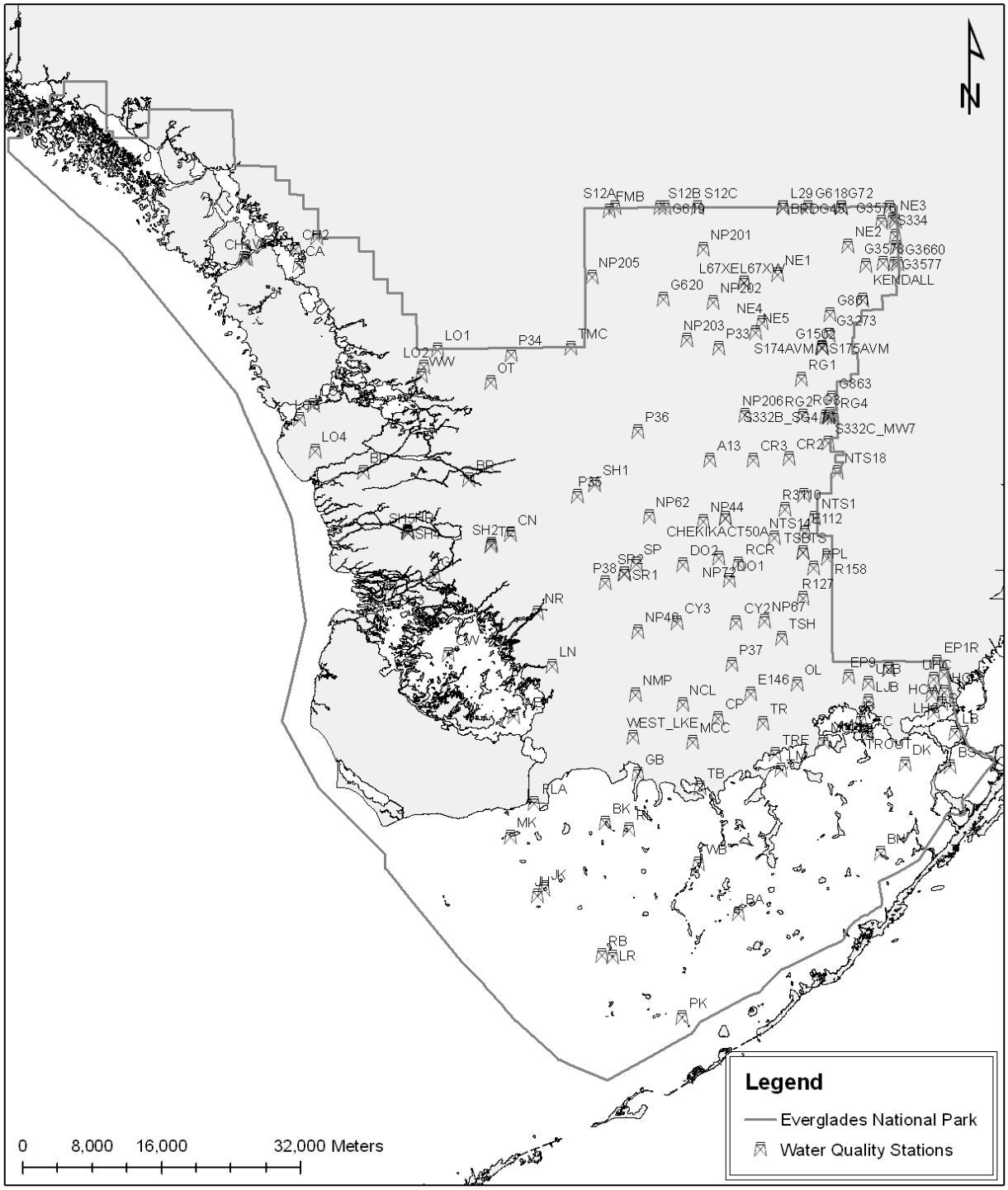
Water Quality Monitoring Stations
Big Cypress National Preserve



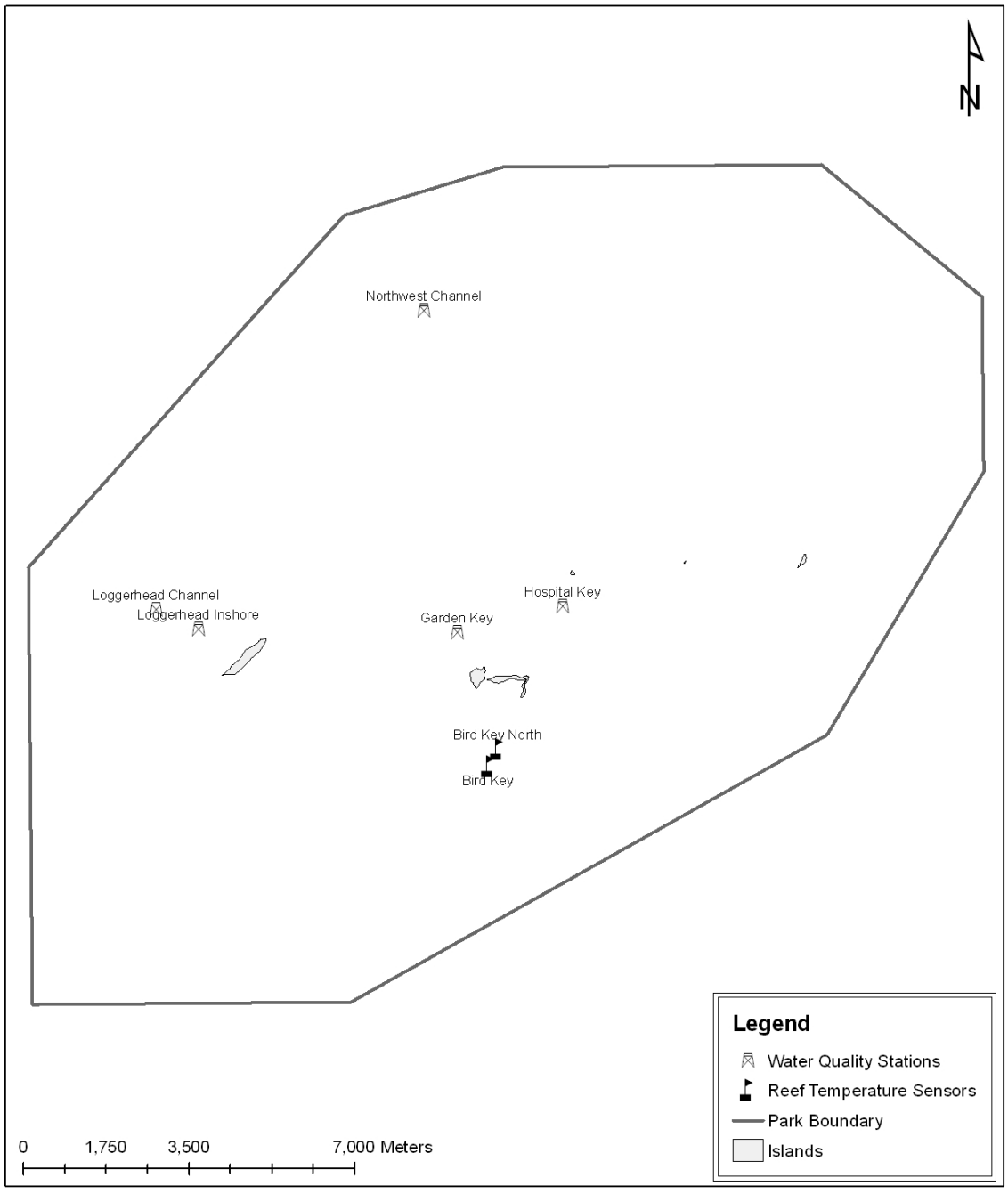
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Biscayne National Park



Water Quality Monitoring Stations
Everglades National Park

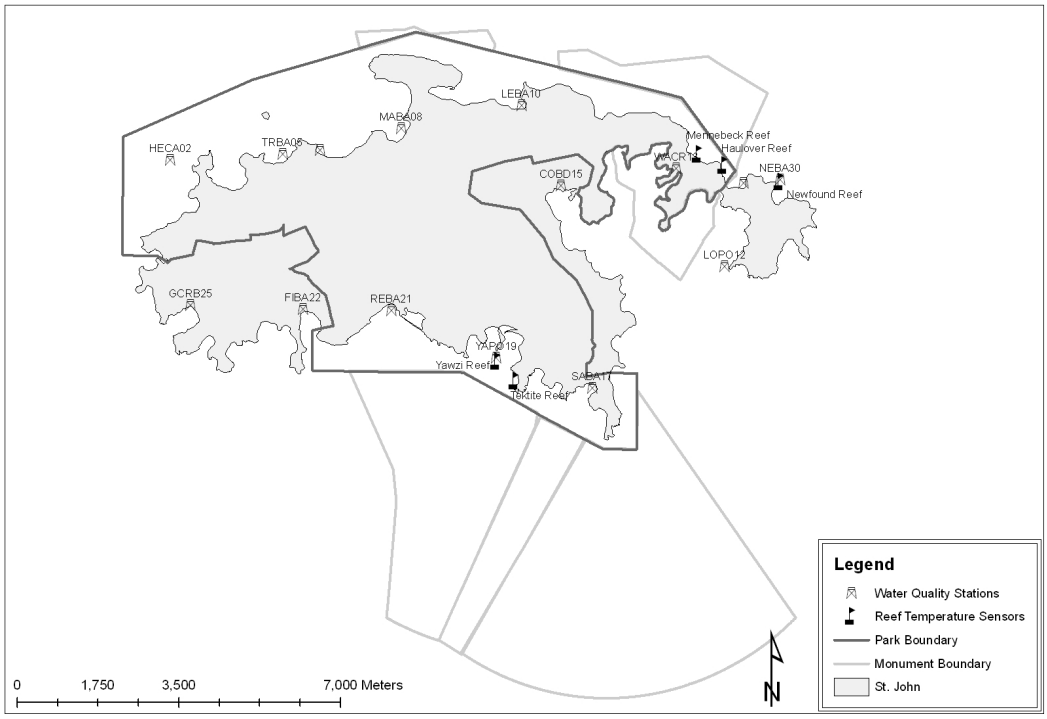


Water Quality Monitoring Stations
Dry Tortugas National Park



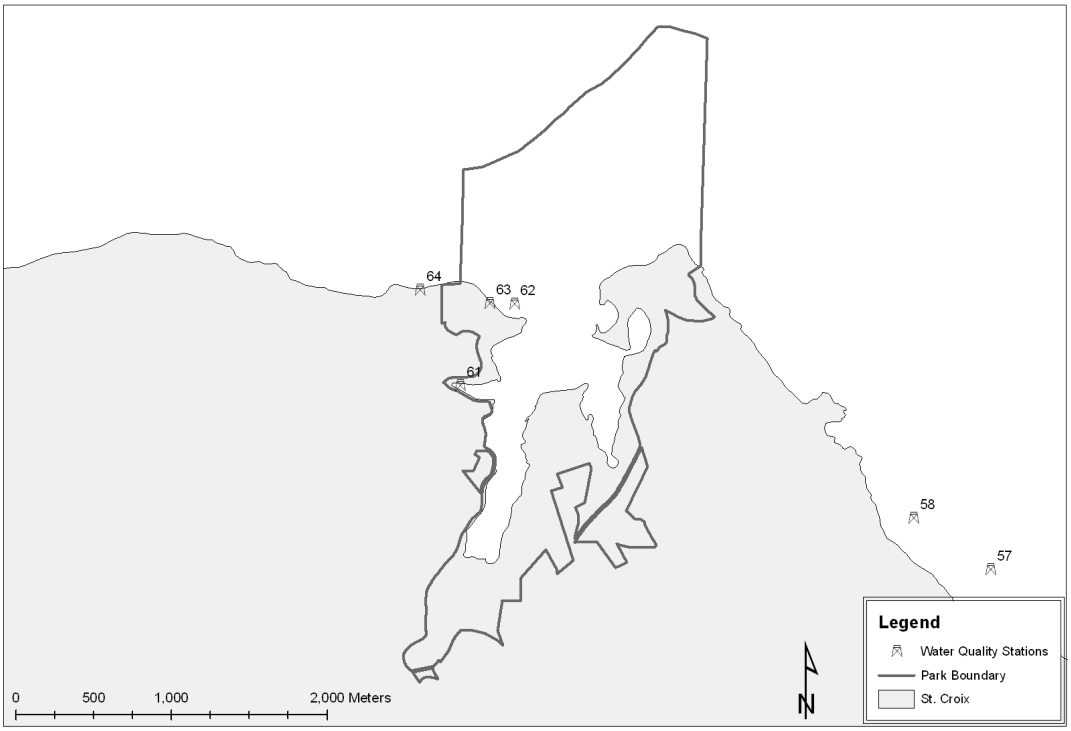
Water Quality Monitoring Stations

Virgin Islands National Park and Virgin Islands Coral Reef National Monument

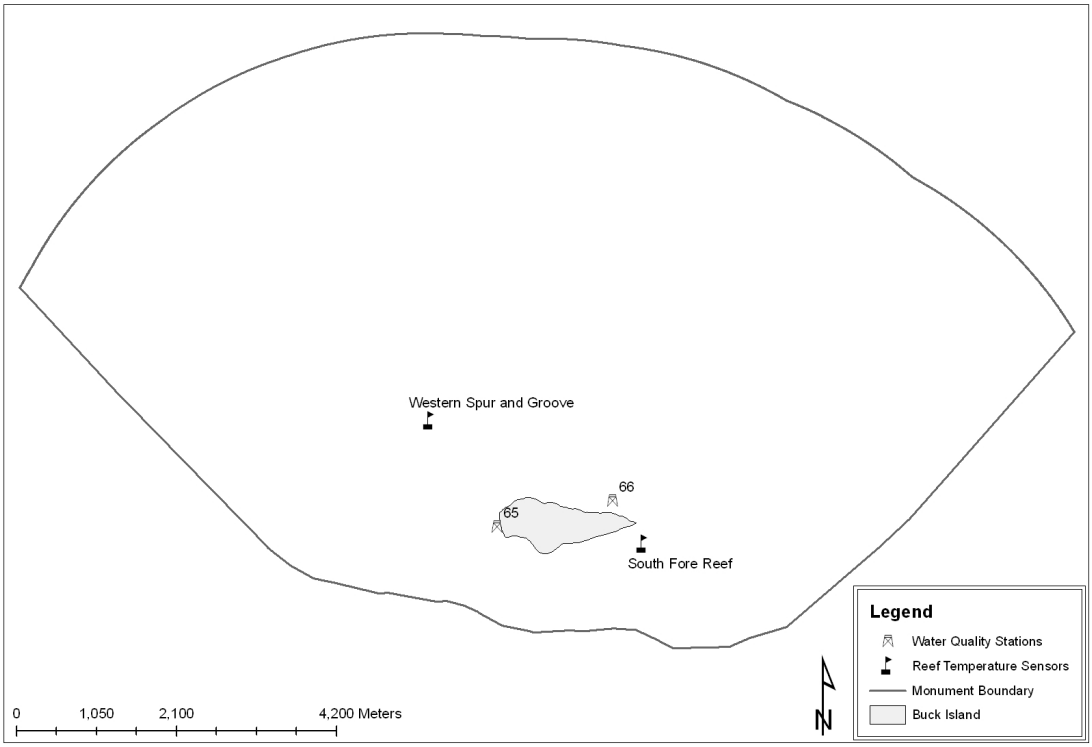


Water Quality Monitoring Stations

Salt River Bay National Historic Park and Ecological Preserve



Water Quality Monitoring Stations
Buck Island Reef National Monument



APPENDIX G

SCOPING SUMMARY
SFCN NETWORK MANAGEMENT ISSUES

South Florida Caribbean Network
2005

The South Florida/ Caribbean Inventory and Monitoring Network hosted a meeting in the Map Room of the Rosenstiel School of Marine and Atmospheric Science – University of Miami Library on January 9-10, 2002. The meeting provided a forum for Resource Managers and Superintendents to help develop a network charter, rank network management issues, and hear from a variety of experts regarding network activities.

As –part of that meeting, results from a survey were presented identifying individual park natural resource management issues (Table 1),

Table 1. SFCN Network Natural Resource Management Issues

	BISC	BICY	BUIS	DRTO	EVER	SARI	VIIS	Overall
Fishing, closures, No extraction	High	N/A	1	High	Med	2	10	High
Hunting	Low	6	N/A		Med/Low	18	N/A	Med/Low
Expansion area, resources in these areas	High	3	2		High	3	N/A	High
Why are coral reefs dying/ processes where management actions help?	High	N/A	3	High		7	2	High
Visitor carrying capacity	Med	14	6	Med	Med	10	1	Med
Resource restoration success	High	7	10		High	17	13	Med
Exotic Plant/Animals impacts	High	2	8	High	High/Med	14	3	High
Fire	Low	8	N/A		Med	13	21	Med
Noise – Soundscape/resource and visitor experience	Low	16	N/A		Med	N/A	14	Low
Reintroduction native species	Low	11	9			N/A	15	Low
Socio-economic benefits	Low	17	13			15	16	Low
Bio-prospecting	Low	10	N/A			N/A	N/A	Low
Public Involvement/Education and Outreach	High	9	4			4	8	High/Med
Economic modeling	Low	18	N/A			N/A	19	Low
Regional Development	High	4	14		High	16	5	High/Med
Traditional/Cultural Use	Low	5	15			11	14	Med/Low
Mooring buoys	Med	N/A	5			N/A	11	Med
Vessel management, how are they using the park? Anchoring	Med	N/A	7	Med/ High	High	12	7	Med
Electronic charts	Low	N/A	N/A			N/A	18	Low
Commercial activities (dive boats)	Low	N/A	12			9	15	Med/Low
Concession activities	Low	N/A	11			8	4	Med/Low
Diffuse vs. Concentrate (Visitor concentration/controversial)	Med	15	16			4	8	Med/Low
Air quality	Low	13	N/A		High/Med	N/A	20	Low
Water quality	High	1	N/A	Med	High	6	12	High/Med
Overpopulation of native species	Low	N/A	17			N/A	17	Low
Cultural landscapes/natural environment	Low	12	N/A			5	9	Med
Archeological Resource Protection (SARI Write In)						1		
Sedimentation (VIIS Write In)					High		6	
Global Warming (EVER Write In)					High			
Native Species Reintroduction (EVER Write In)					Med			

Table 2. SFCN Primary Vital Signs Monitoring Needs

	BISC	BICY	BUIS	DRTO	EVER	SARI	VIIS
No-take zone effectiveness				x			
Ecosystem "health" - marine	x		x	x		x	
Ecosystem "health" - terrestrial		x			x		
Exotic Plants/animals			x		x	x	x
Sedimentation							x
Reef Fish Monitoring							x
Coral Reef Monitoring	x						
Seagrass Monitoring	x				x		
Fishing Pressure					x		
ORV Impacts (airboat)					x		
Birds		x			x		
Herps					x		
Vessel Impacts	x				x		
Groundwater					x		
T&E Species			x			x	

Table 3. SFCN Network Staffing Priorities

Priority	Position Title	BISC	BICY	BUIS	DRTO	EVER	SARI	VIIS
1	Marine Ecologist	x			x	x		
2	Marine Biologist			x			x	
3	Biometrician/Statistician					x		x
4	Database Developer					x		
5	Entomologist					x		
6	Pilot					x		
7	GIS Specialist(Ecologist)	x						
8	Terrestrial Ecologist							x
9	Fish Ecologist/Biologist				x			
10	Ecologist		x					
11	Research Biologist		x					

Table 4. Current SFCN I&M Staff Office Availability (# of staff)

	BISC	BICY	BUIS	DRTO	EVER	SARI	VIIS
Open office space	Possibly	0	yes,4	0	1	see BUIS	1

Table 5. SFCN Equipment Needs

BISC	underwater positioning system, mapping equipment; vessels; outboards
BICY	real time telemetry of hydrologic (and other) information
BUIS	SCUBA equipment, herbarium cabinet, Updated Science Library
DRTO	Water quality monitoring for human pathogens
EVER	Kevlar Flight helmets, ArcPad GIS/GPS hand-held units
SARI	Small inflatable with trailer
VIIS	Remote camera fish censusing station for deep-water sites; movement trip sensors for wildlife, radio-telemetry applicable for dense/steep environments; large format plotter

Table 6. SFCN Technical Needs

BISC	GIS, STATS
BICY	Updated competency on software (GIS)
BUIS	Stats (multivariate), Advanced GIS, Access, VBA, Visual Fox Pro
DRTO	GIS
EVER	GIS, ARCGis, ARCPad, General wildlife/fisheries management, instrumentation, ACETA (animal capture, restraint, immobilization, transportation training)
SARI	Stats (multivariate), Advanced GIS, Access, VBA, Visual Fox Pro
VIIS	Intermediate to advanced ArcView training, biostatistics workshop, wildlife handling, restraint, and immobilization techniques

Table 7. SFCN Training Needs

BISC	GIS, stats, NPS I&M program, SFC network
BICY	Anabat or other monitoring equipment
BUIS	Stats (multivariate), Advanced GIS, Access, VBA, Visual Fox Pro
DRTO	Network activities, roles, and f(x); newsletter
EVER	Presentation to explain what we are doing
SARI	Stats (multivariate), Advanced GIS, Access, VBA, Visual Fox Pro
VIIS	MS Access

Table 8. SFCN Opinion on Volunteer monitoring

BISC	consistency?; better used for other tasks
BICY	Would support volunteer monitoring
BUIS	good outreach/education - limited data value
DRTO	with sufficient training and supervision
EVER	useful w/ training and supervision
SARI	good outreach/education - limited data value
VIIS	birds, sea turtles OK, fish not OK

APPENDIX H

ONGOING NATURAL RESOURCE MONITORING

H.1 Big Cypress National Preserve
H.2 Biscayne National Park
H.3 Buck Island Reef National Monument
H.4 Dry Tortugas National Park
H.5 Everglades National Park
H.6 Salt River National Historic Park and Ecological Preserve
H.7 Virgin Islands National Park and Coral Reef National Monument

APPENDIX H.1

BIG CYPRESS NATIONAL PRESERVE

ONGOING NATURAL RESOURCE MONITORING

South Florida Caribbean Network
2005

Appendix H.1 Big Cypress National Preserve Ongoing Natural Resource Monitoring

Activity	Objective	Organization	Frequency	Year initiated	Primary Parameters	Methods/Scope
Alligator surveys	Determine population size and condition	USGS	Annually	2000	Condition, length, sex	Night surveys, capture-recapture
Archaeological site monitoring	Track status of 400 known sites and add new sites	NPS-BICY		1978?		Visits to sites
Backcountry camps monitoring	Track status of over 100 backcountry camps	NPS-BICY	Annually	mid-1980s?	status of camps, whether buildings are being maintained, existence of new buildings and compliance status	Visits to camps
Contaminants in water column	Contaminant distribution, range, variablility, concentration	NPS-CESI				
Deer harvest		FWC	Annually			Check stations operated during peak hunting season
Deer surveys		NPS-BICY	Annually			
Fire effects monitoring		NPS-BICY				
Florida Panther Monitoring	Track the locations, home ranges, and mortality of all adult lions in BICY	NPS-BICY	Check locations every other day		Locations of cats at each point in time	Radio collar tracking with signal location every 2 days; new adult cats collared as soon as possible
Hiking/backcountry visitor use	To estimate off-road visitor use and provide safety check-in data for visitors	NPS-BICY	Continuous		Number visitors, duration of visit, type of use	Permits must be filled out at trail head for hikers & ORV visitors (about 50% compliance)
Hog harvest data		FWC	Annually			Check stations operated during peak hunting season
Invasive plants systematic reconnaissance flights	To track the distribution and location of exotic plants and create a map to tell contractors where to initiate control actions	NPS-EPMT; SFWMD funds	every 2 years	1989	Points where invasive species identified	Collected via air by covering park in 1 km lines

Appendix H.1 Big Cypress National Preserve Ongoing Natural Resource Monitoring

Activity	Objective	Organization	Frequency	Year initiated	Primary Parameters	Methods/Scope
Invasive plant treatment database updates	To track where exotics treatment/control efforts have been initiated	NPS		1984		
Manatee monitoring		USFWS	Annually			Part of Florida-wide monitoring program
Oil & gas monitoring	To track locations, status, pumpage of wells	Oil & gas companies		Varies with well	Production data, well depth, zone tapped, locations, date plugged if well closed	
Park visitation monitoring	To provide relative estimates of park visitor use	NPS-BICY	Continuous		Number of cars	Traffic counter at Visitor Center (HWY 41) and Loop Road
Red cockaded woodpecker monitoring	To track number, location, and size of RCW colonies (clusters)	NPS-BICY	Annually		Number and location of individuals and size of colonies	Bird banding
Turkey harvest ???		FWC	Annually			Check stations operated during peak hunting season
Vegetation mapping	Track changes of spatial patterns of vegetation in wet prairies, marshes, forests, tree islands, mangroves, beaches and tidal wetlands	CERP	Every 5 years	2004	Spatial coverage of vegetation types	1:24000 color infrared photography, 1/4 h mmu, not complete coverage of park
Water depth monitoring	To provide water depth measurements useful for depth computer modeling	SFWMD			Water depth	100 station; 20 also take water quality data
Water quality monitoring		SFWMD			Dissolved oxygen, pH, temperature, conductivity	20 stations
Weather stations	To provide weather data for the fire program	NWS	Continuous			3 RAWS stations. One is 25 years old

Appendix H.1 Big Cypress National Preserve Ongoing Natural Resource Monitoring

Activity	Objective	Organization	Frequency	Year initiated	Primary Parameters	Methods/Scope
Woodstork nest monitoring	To assess woodstork nesting success	NPS-BICY	Annually			

APPENDIX H.2

BISCAYNE NATIONAL PARK

ONGOING NATURAL RESOURCE MONITORING

South Florida Caribbean Network
2005

Appendix H.2 Biscayne National Park Ongoing Natural Resource Monitoring

Activity	Objective	Organization	Frequency	Year initiated	Primary Parameters	Methods/Scope
Avian Monitoring (Christmas Bird Count)	Identify Annually trends in abundance and distribution of bird species	NPS	Annually	1979	Species present and abundance	
Boat use management	Track boat visitation	NPS	Weekly/bi-weekly	1976	Location, number of boat trailers	
Climate monitoring	Track changes in local weather	NOAA-NDBC	Continuous		Location, windspeed/direction, wind gust, water temperature	
Coral monitoring	Track change in composition of major benthic functional groups	NPS	Annually	2000	Location, species, percent cover	
Creel monitoring	Track fishing pressure	NPS	Weekly/bi-weekly	1976	Location, species, size, harvest method	
Exotic plant monitoring	Track invasion of exotic species	NPS	Annually	2003	Location and extent	
Fish monitoring	Describe and identify trends in shallow-water habitat utilization	NPS/ NOAA/ USGS	Monthly	2003	Species present, abundance, lengths (for target species)	
Larval fish and invertebrates monitoring	Identify trends in larval supply	NPS	Monthly	2004	Number per species	
Lobster monitoring	Track regional trends	State	Annually	1990's	Location, number, sex, size	
Lobster monitoring	Track trends and effects of mini-season at specific reef sites	NPS	Annually		Lobster densities, distributions, and size distributions at a number of reef and hard-bottom sites before and after lobster mini-season	

Appendix H.2 Biscayne National Park Ongoing Natural Resource Monitoring

Activity	Objective	Organization	Frequency	Year initiated	Primary Parameters	Methods/Scope
Lobster larval and juvenile monitoring	Identify trends in larval supply	NPS	Monthly	2005	Number and larval or juvenile stage	
Lobster Mini-season recreational catch monitoring	Track recreational extractive use of Spiny Lobster	NPS	Annually	1988	Location, number, size, sex, eggs	
Manatee monitoring	Track population size	State/NOAA	Annually	1980's	Location and number of individuals	
Reef fish monitoring	Estimate exploited species population park-wide	NOAA NMFS / NPS / RSMAS	Annually	1980's	Location, species, size	
Sea grass monitoring	Composition, distibution, trend analysis	Dade County	Monthly/Annually		Density per square meter, species	
Sea turtle	Nesting activity/success	NPS	Daily during nesting season	1991	Location, predation, number of eggs	
Vegetation mapping	Track changes of spatial patterns of vegetation in wet prairies, marshes, forests, tree islands, mangroves, beaches and tidal wetlands	CERP	Every 5 years	2004	Spatial coverage of vegetation types	1:24000 color infrared photography, 1/4 h mmu, not complete coverage of the park
Water quality	Detect trends in water quality parameters	NPS/Dade/FIU/SFWMD/USACE	Continuous/monthly	1972	Temperature, conductivity, pH, dissolved oxygen, turbidity	

APPENDIX H.3

BUCK ISLAND REEF NATIONAL MONUMENT

ONGOING NATURAL RESOURCE MONITORING

South Florida Caribbean Network
2005

Appendix H.3 Buck Island Reef National Monument Ongoing Natural Resource Monitoring

Activity	Objective	Organization	Frequency	Year initiated	Primary Parameters	Methods/Scope
Acropora palmata monitoring	To determine population parameters, distribution, abundance, disease, urchin, and predatory snail presence	NPS-BUIS	Ongoing	2000	Location, size, predation, survivorship	
Air temperature monitoring		NPS-BUIS	Ongoing	2003	Also in sand at 30 cm	
Avian monitoring (Christmas Bird Count)	To loosely assess regional trends in abundance and presence of birds	Audubon	Annually	1999	Species richness	
Coastal geomorphology		NPS-BUIS	Ocassionally/ post storm	1977	Sand transport	
Conch monitoring	To assess current population and fecundity	FWRI	Ongoing	2004	Size, lip thickness, and distribution	
Coral colony monitoring	To detect boulder coral survivorship and life history	NPS-BUIS	Bi-annually	1987	Location, size, growth, fission/fusion, survivorship, basic life history	
Coral reef monitoring-chain transects	To detect changes in coral reef community cover, structure, composition, and disease detection	NPS-BUIS	Every 2 years	1988	% cover, coral species, rugosity, disease	
Coral reef habitat characterization mapping	To detect changes at landscape scale of benthic community	NOAA-Biogeography Team	Ongoing	1999	Habitat area	
Coral reef monitoring-Random video	To detect changes in coral reef community cover	NPS-SFCN	Annually	2000	% cover, coral species, urchin density, disease presence	2 sites
Exotic animals		NPS-BUIS	Bi-annually	1999	Rats, mice	

Appendix H.3 Buck Island Reef National Monument Ongoing Natural Resource Monitoring

Activity	Objective	Organization	Frequency	Year initiated	Primary Parameters	Methods/Scope
Juvenile sea turtle monitoring	To assess basic life history info, survivorship, and health, habitat utilization, residency, growth rates, foraging	NPS-BUIS	Year round	1994	Size, recapture status, blood work, growth rates, location, genetics, population, habitat utilization, foraging behavior, residency	Index sites include Mona Island PR, DR, Barbados and BUIS, with additional work in Australia
Lobster monitoring	To assess current population	FWRI	Ongoing	2004	Larval life history, size, molt condition, reproductive status, distribution and disease	
Migratory and native birds monitoring	To assess qualitative avian presence	NPS-BUIS	Incidental, when on site	1960's	Bird data collected in addition to other projects when sighted	
Park visitation monitoring		NPS-BUIS	Daily when law enforcement patrols	1975	Number of visitors, boats, snorkelers	
Precipitation monitoring		NPS-BUIS	Ongoing	2003	Rain gauge checked daily July-Oct, intermitent (weekly/twice a week when on site)	
Reef fish monitoring	To assess species composition, size and abundance	NOAA-Biogeography Team	Bi-annually	1987	Species richness, abundance, habitat/assemblege association	Random sites by habitat throughout park; transects (sites)

Appendix H.3 Buck Island Reef National Monument Ongoing Natural Resource Monitoring

Activity	Objective	Organization	Frequency	Year initiated	Primary Parameters	Methods/Scope
Seabird monitoring	To track threatened and endangered bird populations	NPS-BUIS	Seasonal	1969	Pelican nesting, least tern nesting, neotropical migrant and resident songbirds, ducks, pigeons	
Sea turtle nesting monitoring	To assess Hawksbill turtle recovery, and track green, loggerhead, and leatherback nest at Buck Island	NPS-BUIS	Year round	1970s	Nesting success, nesting population, spatial and temporal info at beach, index site for hawksbill recovery, mongoose predation	Saturation tagging began in 1993
Water Quality		USVI-DPNR	Ongoing	1968	Temperature, conductivity, pH, turbidity (see Horizon report)	
Water Quality - fecal		USVI-DPNR	Ongoing	1975	Fecal coliform at swimming beaches	
Water temperature		NPS-BUIS	Ongoing	1987	Temperature	

APPENDIX H.4

DRY TORTUGAS NATIONAL PARK

ONGOING NATURAL RESOURCE MONITORING

South Florida Caribbean Network
2005

Appendix H.4 Dry Tortugas National Park Ongoing Natural Resource Monitoring

Activity	Objective	Organization	Frequency	Year initiated	Primary Parameters	Methods/Scope
Climate monitoring	Track changes in local weather	NOAA-NDBC	Continuous		Location, windspeed/direction, wind gust, water temperature	
Coral monitoring	Track change in composition of major benthic functional groups	NPS	Annually	2004	Location, species, percent cover	
Coral monitoring-CREMP	Track change in composition of major benthic functional groups	State	Annually	1998	Location, species, percent cover	
Coral Monitoring-historic	Track change in composition of major benthic functional groups	State	Not continuous	1972	Location, species, percent cover	
Creel monitoring	Track fishing pressure	NPS	Continuous	1981-84, 2000 to present	Location, species, size, harvest method	
Exotic plant monitoring	Track invasion of exotic species	NPS	Annually	2003	Location and extent	
Lobster monitoring	Track regional trends	State	Annually	1995	Location, number, sex, size	
Manatee monitoring	Track population size	State/NOAA	Annually	1980's	Location and number of individuals	
Red Grouper monitoring	Record life history information	State	Continuous	2005	Movement	
Reef fish monitoring	Estimate exploited species population park-wide	NOAA NMFS; UM/RSMAS/NURC	Annually/ Biennial	1980's	Location, species present, size	
Sea grass	Composition, distibution, trend analysis	FIU?	Monthly/ Annually		Density per square meter, species	
Sea turtle	Nesting activity/success	NPS			Location, predation, number of eggs	

Appendix H.4 Dry Tortugas National Park Ongoing Natural Resource Monitoring

Activity	Objective	Organization	Frequency	Year initiated	Primary Parameters	Methods/Scope
Water quality	Detect trends in water quality parameters	FIU	continuous/ monthly	1980's	Temperature, conductivity, pH, dissolved oxygen, turbidity	

APPENDIX H.5

EVERGLADES NATIONAL PARK

ONGOING NATURAL RESOURCE MONITORING

South Florida Caribbean Network
2005

Appendix H.5 Everglades National Park Ongoing Natural Resource Monitoring

Activity	Objective	Organization	Frequency	Year initiated	Primary Parameters	Methods/Scope
Air quality monitoring	To provide air quality and atmospheric deposition information	NPS-EVER	Deposition - weekly; particulates (visibility)- every 3 days; ozone - continuous		Ozone, wind speed, visibility, wet & dry deposition of anions, cations, and mercury	Atmospheric deposition collector; IMPROVE particle monitor; ozone monitor
Alligator nest surveys systematic reconnaissance flights	Determine breeding population	NPS-EVER	Annually	1985	Nest abundance, clutch size, nest success	Collected via air by covering park in 500 m wide belt transect spaced every 1km
Alligator surveys	Determine population size and condition	USGS	Annually	2000	Condition, length, sex	Night surveys, capture-recapture
Cape Sable Seaside Sparrow surveys	Determine population size and condition	NPS-EVER	Annually - during breeding season		Abundance of calling males	Abundance of calling males
Deer surveys systematic reconnaissance flights	Determine population size and condition	NPS-EVER	Annually	1985		
Fire effects monitoring	Determine the size, frequency, and ignition source of fires	NPS-EVER fire and aviation division		1971	Fire area, ignition source, treatment	GIS survey, ground visits
Fire effects monitoring	Determine the effect and role of fire in the ecosystem.	NPS-EVER fire and aviation division			Vegetation plots - percent cover, DBH, species composition of trees and species in tree, shrub, herb layer	Vegetation plots

Appendix H.5 Everglades National Park Ongoing Natural Resource Monitoring

Activity	Objective	Organization	Frequency	Year initiated	Primary Parameters	Methods/Scope
Phosphorus survey	Track impacts of soluble reactive phosphorus	FIU/Florida Coastal Everglades Long Term Ecological Research (FCE-LTER)	Continuous	2000	SRP, Water monitoring, plant productivity, fish productivity, soil elevation	Shark River Transect (Six Sites), Taylor River Transect (Eight sites)
Florida Panther monitoring	To track the locations, home ranges, and mortality of all adult lions in EVER	NPS-EVER	Check locations every other day		Locations of cats at each point in time	Radio collar tracking with signal location every 2 days; new adult cats collared as soon as possible
Freshwater fish surveys	Determine population size and reproductive output	USGS / FIU	Annually		Fish density	Repeat throw trapping
Game fish harvest surveys	Determine population size, sustainable harvest, and condition	NPS-EVER	Continuous	1958	Species, effort, fish length, angler information, recreational and commercial (guides)	Creel survey check stations at Flamingo Ramp, Chokoloskee; trailer and boat counts
Ground water quality monitoring	To provide water quality measurements for long-term park management.	NPS-EVER			Dissolved oxygen, pH, temperature, conductivity	
Hiking/backcountry visitor use surveys	To estimate off-road visitor use and provide safety check-in data for visitors	NPS-EVER	Continuous		Number visitors, duration of visit, type of use	Permits must be filled out at trailhead for hikers & backcounty boating
Invasive plants systematic reconnaissance flights	To track the distribution and location of exotic plants and create a map to tell contractors where to initiate control actions	NPS-EMPT; SEWED funds	Every 2 years	1999	Points where invasive species identified	Collected via air by covering park in 1 km lines
Invasive plant treatment database updates	To track where exotics treatment/control efforts have been initiated	NPS		1984		
Manatee monitoring	Determine Population size and condition	USFWS	Annually			Part of Florida-wide monitoring program

Appendix H.5 Everglades National Park Ongoing Natural Resource Monitoring

Activity	Objective	Organization	Frequency	Year initiated	Primary Parameters	Methods/Scope
Park visitation monitoring	To provide relative estimates of park visitor use	NPS-EVER	Continuous		Number of cars	
Pink Shrimp surveys	Determine population size and reproductive output	USGS	Annually		Density and larval production	Repeat throw trapping, larval spawn netting
Seagrass monitoring	To provide seagrass popluation and distribution	FIU	Monthly	1990	Seagrass distribution, productivity	Long term plot based sampling
Soil elevation	To determine role of accretion, subsidence and change in soil elevation	USGS, SFWMD	Quarterly to annually	1998	Accretion, soil elevation	Soil Elevation Table (SET)
Solution hole vegetation survey	Detect change in vegetation	NPS-EVER			Plant distribution and dominant species	100 solution holes
Surface water quality monitoring	To provide water quality measurements for long-term park management.	NPS-EVER	Monthly		Dissolved oxygen, pH, temperature, conductivity	

APPENDIX H.6

SALT RIVER NATIONAL HISTORIC PARK

& ECOLOGICAL PRESERVE

ONGOING NATURAL RESOURCE MONITORING

South Florida Caribbean Network
2005

Appendix H.6 Salt River Bay National Historic Site and Ecological Preserve Ongoing Natural Resource Monitoring

Activity	Objective	Organization	Frequency	Year initiated	Primary Parameters	Methods/Scope
Coral monitoring	To detect changes in the coral community	USVI-DPNR	Various	1978	Multiple projects with overlap (see Kendall et al 2005)	
Coral reef habitat characterization mapping	To detect changes at landscape scale of benthic community	NOAA-Biogeo	Ongoing	1999	habitat area	
Water quality	To provide water quality measurements for long-term park management.	USVI-DPNR	Ongoing	1968	Temperature, conductivity, pH, turbidity (see Horizon report)	
Water quality - fecal	To provide water quality measurements for long-term park management.	USVI-DPNR	Ongoing	1975	Fecal coliform at swimming beaches	
Water temperature		NPS-BUIS	Ongoing	1987	temp	

APPENDIX H.7

VIRGIN ISLANDS NATIONAL PARK

& CORAL REEF NATIONAL MONUMENT

ONGOING NATURAL RESOURCE MONITORING

South Florida Caribbean Network
2007

Appendix H.7 Virgin Islands National Park Ongoing Natural Resource Monitoring

Activity	Objective	Organization	Frequency	Year initiated	Primary Parameters	Methods/Scope
Acropora palmata monitoring	Propose species for listing; determine if elkhorn coral is recovering in VIIS & determine role of various pressures on recovery	USGS/NPS-VIIS/University of Virgin Islands/Disney Wildlife Conservation Fund	At least monthly	2003	Spatial distribution, size, percent mortality, predators, diseases, physical damage, temperature	2 main sites (Hollover, Hawkness) plus 12 that were visited once; GPS coordinates of colonies
African dust monitoring	To monitor amount and composition of african dust with special focus on contaminants- pesticides, persistent organic pollutants	USGS-Virginia Garrison	Seasonal during dust season	late 1990's early 2000	Collecting dust	
Air quality monitoring	Baseline site to monitor air quality	NPS-VIIS	Deposition - weekly; Particulates (visibility) - every 3 days	1998	Wet & dry deposition of anions and cations, visibility	1 air quality monitoring station -- atmospheric deposition collector, particle monitor
Avian monitoring (Christmas bird count)	To loosely assess regional trends in abundance and distribution (presence) of birds	Audobon/NPS-VIIS - Laurel Branick local contact	Annually	1981	Species richness, presence of individual species	Throughout islands, divided into 4 segments; see data sheets
Beach profiles (sand migration)	To measure beach erosion & migration	NPS-VIIS	Quarterly & after major events	Feb, 1998	Beach profiles	5 beaches, Trunk, cinnamon, Honeymoon, Coco Lobo, Western Reef
Catastrophic event effects on plant growth & diversity	To evaluate influence of catastrophic events on succession and develop a photo herbarium of tree species at site	Dr. Patrick Keller	revisited 2004 & 2005	1975	Map trails, stonewalls, existing dry streambeds, relative elevations, physical locations of 5 uncommon species	Using same 40 hectare study area by Forman and Hahn (1980)

Appendix H.7 Virgin Islands National Park Ongoing Natural Resource Monitoring

Activity	Objective	Organization	Frequency	Year initiated	Primary Parameters	Methods/Scope
Coral recruitment surveys	Determine recruitment of corals	USGS - Ilsa Kuffner				
Coral reef monitoring-Random video	To detect changes in coral reef community cover	NPS-SFCN	Annually	1999	% cover, major coral spp, urchin density, disease presence	Random video, 4 sites
Coral - White plague monitoring	To determine effects of disease on major reef building corals		Annually	2005	Presence/absence & area affected; belt transects along random coral monitoring transects	1 site at Buck Island, Hollover, Lameshur, Newfound, Mennebeck
Coral disease and recruitment	To assess long term dynamics, especially recruitment population biology & role of temperature	California State Univiversity Northridge-Pete Edmunds	Annually	1987	Recruitment, % coral cover,, % algae, % vacant space, mortality, seawater chemistry (temperature, salinity)	8 sites (Lameshure area) , 250 photo quadrats
Coral reef monitoring-chain transects	To detect changes in coral reef community cover, structure, composition, and disease detection	NPS-SFCN	Every 5 years	1989	% cover, major coral spp, rugosity, disease	2 reference sites
Coral reef monitoring - disease	To evaluate disease abundance, progression and coral mortality	NPS-SFCN	monthly	1997	% coral cover, % disease cover	1 site (Tektite)
Coral reef monitoring-video of chain transects	To detect changes in coral reef community cover	NPS-SFCN	Annually	1998	% cover, major coral spp, urchin density, disease presence	2 reference sites

Appendix H.7 Virgin Islands National Park Ongoing Natural Resource Monitoring

Activity	Objective	Organization	Frequency	Year initiated	Primary Parameters	Methods/Scope
Exotic plant monitoring	To qualitatively assess the need to treat exotic plants	NPS-EPMT	As needed		Inventory prior to treatment & followup site visits	
Forest Inventory and Monitoring in the Puerto Rican and US Virgin Islands	To monitor basal area, stem density, forest condition, merchantable volume and total aboveground biomass	USDA-USFS		2004	Basal area, stem density, forest condition, merchantable volume and total aboveground biomass; tree crown condition, soil productivity and down woody debris at a subset of sampling sites; forest structure and diversity described in greater detail in pilot project on St. John	random selection of sample sites using FIA protocol
Fish monitoring - reference site - adult	To monitor species composition, size and abundance	NPS-SFCN/cooperators	Annually	1991?	Species richness, abundance	4 Reference sites; point counts
Fish monitoring - reference site - juvenile	To monitor species composition, size and abundance	NPS-SFCN/cooperators	Annually	1991?	Species richness, abundance	4 Reference sites; transects

Appendix H.7 Virgin Islands National Park Ongoing Natural Resource Monitoring

Activity	Objective	Organization	Frequency	Year initiated	Primary Parameters	Methods/Scope
Marine sediments, seawater, fish tissue - chemistry & contaminants monitoring	To report periodically on the condition of the nations waters	USEPA- Environmental Monitoring and Assessment Program: National Coastal Assessment		2004	Marine sediment for organic & inorganic contaminant analysis, TOC, grain size, infaunal organisms, seawater (dissolved and total nutrients, chl a TSS); fish tissue - organic & inorganic contaminant analysis	Samples from around the island
Re-mapping Mary Creek fringing reef complex, St. John	To assess changes in coral composition & cover	Williams College-Ronadh Cox	1998 remapped, remapping again in 2004	1968		Mary's Creek
Reef fish monitoring - fish	To assess species composition, size and abundance	NOAA-Biogeography Team	Annually		Species richness, abundance	Random sites by habitat sites throughout park;approx 170 transects (sites)
Reef fish monitoring - fish associated habitat	Benthic community composition, rugosity	NOAA-Biogeography Team	Annually		% cover, all coral spp, rugosity, disease	Random sites by habitat sites throughout park;approx 170 transects (sites)
Regional tropical dry forest monitoring	Part of regional network to examine tropical dry forests	Smithsonian MAB-Francisco Del Mayer	Every 5+ years	early 1990s	Species, DBH, growth rates, succession	1 1-hectare plot on Margaret Hill

Appendix H.7 Virgin Islands Coral Reef National Monument Ongoing Natural Resource Monitoring

Activity	Objective	Organization	Frequency	Year initiated	Primary Parameter	Methods/Scope
Fish monitoring - adult	To monitor species composition, size and abundance	NPS-SFCN/cooperators	Annually	2001	spp. richness, abundance	6 sites; point counts
Marine sediments, seawater, fish tissue - chemistry & contaminants	To report periodically on the condition of the nations waters	USEPA- Environmental Monitoring and Assessment Program: National Coastal Assessment		2004	marine sediment for organic & inorganic contaminant analysis, TOC, grain size, infaunal organisms, seawater (disolved and total nutrients, chl a TSS); fish tissue - organic & inorganic contaminant analysis	samples from around the island
Monumental sweep - fish pot removal	To remove abandoned fish traps	NPS-VIIS		2004	habitat description	also identify habitats while diving for pots; not sure if qualifies as monitoring
Reef fish monitoring - fish	To assess species composition, size and abundance	NOAA-Biogeo	Annually		spp. richness, abundance	Random sites by habitat sites throughout park;approx 170 transects (sites)
Reef fish monitoring - fish associated habitat	benthic community composition, rugosity	NOAA-Biogeo	Annually		% cover, all coral spp, rugosity, disease	Random sites by habitat sites throughout park;approx 170 transects (sites)
Water Quality		NPS-VIIS	quarterly (in 1995; prior was monthly)	1988	temp, salinity, conductivity, DO, turbidity, N, P, Transmisivity, spectralradiometry,	1 site

Appendix H.7 Virgin Islands Coral Reef National Monument Ongoing Natural Resource Monitoring

Activity	Objective	Organization	Frequency	Year initiated	Primary Parameter	Methods/Scope

APPENDIX I.1

AIR QUALITY MONITORING CONSIDERATIONS FOR THE SOUTH FLORIDA/CARIBBEAN NETWORK

Tonnie Maniero
NER Air Quality Ecological Effects Coordinator
August 2005

Appendix I.1.

AIR QUALITY MONITORING CONSIDERATIONS FOR THE SOUTH FLORIDA/CARIBBEAN NETWORK

Tonnie Maniero
NER Air Quality Ecological Effects Coordinator
August 2005

Introduction

As part of the National Park Service (NPS) Inventory and Monitoring (I&M) Program's Vital Signs scoping process, the South Florida/Caribbean Network (SFCN) will evaluate the need for ambient air quality and air pollution effects monitoring in Network parks. This report contains background and summary air quality information to assist Network staff in that effort. On-site and nearby off-site ambient air quality data were used in conjunction with park-specific resource information to evaluate the following relative to the SFCN: 1) the need for additional ambient air quality monitoring at any Network park, i.e., wet deposition, dry deposition, visibility, and/or ozone monitoring, and 2) the need for air quality effects-related monitoring at any Network park.

The evaluation for SFCN parks relied on data collected through a number of Federal- and state-sponsored ambient air quality monitoring programs. Monitor locations, site numbers, and distances from SFCN parks are provided in Tables 1 and 2. Maps displaying monitor locations and graphics summarizing monitoring data are provided in a separate PowerPoint file as an addendum to this report.

The evaluation used products developed by the NPS Air Resources Division (ARD) specifically for the I&M Program. In 2004, the ARD finalized an Air Quality Inventory for I&M parks. The Air Quality Inventory consists of GIS-based maps and associated look-up tables that provide baseline values for a set of air quality parameters for all I&M parks. The values are based on averaged 1995 to 1999 data. Air Quality Inventory products are in the NPS Air Atlas (http://www2.nature.nps.gov/air/maps/airatlas/). NPS Air Atlas estimates for select air quality parameters for SFCN parks are provided in Appendix 1 of this report, and a description of those parameters is provided in Appendix 2. Because ozone is a regional pollutant, in most cases the estimates are likely representative of ozone concentrations in a park. Greater variability, and uncertainty, may exist for deposition and visibility values, since those pollutants are more likely to be influenced by meteorological differences.

In another project, completed in October 2004, ARD contracted with an ozone effects expert to assess the risk of ozone-induced foliar injury on sensitive vegetation in I&M parks. The risk assessments are based on NPS Air Atlas ozone values, the Palmer Z Drought Index and park vascular plant lists. The assessment for the SFCN is attached as Appendix 3.

Wet Deposition

The National Atmospheric Deposition Program/National Trends Network (NADP/NTN) is a nationwide network of precipitation monitoring sites. The network is a cooperative effort between many different groups, including the U.S. Environmental Protection Agency (EPA), U.S. Geological Survey (USGS), U.S. Department of Agriculture, and private entities. The NPS is a major participant in NADP/NTN, and the ARD recommends that any new wet deposition site installed in a park meet NADP/NTN siting criteria and follow NADP/NTN monitoring protocols. There are currently more than 200 NADP/NTN sites spanning the continental U.S., Alaska, Puerto Rico, and the Virgin Islands (http://nadp.sws.uiuc.edu/).

The purpose of the NADP/NTN network is to collect data on the chemistry of precipitation in order to monitor geographical and temporal long-term trends. The precipitation at each station is collected weekly according to strict clean-handling procedures. It is then sent to the Central Analytical Laboratory in Illinois where it is analyzed for hydrogen (acidity as pH), sulfate (SO_4), nitrate (NO_3), ammonium (NH_4), chloride, and base cations (such as calcium, magnesium, potassium and sodium). NADP/NTN's excellent quality assurance programs ensure that the data remain accurate and precise.

The NADP/NTN has also expanded its sampling to include the Mercury Deposition Network (MDN), which currently has over 85 sites in North America. The MDN was formed in 1995 to collect weekly samples of precipitation, which are analyzed for total mercury. The objective of the MDN is to monitor the amount of mercury in precipitation on a regional basis (http://nadp.sws.uiuc.edu/mdn/).

Deposition varies with the amount of annual on-site precipitation, and is useful because it gives an indication of the total annual pollutant loading at the site. Concentration is independent of precipitation amount, therefore, it provides a better indication of whether ambient pollutant levels are increasing or decreasing over the years. In general, annual average wet deposition and concentration of SO_4, NO_3, and NH_4 are higher in the eastern than in the western U.S. At many NADP/NTN sites across the U.S., concentration and deposition of SO_4 have declined in recent years as sulfur dioxide emissions have decreased. Trends have been variable for NO_3 and NH_4, with concentration and deposition at different sites increasing, decreasing, or showing no overall change. MDN deposition maps show that, similar to SO_4 and NO_3, wet mercury deposition is higher in the eastern U.S. than in the western U.S. Highest wet mercury deposition values are consistently reported for sites in Florida and along the Gulf of Mexico. The MDN program has not yet performed trend analyses for mercury deposition data due to the relatively short time the monitors have been in operation.

Everglades National Park (NP) has both NADP/NTN and MDN monitors on-site and Virgin Islands NP has an on-site NADP/NTN monitor. Big Cypress National Preserve (NPres) and Biscayne NP are within 38 and 30 km, respectively, of the Everglades NP monitors, while Buck Island Reef National Monument (NM) is about 85 km south of the Virgin Islands NP monitor. There are no NADP/NTN or MDN monitors near Dry Tortugas NP. The average 1995 through 1999 Air Atlas wet deposition values for SFCN parks in Florida were 3.49 to 4.63 kilograms per hectare per year (kg/ha/yr) for sulfur (S) and 2.97 to 3.93 kg/ha/yr for nitrogen (N). The 1999 deposition values at Virgin Islands NP were 2.67 kg/ha for S and 0.99 kg/ha for N, comparable to amounts recorded at the park in 2003. Further information on the Everglades and Virgin Islands NP wet deposition monitors is provided below.

<u>Everglades NP</u>

The NADP/NTN monitor was installed at the park Research Center in 1980 (site FL11). NADP/NTN trend analyses indicate no change in SO_4 concentration or wet deposition, no trend in NO_3 or NH_4 concentration, and slight increases in NO_3 and NH_4 wet deposition. The

MDN monitor was installed at the Research Center in 1995 (site FL11). Mercury concentration and wet deposition were substantially higher in 2003 than in previous years.

Virgin Islands NP
A NADP/NTN monitor was installed at the park in 1998 (site VI01). Because the data have not met the program's completeness criteria for most years, NADP/NTN has not performed a trend analysis for the site.

Dry Deposition
The Clean Air Status and Trends Network (CASTNet) is the nation's primary source for atmospheric data to estimate dry acidic deposition (http://www.epa.gov/castnet/). Established in 1987, CASTNet now comprises about 95 monitoring sites across the U.S. The majority of the monitoring stations are operated by EPA; however, approximately 30 stations are operated by the NPS in cooperation with EPA. Each CASTNet dry deposition station measures weekly average atmospheric concentrations of SO_4, NO_3, NH_4, sulfur dioxide, and nitric acid; hourly concentrations of ambient ozone; and some meteorological parameters. Dry deposition rates are calculated using atmospheric pollutant concentrations, meteorological data, and information on land use, vegetation, and surface conditions. CASTNet complements the database compiled by NADP/NTN; therefore, CASTNet sites are located at or near NADP/NTN sites. Dry deposition monitoring is more difficult, and more expensive, than wet deposition monitoring; consequently, there are fewer CASTNet than NADP/NTN sites nationwide. Because CASTNet calculates dry deposition based on estimated deposition velocities, there is greater uncertainty in the reported values than in the values measured by NADP/NTN. CASTNet recently developed ambient concentration isopleth maps (http://www.epa.gov/castnet/mapindex.html), but has not produced similar maps for dry deposition.

Both Everglades and Virgin Islands NPs have/had a CASTNet monitor on-site; data summaries and trend analyses for the sites are provided below. There are no sites near Dry Tortugas NP.

Everglades NP
The Everglades NP CASTNet site was installed at the Research Center in 2000 (site EVE419). 2000 through 2003 data showed no trends in either dry S deposition or dry N deposition. Total S deposition at Everglades NP was composed of 17 percent dry deposition and 83 percent wet deposition, while total N deposition was 18 percent dry and 82 percent wet.

Virgin Islands NP
The CASTNet site was installed at Lind Point in 1993 and discontinued in 2004 (site VII423). 1999 through 2003 data showed no trends in either dry S deposition or dry N deposition. Total S deposition at the site consisted of 15 percent dry and 85 percent wet deposition, while total N deposition was 18 percent dry and 82 percent wet.

Chemical Analyses of Surface Water, Sediments and Biota
It is generally accepted that surface waters with a pH below 6.0 and an acid neutralizing capacity (ANC) below 100 microequivalents per liter (μeq/l) are sensitive to acidification from atmospheric deposition. The NPS Water Resources Division's *Baseline Water Quality Data Inventory and Analysis* reports were reviewed for all SFCN parks except Dry Tortugas NP, for which a report was not available. In addition, state agency and the NPS Research Permit and Reporting System (RPRS) websites were reviewed for reports of any additional, relevant surface water or sediment chemistry data. The websites were also reviewed for information pertaining to any chemical analyses conducted on biota in the park. The results are summarized below.

Acidification due to atmospheric deposition does not appear to be a threat to surface waters of any SFCN parks. Eutrophication from nitrogen deposition is a concern in many coastal areas, and may be an issue for the SFCN, particularly in Biscayne and Everglades NPs. Florida has fish consumption advisories to limit ingestion of mercury from fish. Advisories are in effect for water bodies in Collier, Monroe and Miami-Dade counties, which encompass Big Cypress NPres, Biscayne NP and Everglades NP (http://www.doh.state.fl.us/environment/community/fishconsumptionadvisories/index.html) . It does not appear that Virgin Islands has issued any fish consumption advisories (http://www.dpnr.gov.vi/dep/home.htm). A number of studies relative to mercury and other pollutants have been conducted in SFCN parks.

The U.S. Department of Agriculture (USDA) collected weekly ambient air, rain and surface water samples in 2002-2003 to determine whether pesticides are entering south Florida waters through atmospheric deposition. A number of pesticides were detected in the samples. Higher concentrations were found in air, rain and surface water during harvest (March) than during the planting season (November). Pesticide concentrations were lower in samples collected at Biscayne NP than in those from Everglades NP. (Kathleen Hapeman, USDA, 301-504-6511)

The Science Museum of Minnesota collected sediment cores from Florida lakes, and used ^{210}Pb-dating to try to evaluate changes in atmospheric mercury deposition over time and to distinguish mercury deposition resulting from local versus global sources. They were not successful in obtaining a core from Deep Lake in Big Cypress NPres, but they did get a core from Nine-Mile Pond in Everglades NP and from three other Florida lakes. Mercury concentrations and deposition varied between sites. A core from a central Florida lake indicated a decrease in mercury deposition over time, while cores from south Florida lakes showed no change in deposition. (Dan Engstrom, The Science Museum of Minnesota, 651-433-5953)

The USGS collected sediment cores at Big Cypress NPres and Everglades NP in 2002-2003 to examine mercury, S and nutrient cycling. Results were not provided on the RPRS website. (Ben McPherson, USGS, 813-975-8620)

The South Florida Water Management District collected water and sediment samples from Everglades NP in 2000-2001 and analyzed them for total and methylmercury. They found a pattern of elevated concentrations of methylmercury where runoff mixed with saline bay waters. This indicated a local source of methylmercury formation. (Darren Rumbold, South Florida Water Management District, 561-682-2132)

Long-term monitoring of mercury concentrations in largemouth bass and other fish has taken place in Everglades NP and peninsular Florida. Sampling began in Everglades NP in 1989. Fish mercury concentrations appear to increase from north to south in the park. Fish from North Prong Creek in Everglades NP and from Big Lostmans/Indian Camp Creek in the drainage basin of Big Cypress NPres exceeded Florida's "no consumption" threshold in 2001, 2002 and 2003. Results from earlier years were not reported on the RPRS website. (Ted Lange, 352-742-6461)

The South Florida Water Management District evaluated mercury concentrations in mosquitofish, sunfish and largemouth bass collected at Everglades NP in 2002-2004. While increased concentrations were observed between 2002 and 2003, the reason for, and significance of, the change is unknown. 2004 results were not provided on the RPRS website. (Nicole Niemeyer, South Florida Water Management District, 561-753-2400)

The USGS collected pig frogs (*Rana grylio*) in Everglades NP in 2001 and measured total mercury concentrations in frog leg muscle. They reported a maximum concentration of 2.3 mg/l (wet mass). (Kenneth Rice, USGS, 954-577-6305)

A researcher collected blood samples from eaglets and osprey nestlings at Everglades NP in 2003 to determine mercury levels in serum. No results were provided on the RPRS website. (Brian Mealey, 305-975-0200)

P.E.A.K. Research quantitatively evaluated pre-1992 and 2002 risks of chronic dietary mercury exposure to panthers in the Everglades. They determined that pre-1992, there was a 46 percent probability of exceeding chronic dietary thresholds for methylmercury. The 2002 risk was a 4 percent probability of exceedances. P.E.A.K. Research concluded that past mercury exposures likely adversely affected panthers in the Everglades, but that current risks from mercury are low. (Barron, M.G., S.E. Duvall, and K.J. Barron. 2004. Retrospective and current risks of mercury to panthers in the Florida Everglades. **Ecotoxicology** 13:223-229)

The Academy of Natural Sciences and others investigated factors that control aquatic cycling of mercury in the Everglades. Using a process-oriented, multidisciplinary approach that involved a number of intensively-studied sites in the Everglades, the investigators determined that: 1) mercury methylation in the Everglades is mediated by sulfate-reducing bacteria in the soil, 2) methylmercury bioaccumulation occurs primarily through the benthic food web, 3) S has the largest impact on methylmercury production, but the magnitude and direction of the impact vary with S concentration, and 4) phosphate and NO_3 have no direct effect on methylmercury production rates in sediment cores. (Cynthia Gilmour, The Academy of Natural Sciences, 410-586-9713)

The Florida Department of Environmental Protection (FDEP) used emissions, deposition and fish and wildlife data to show that a decline in local mercury emissions resulted in reduced mercury concentrations in Everglades wildlife. There was a significant reduction in mercury emissions in Dade, Broward and Palm Beach counties in about 1990. Analysis of lake cores showed a mercury reduction at about the same time. Mercury concentrations in egret feathers decreased between 1994 and 2003, approaching pre-1980 levels. Mercury concentrations in largemouth bass and mosquitofish also declined in the 1990s. The FDEP concluded a decline in local atmospheric mercury emissions resulted in a 75 percent decline in mercury concentrations in fish and wildlife in less than 15 years from peak deposition. They further concluded that atmospheric deposition drives the Everglades mercury problem. (Tom Atkeson, FDEP, 850-245-8305)

Particulate Matter

Small or "fine" particles in the air, typically those less than 2.5 microns in diameter, $PM_{2.5}$, are a leading cause of human respiratory illness. Particles are present everywhere, but high concentrations and/or specific types have been found to present a serious danger to human health. Fine particles in the air are also the main contributor to human-caused visibility impairment. The particles not only decrease the distance one can see; they also reduce the colors and clarity of scenic vistas.

The pre-existing human-health based National Ambient Air Quality Standards (NAAQS) for particulate matter (set by the EPA) are for particles 10 microns or less in diameter (PM_{10}). Areas where air quality exceeds the NAAQS are designated "nonattainment" for that pollutant. Only Buck Island Reef NM and Everglades NP have nearby PM_{10} monitors. In 1997, EPA finalized an additional, stricter NAAQS for particulate matter based on $PM_{2.5}$. Nationwide $PM_{2.5}$ monitoring was initiated in 1999. $PM_{2.5}$ monitors are located near all SFCN parks except Big Cypress NPres and Dry Tortugas NP. Neither Florida nor Virgin Islands have designated PM_{10} or $PM_{2.5}$ nonattainment areas (http://www.epa.gov/air/data/index.html).

In 2001, the USGS began investigating potential ecological effects in the Caribbean due to dust storms that originate in Africa. Air samples taken during dust storms at Dry Tortugas and Virgin Islands NPs contained bacteria, fungi, heavy metals and persistent organic pollutants. Laboratory studies indicate the dust could be toxic to some marine organisms. (Virginia Garrison and Dale Griffin, USGS, 727-803-8747)

Visibility

In 1985, in response to the mandates of the Clean Air Act, Federal and regional/state organizations established the Interagency Monitoring of Protected Visual Environments (IMPROVE) program to protect visibility in Class I air quality areas. Class I areas are national parks greater than 5,000 acres and wilderness areas greater than 6,000 acres, that were established prior to August 7, 1977. All other NPS areas are designated Class II. Everglades and Virgin Islands NPs are Class I areas. The objectives of the IMPROVE program are to: establish current visibility conditions in all Class I areas, identify pollutants (particles and gases) and emission sources responsible for existing man-made visibility impairment, and document long-term trends in visibility. The IMPROVE network is designed to assess regional visibility; standard operation does not identify individual sources that impair visibility at a monitoring site.

In 1999, there were 30 official IMPROVE sites and 40 protocol sites. Because of recently enacted Regional Haze regulations that require improving visibility in Class I areas, the number of visibility monitors has increased. Protocol sites were upgraded to full IMPROVE sites and 80 new sites were added to the IMPROVE network. While the IMPROVE program has focused on Class I air quality areas, a great deal of visibility monitoring has been conducted in Class II areas. Installation and annual operating costs for a full IMPROVE site are expensive. The ARD is currently developing a monitoring protocol for less-expensive view monitoring using a digital camera. While this type of monitoring would not be adequate for regulatory purposes, it is useful for documenting visibility conditions and trends and presents an excellent means of sharing that information with the public.

IMPROVE provides maps of visibility conditions, pie charts of the pollutants that contribute to visibility impairment, and trend data for sites that have been operating 10 years or longer (http://vista.cira.colostate.edu/views/). One measurement used to report visibility is light extinction, or b_{ext}, reported in inverse megameters (Mm^{-1}). Light extinction occurs when particles in the air scatter or absorb light; extinction generally increases as particle concentrations in the air increase. Therefore, the higher the b_{ext}, the worse the visibility. The Regional Haze regulations require improvements in visibility on both the best (clearest), and the worst (haziest), days. In general, visibility is much better in the western, than in the eastern, U.S.

Everglades and Virgin Islands NPs have on-site IMPROVE monitors. The Everglades site, EVER1, has been operating since 1988 while the Virgin Islands site, VIIS1, has been operating since 1998. No monitors are located near Dry Tortugas NP.

The average 1995 to 1999 estimates provided in the NPS Air Atlas indicate values at Florida SFCN parks of 38 to 39 Mm^{-1} on the best visibility days and 151 to 155 Mm^{-1} on the worst visibility days. 2003 IMPROVE data indicated b_{ext} at Florida SFCN parks on the best visibility days ranged from 23 to 27 Mm^{-1}. On the worst visibility days, b_{ext} at south Florida parks ranged from 72 to 90 Mm^{-1}. Everglades NP 2003 IMPROVE data show that on the clearest days, impairment was due to ammonium sulfate (52 percent), organic carbon (17 percent) and ammonium nitrate (12 percent). On the haziest days, impairment was due mostly to organic carbon (49 percent) and ammonium sulfate (38 percent). Sources of ammonium sulfate include coal combustion and oil refineries; sources of ammonium nitrate are coal and natural

gas combustion and automobiles; and sources of organic carbon include automobiles. The other constituents that contribute to visibility impairment are elemental carbon (from wood burning) and coarse mass (source unknown). 1990 through 2003 trend analyses for Everglades NP show improvements on both the clearest and haziest days through 2002, but substantial deterioration in 2003.

Ozone

Ozone is created by a chemical reaction between oxides of nitrogen and volatile organic compounds in the presence of heat and sunlight. Some major sources of ozone-forming chemicals are motor vehicle exhaust and industrial emissions, gasoline vapors, and chemical solvents. High ozone concentrations cause respiratory problems in humans, and are a particular concern for those who are engaging in strenuous aerobic activity, such as hiking. Ozone also damages sensitive plant species. It injures plant leaves by causing a visible spotting or "stipple" on the upper surface of the leaves. Ozone can affect plant physiology by reducing growth, increasing susceptibility to disease, and increasing senescence.

Everglades and Virgin Islands NPs have an ozone monitor on-site; Buck Island Reef NM and Dry Tortugas NP have no nearby monitors (http://www.epa.gov/air/data/index.html). EPA recently established a new NAAQS for ozone which is based on an 8-hour ozone concentration. The previous, less-stringent, NAAQS was based on a 1-hour concentration. There are no 1-hour or 8-hour ozone nonattainment areas in either Florida or Virgin Islands (http://www.epa.gov/ttn/naaqs/ozone/index.html).

The NPS focuses on plant sensitivity to ozone for a couple of reasons. First, ozone is a regional pollutant and is, therefore, more likely to affect park resources than other gaseous pollutants such as sulfur dioxide and nitrogen oxide which quickly convert to other compounds. Second, the literature on ozone sensitivity is more recent and more reliable than that for other pollutants. The ARD contracted with an ozone effects expert from Cornell University to perform ozone injury risk assessments for all parks in the NPS I&M program. The risk assessments relied on the ozone concentration data provided in Air Atlas, vascular plant lists contained in NPSpecies, a master list of ozone-sensitive vascular plant species developed at a 2003 expert workshop convened by the ARD (http://www2.nature.nps.gov/air/Pubs/index.htm), and the Palmer Z Index, which is used to indicate soil moisture status. Note that the ARD workshop report provides a general guide to ozone sensitivity. Differences in plant genetics, weather conditions, soil water availability, and ozone concentrations will affect whether or not a species exhibits injury in a park. In particular, studies have shown that plants will not take up ozone unless there is sufficient soil moisture. The risk assessments for the SFCN parks are in Appendix 3. An assessment could not be performed for Dry Tortugas NP due to the lack of ambient ozone data. For the remaining SFCN parks, there is a low risk of ozone-induced foliar injury of sensitive vegetation.

Conclusions

Except for Dry Tortugas NP, all SFCN parks have both wet and dry deposition monitors on-site or nearby. Given the remoteness of Dry Tortugas and lack of acid-sensitive surface waters, monitoring deposition at the park is not warranted. Only the south Florida SFCN parks have an on-site or nearby MDN monitor. Installation of additional MDN monitors is not recommended at this time.

Data indicate surface waters in SFCN parks are not susceptible to acidification from atmospheric deposition; however, atmospherically-deposited N could be a concern from an eutrophication standpoint. Atmospherically-deposited mercury is a significant concern in south Florida, as numerous studies have shown elevated methylmercury concentrations in fish and other biota. While reductions in mercury emissions have led to substantial reductions in

mercury deposition and tissue methylmercury levels since 1990, continued monitoring of mercury levels in biota is recommended.

$PM_{2.5}$ and/or PM_{10} are monitored near all SFCN parks except Big Cypress NPres and Dry Tortugas NP. All parks except Dry Tortugas have on-site or nearby IMPROVE monitoring. Because of the remoteness of the area, monitoring particulates at Dry Tortugas NP is not warranted. If visibility impairment is of particular interest for any Network park, the SFCN may want to consider installing a digital camera to record and interpret visibility conditions. Given concerns about African dust storms, the Network may want to consider ambient monitoring of dust events for toxic pollutants and/or biological agents.

Except for Buck Island Reef NM and Dry Tortugas NP, all SFCN parks have an on-site or nearby ozone monitor. Given the low ozone values recorded at, or estimated for, the other Network parks, monitoring ozone at Buck Island Reef and Dry Tortugas is not warranted at this time. The ozone injury risk assessments indicate a low risk of ozone injury of sensitive vegetation in SFCN parks. Therefore, foliar injury surveys are not recommended for Network parks.

APPENDIX I.2

WEATHER AND CLIMATE INVENTORY

National Park Service
U.S. Department of the Interior

Natural Resource Program Center

Weather and Climate Inventory
National Park Service
South Florida / Caribbean Network

Natural Resource Technical Report NPS/SFCN/NRTR—2007/037



ON THE COVER
Buck Island Reef National Monument
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Weather and Climate Inventory
National Park Service
South Florida / Caribbean Network

Natural Resource Technical Report NPS/SFCN/NRTR—2007/037
WRCC Report 2007-12

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Fort Collins, Colorado

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Acronyms

AASC	American Association of State Climatologists
ACIS	Applied Climate Information System
ASOS	Automated Surface Observing System
AWOS	Automated Weather Observing System
BICY	Big Cypress National Preserve
BISC	Biscayne National Park
BLM	Bureau of Land Management
BUIS	Buck Island Reef National Monument
CASTNet	Clean Air Status and Trends Network
COOP	Cooperative Observer Program
CRN	Climate Reference Network
CWOP	Citizen Weather Observer Program
DFIR	Double-Fence Intercomparison Reference
DRTO	Dry Tortugas National Park
DST	daylight savings time
ENSO	El Niño Southern Oscillation
EPA	Environmental Protection Agency
EVER	Everglades National Park
FAA	Federal Aviation Administration
FAWN	Florida Automated Weather Network
FIPS	Federal Information Processing Standards
GMT	Greenwich Mean Time
GOES	Geostationary Operational Environmental Satellite
GPMP	NPS Gaseous Pollutant Monitoring Program
GPS	Global Positioning System
GPS-MET	NOAA ground-based GPS meteorology
I&M	NPS Inventory and Monitoring Program
LEO	Low Earth Orbit
LST	local standard time
MDN	Mercury Deposition Network
NADP	National Atmospheric Deposition Program
NASA	National Aeronautics and Space Administration
NCDC	National Climatic Data Center
NetCDF	Network Common Data Form
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
NRCS	Natural Resources Conservation Service
NWS	National Weather Service
PRISM	Parameter Regression on Independent Slopes Model
RAWS	Remote Automated Weather Station network
RCC	regional climate center
SAO	Surface Airways Observation network
SARI	Salt River Bay National Historical Park and Ecological Reserve
SCAN	Soil Climate Analysis Network

SFCN	South Florida / Caribbean Inventory and Monitoring Network
SOD	Summary Of the Day
Surfrad	Surface Radiation Budget network
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
UTC	Coordinated Universal Time
VIIS	Virgin Islands National Park
WBAN	Weather Bureau Army Navy
WMO	World Meteorological Organization
WRCC	Western Regional Climate Center
WX4U	Weather For You network

Executive Summary

Climate is a dominant factor driving the physical and ecologic processes affecting the South Florida / Caribbean Inventory and Monitoring Network (SFCN). Climate in the SFCN is generally warm and humid, influenced strongly by the network's proximity to water. The SFCN is characterized by hot, wet summers (the wet season) and warm, drier winters (the dry season). Drought cycles in the SFCN, particularly in south Florida, are connected to increased fire activity and decreased freshwater input vital for bay ecosystems. Major weather events such as hurricanes, tropical storms, large wind and large wave events are natural but substantial sources of disturbance for ecological communities throughout the SFCN. Possible effects of future climate changes in the SFCN include sea level rises, coral bleaching, northward expansion of tropical flora, modified migratory patterns, and possible increases in the frequency of extreme weather/climate events. Because of its influence on the ecology of SFCN park units and the surrounding areas, climate was identified as a high-priority vital sign for SFCN and is one of the 12 basic inventories to be completed for all National Park Service (NPS) Inventory and Monitoring Program (I&M) networks.

This project was initiated to inventory past and present climate monitoring efforts in the SFCN. In this report, we provide the following information:

- Overview of broad-scale climatic factors and zones important to SFCN park units.
- Inventory of weather and climate station locations in and near SFCN park units relevant to the NPS I&M Program.
- Results of an inventory of metadata on each weather station, including affiliations for weather-monitoring networks, types of measurements recorded at these stations, and information about the actual measurements (length of record, etc.).
- Initial evaluation of the adequacy of coverage for existing weather stations and recommendations for improvements in monitoring weather and climate.

The SFCN experiences relatively uniform temperature characteristics. The Virgin Islands park units have daily temperatures ranging from lows between 23-27°C and highs between 29-32°C. Mean annual temperatures on the Florida peninsula generally follow a latitudinal gradient, with cooler conditions to the north. Mean annual temperatures within Florida park units range from under 23°C to near 25°C. Average winter minimum temperatures in south Florida can get as low 12°C in Big Cypress National Preserve (BICY) and northern portions of Everglades National Park (EVER). Average summer maximum temperatures are warmest on the Florida peninsula, with interior locations exceeding 32°C. Unlike temperature, precipitation in the SFCN is quite variable in both space and time, as it is largely convective in nature, associated with wet season thunderstorms. The park units around the Virgin Islands generally see between 900 and 1400 mm of precipitation per year. In south Florida, interior locations are generally the driest, with coastal locations receiving somewhat higher precipitation totals. Mean annual precipitation exceeds 1500 mm in portions of Biscayne National Park (BISC) while Dry Tortugas National Park (DRTO) and southernmost EVER, receive under 1200 mm on average each year.

Through a search of national databases and inquiries to NPS staff, we have identified 31 weather and climate stations within SFCN park units. EVER has the most stations within park boundaries

(13). Most of the weather and climate stations identified for SFCN park units had metadata and data records that are sufficiently complete and satisfactory in quality.

The island-based SFCN park units such as DRTO and the park units on the relatively small U.S. Virgin Islands cannot support the same number of weather and climate stations as can larger islands or mainland locations. It is important that those stations which have been identified continue to operate and maintain reliable observations.

No weather/climate station coverage is available currently in central and southern BISC. This coverage gap could begin to be addressed by installing an automated station on Elliott Key, at the main ranger station. Candidate weather/climate station networks for this installation would include the FAWN (Florida Automated Weather Network) and RAWS (Remote Automated Weather Station) networks. Weather/climate monitoring efforts in the park unit would likely benefit from such an installation.

The importance of monitoring wet season/dry season cycles and spatiotemporal patterns in precipitation is quite evident for both BICY and EVER, where precipitation patterns play a integral role in the ecosystems in these park units. Drought monitoring, monitoring of fire conditions, and monitoring of ecosystem health all will benefit from a better understanding of regional convective precipitation patterns, which are quite variable in space and time across both BICY and EVER. In order to improve this understanding, however, the existing coverage of near-real-time weather stations in these parks needs to be increased, and weather/climate monitoring efforts in both BICY and EVER would benefit by gradually implementing this strategy. Since the RAWS network already has a presence within both BICY and EVER, a natural first step would be to install more of these stations. Potential sites in BICY could include 1) a location along Highway 839 between US Highway 41 and Interstate 75, and 2) northeastern BICY, near the rest area at the Recreation Access Point on Interstate 75. Potential sites in EVER could include 1) the Gulf Coast Visitor Center, 2) the Royal Palm Visitor Center, and 3) along Highway 9336, near access points such as the Pa-hay-okee or Mahogany Overlooks.

The marine setting of the SFCN ensures relatively uniform temperatures, both spatially and temporally. These stable temperatures do provide a useful indicator of longer-term global temperature trends, as the heat content of the water bodies in the SFCN governs overall temperature characteristics in the region and thus will respond to global-scale temperature trends. Many of the SFCN park units would be directly impacted by any sea level changes associated with global-scale temperature changes. Therefore, NPS climate-monitoring efforts will benefit by making the monitoring of long-term temperature characteristics for the SFCN a high priority, for example, by continuing the operation of any existing weather/climate stations that do provide longer data records in SFCN park units.

Acknowledgements

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1.0. Introduction

Weather and climate are key drivers in ecosystem structure and function. Global- and regional-scale climate variations will have a tremendous impact on natural systems (Chapin et al. 1996; Schlesinger 1997; Jacobson et al. 2000; Bonan 2002). Long-term patterns in temperature and precipitation provide first-order constraints on potential ecosystem structure and function. Secondary constraints are realized from the intensity and duration of individual weather events and, additionally, from seasonality and inter-annual climate variability. These constraints influence the fundamental properties of ecologic systems, such as soil–water relationships, plant–soil processes, and nutrient cycling, as well as disturbance rates and intensity. These properties, in turn, influence the life-history strategies supported by a climatic regime (Neilson 1987; Patterson et al. 2005).

Given the importance of climate, it is one of 12 basic inventories to be completed by the National Park Service (NPS) Inventory and Monitoring Program (I&M) network (I&M 2006). As primary environmental drivers for the other vital signs, weather and climate patterns present various practical and management consequences and implications for the NPS (Oakley et al. 2003). Most park units observe weather and climate elements as part of their overall mission. The lands under NPS stewardship provide many excellent locations for monitoring climatic conditions.

It is essential that park units within the South Florida / Caribbean Inventory and Monitoring Network (SFCN) have an effective climate-monitoring system in place to track climate changes and to aid in management decisions relating to these changes. The purpose of this report is to determine the current status of weather and climate monitoring within the SFCN (Table 1.1; Figure 1.1). In this report, we provide the following informational elements:

- Overview of broad-scale climatic factors and zones important to SFCN park units.
- Inventory of locations for all weather stations in and near SFCN park units that are relevant to the NPS I&M networks.
- Results of metadata inventory for each station, including weather-monitoring network affiliations, types of recorded measurements, and information about actual measurements (length of record, etc.).
- Initial evaluation of the adequacy of coverage for existing weather stations and recommendations for improvements in monitoring weather and climate.

Table 1.1. Park units in the South Florida / Caribbean Network.

Acronym	Name
BICY	Big Cypress National Preserve
BISC	Biscayne National Park
BUIS	Buck Island Reef National Monument
DRTO	Dry Tortugas National Park
EVER	Everglades National Park
SARI	Salt River Bay National Historical Park and Ecological Reserve
VIIS	Virgin Islands National Park

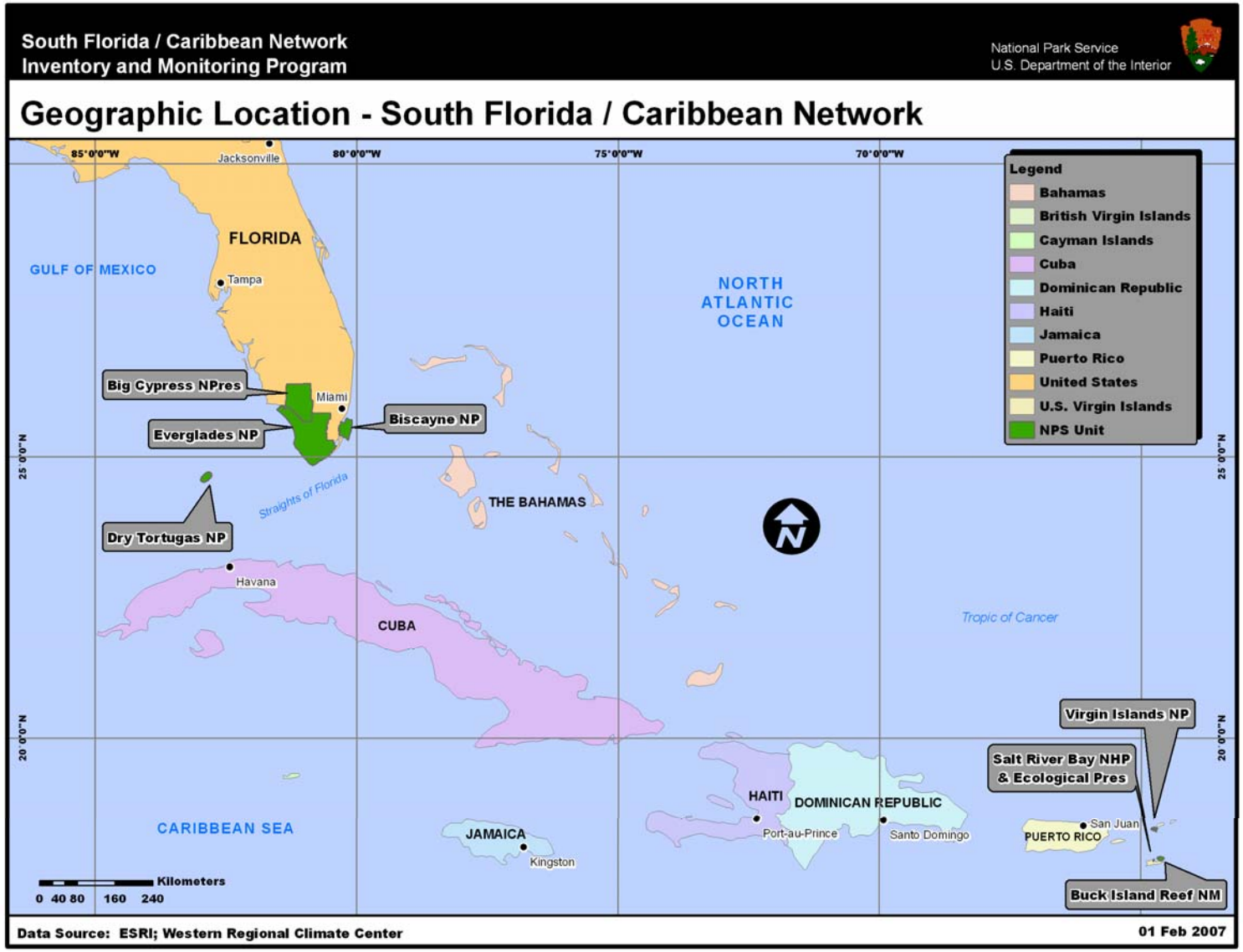


Figure 1.1. Map of the South Florida / Caribbean Network.

1.1. Network Terminology

Before proceeding, it is important to stress that this report discusses the idea of "networks" in two different ways. Modifiers are used to distinguish between NPS I&M networks and weather/climate station networks. See Appendix A for a full definition of these terms.

1.1.1. Weather/Climate Station Networks

Most weather and climate measurements are made not from isolated stations but from stations that are part of a network operated in support of a particular mission. The limiting case is a network of one station, where measurements are made by an interested observer or group. Larger networks usually have additional, enhanced inventory data and station-tracking procedures. Some national weather/climate networks are associated with the National Oceanic and Atmospheric Administration (NOAA), including the National Weather Service (NWS) Cooperative Observer Program (COOP). Other national networks include the interagency Remote Automated Weather Station network (RAWS) and the U.S. Department of Agriculture/Natural Resources Conservation Service (USDA/NRCS) Soil Climate Analysis Network (SCAN). Usually a single agency, but sometimes a consortium of interested parties, will jointly support a particular weather/climate network.

1.1.2. NPS I&M Networks

Within the NPS, the system for monitoring various attributes in the participating park units (about 270–280 in total) is divided into 32 NPS I&M networks. These networks are collections of park units grouped together around a common theme, typically geographical.

1.2. Weather versus Climate Definitions

It is also important to distinguish whether the primary use of a given station is for weather purposes or for climate purposes. Weather station networks are intended for near-real-time usage, where the precise circumstances of a set of measurements are typically less important. In these cases, changes in exposure or other attributes over time are not as critical. Climate networks, however, are intended for long-term tracking of atmospheric conditions. Siting and exposure are critical factors for climate networks, and it is vitally important that the observational circumstances remain essentially unchanged over the duration of the station record. Some climate networks can be considered hybrids of weather/climate networks. These hybrid climate networks can supply information on a short-term "weather" time scale and a longer-term "climate" time scale.

In this report, "weather" generally refers to current (or near-real-time) atmospheric conditions, while "climate" is defined as the complete ensemble of statistical descriptors for temporal and spatial properties of atmospheric behavior (see Appendix A). Climate and weather phenomena shade gradually into each other and are ultimately inseparable.

1.3. Purpose of Measurements

Climate inventory and monitoring climate activities should be based on a set of guiding fundamental principles. Any evaluation of weather/climate monitoring programs begins with asking the following question:

- What is the purpose of weather and climate measurements?

Evaluation of past, present, or planned weather/climate monitoring activities must be based on the answer to this question.

Weather and climate data and information constitute a prominent and widely requested component of the NPS I&M networks (I&M 2006). Within the context of the NPS, the following services constitute the main purposes for recording weather and climate observations:

- Provide measurements for real-time operational needs and early warnings of potential hazards (landslides, mudflows, washouts, fallen trees, plowing activities, fire conditions, aircraft and watercraft conditions, road conditions, rescue conditions, fog, restoration and remediation activities, etc.).
- Provide visitor education and aid interpretation of expected and actual conditions for visitors while they are in the park and for deciding if and when to visit the park.
- Establish engineering and design criteria for structures, roads, culverts, etc., for human comfort, safety, and economic needs.
- Consistently monitor climate over the long-term to detect changes in environmental drivers affecting ecosystems, including both gradual and sudden events.
- Provide retrospective data to understand *a posteriori* changes in flora and fauna.
- Document for posterity the physical conditions in and near the park units, including mean, extreme, and variable measurements (in time and space) for all applications.

The last three items in the preceding list are pertinent primarily to the NPS I&M networks; however, all items are important to NPS operations and management. Most of the needs in this list overlap heavily. It is often impractical to operate separate climate measuring systems that also cannot be used to meet ordinary weather needs, where there is greater emphasis on timeliness and reliability.

1.4. Design of Climate-Monitoring Programs

Determining the purposes for collecting measurements in a given weather/climate monitoring program will guide the process of identifying weather/climate stations suitable for the monitoring program. The context for making these decisions is provided in Chapter 2 where background on the SFCN climate is presented. However, this process is only one step in evaluating and designing a climate-monitoring program. The following steps must also be included:

- Define park and network-specific monitoring needs and objectives.
- Identify locations and data repositories of existing and historic stations.
- Acquire existing data when necessary or practical.
- Evaluate the quality of existing data.
- Evaluate the adequacy of coverage of existing stations.
- Develop a protocol for monitoring the weather and climate, including the following:
  - Standardized summaries and reports of weather/climate data.
  - Data management (quality assurance and quality control, archiving, data access, etc.).
- Develop and implement a plan for installing or modifying stations, as necessary.

Throughout the design process, there are various factors that require consideration in evaluating weather and climate measurements. Many of these factors have been summarized by Dr. Tom Karl, director of the NOAA National Climatic Data Center (NCDC), and widely distributed as the "Ten Principles for Climate Monitoring" (Karl et al. 1996; NRC 2001). These principles are presented in Appendix B, and the guidelines are embodied in many of the comments made throughout this report. The most critical factors are presented here. In addition, an overview of requirements necessary to operate a climate network is provided in Appendix C, with further discussion in Appendix D.

1.4.1. Need for Consistency

A principal goal in climate monitoring is to detect and characterize slow and sudden changes in climate through time. This is of less concern for day-to-day weather changes, but it is of paramount importance for climate variability and change. There are many ways whereby changes in techniques for making measurements, changes in instruments or their exposures, or seemingly innocuous changes in site characteristics can lead to apparent changes in climate. Safeguards must be in place to avoid these false sources of temporal "climate" variability if we are to draw correct inferences about climate behavior over time from archived measurements.

For climate monitoring, consistency through time is vital, counting at least as important as absolute accuracy. Sensors record only what is occurring at the sensor—this is all they can detect. It is the responsibility of station or station network managers to ensure that observations are representative of the spatial and temporal climate scales that we wish to record.

1.4.2. Metadata

Changes in instruments, site characteristics, and observing methodologies can lead to apparent changes in climate through time. It is therefore vital to document all factors that can bear on the interpretation of climate measurements and to update the information repeatedly through time. This information ("metadata," data about data) has its own history and set of quality-control issues that parallel those of the actual data. There is no single standard for the content of climate metadata, but a simple rule suffices:

- Observers should record all information that could be needed in the future to interpret observations correctly without benefit of the observers' personal recollections.

Such documentation includes notes, drawings, site forms, and photos, which can be of inestimable value if taken in the correct manner. That stated, it is not always clear to the metadata provider *what is important* for posterity and *what will be important* in the future. It is almost impossible to "over document" a station. Station documentation is greatly underappreciated and is seldom thorough enough (especially for climate purposes). Insufficient attention to this issue often lowers the present and especially future value of otherwise useful data.

The convention followed throughout climatology is to refer to metadata as information about the measurement process, station circumstances, and data. The term "data" is reserved solely for the actual weather and climate records obtained from sensors.

1.4.3. Maintenance

Inattention to maintenance is the greatest source of failure in weather/climate stations and networks. Problems begin to occur soon after sites are deployed. A regular visit schedule must be implemented, where sites, settings (e.g., vegetation), sensors, communications, and data flow are checked routinely (once or twice a year at a minimum) and updated as necessary. Parts must be changed out for periodic recalibration or replacement. With adequate maintenance, the entire instrument suite should be replaced or completely refurbished about once every five to seven years.

Simple preventive maintenance is effective but requires much planning and skilled technical staff. Changes in technology and products require retraining and continual re-education. Travel, logistics, scheduling, and seasonal access restrictions consume major amounts of time and budget but are absolutely necessary. Without such attention, data gradually become less credible and then often are misused or not used at all.

1.4.4. Automated versus Manual Stations

Historic stations often have depended on manual observations and many continue to operate in this mode. Manual observations frequently produce excellent data sets. Sensors and data are simple and intuitive, well tested, and relatively cheap. Manual stations have much to offer in certain circumstances and can be a source of both primary and backup data. However, methodical consistency for manual measurements is a constant challenge, especially with a mobile work force. Operating manual stations takes time and needs to be done on a regular schedule, though sometimes the routine is welcome.

Nearly all newer stations are automated. Automated stations provide better time resolution, increased (though imperfect) reliability, greater capacity for data storage, and improved accessibility to large amounts of data. The purchase cost for automated stations is higher than for manual stations. A common expectation and serious misconception is that an automated station can be deployed and left to operate on its own. In reality, automation does not eliminate the need for people but rather changes the type of person that is needed. Skilled technical personnel are needed and must be readily available, especially if live communications exist and data gaps are not wanted. Site visits are needed at least annually and spare parts must be maintained. Typical annual costs for sensors and maintenance at the major national networks are $1500–2500 per station per year but these costs still can vary greatly depending on the kind of automated site.

1.4.5. Communications

With manual stations, the observer is responsible for recording and transmitting station data. Data from automated stations, however, can be transmitted quickly for access by research and operations personnel, which is a highly preferable situation. A comparison of communication systems for automated and manual stations shows that automated stations generally require additional equipment, more power, higher transmission costs, attention to sources of disruption or garbling, and backup procedures (e.g. manual downloads from data loggers).

Automated stations are capable of functioning normally without communication and retaining many months of data. At such sites, however, alerts about station problems are not possible, large gaps can accrue when accessible stations quit, and the constituencies needed to support

such stations are smaller and less vocal. Two-way communications permit full recovery from disruptions, ability to reprogram data loggers remotely, and better opportunities for diagnostics and troubleshooting. In virtually all cases, two-way communications are much preferred to all other communication methods. However, two-way communications require considerations of cost, signal access, transmission rates, interference, and methods for keeping sensor and communication power loops separate. Two-way communications are frequently impossible (no service) or impractical, expensive, or power consumptive. Two-way methods (cellular, land line, radio, Internet) require smaller up-front costs as compared to other methods of communication and have variable recurrent costs, starting at zero. Satellite links work everywhere (except when blocked by trees or cliffs) and are quite reliable but are one-way and relatively slow, allow no re-transmissions, and require high up-front costs ($3000–4000) but no recurrent costs. Communications technology is changing constantly and requires vigilant attention by maintenance personnel.

1.4.6. Quality Assurance and Quality Control

Quality control and quality assurance are issues at every step through the entire sequence of sensing, communication, storage, retrieval, and display of environmental data. Quality assurance is an umbrella concept that covers all data collection and processing (start-to-finish) and ensures that credible information is available to the end user. Quality control has a more limited scope and is defined by the International Standards Organization as "the operational techniques and activities that are used to satisfy quality requirements." The central problem can be better appreciated if we approach quality control in the following way.

- Quality control is the evaluation, assessment, and rehabilitation of imperfect data by utilizing other imperfect data.

The quality of the data only decreases with time once the observation is made. The best and most effective quality control, therefore, consists in making high-quality measurements from the start and then successfully transmitting the measurements to an ingest process and storage site. Once the data are received from a monitoring station, a series of checks with increasing complexity can be applied, ranging from single-element checks (self-consistency) to multiple-element checks (inter-sensor consistency) to multiple-station/single-element checks (inter-station consistency). Suitable ancillary data (battery voltages, data ranges for all measurements, etc.) can prove extremely useful in diagnosing problems.

There is rarely a single technique in quality control procedures that will work satisfactorily for all situations. Quality-control procedures must be tailored to individual station circumstances, data access and storage methods, and climate regimes.

The fundamental issue in quality control centers on the tradeoff between falsely rejecting good data (Type I error) and falsely accepting bad data (Type II error). We cannot reduce the incidence of one type of error without increasing the incidence of the other type. In weather and climate data assessments, since good data are absolutely crucial for interpreting climate records properly, Type I errors are deemed far less desirable than Type II errors.

Not all observations are equal in importance. Quality-control procedures are likely to have the greatest difficulty evaluating the most extreme observations, where independent information usually must be sought and incorporated. Quality-control procedures involving more than one station usually involve a great deal of infrastructure with its own (imperfect) error-detection methods, which must be in place before a single value can be evaluated.

1.4.7. Standards

Although there is near-universal recognition of the value in systematic weather and climate measurements, these measurements will have little value unless they conform to accepted standards. There is not a single source for standards for collecting weather and climate data nor a single standard that meets all needs. Measurement standards have been developed by the World Meteorological Organization (WMO 1983; 2005), the American Association of State Climatologists (AASC 1985), the U.S. Environmental Protection Agency (EPA 1987), Finklin and Fischer (1990), the RAWS program (Bureau of Land Management [BLM] 1997), and the National Wildfire Coordinating Group (2004). Variations to these measurement standards also have been offered by instrument makers (e.g., Tanner 1990).

1.4.8. Who Makes the Measurements?

The lands under NPS stewardship provide many excellent locations to host the monitoring of climate by the NPS or other collaborators. These lands are largely protected from human development and other land changes that can impact observed climate records. Most park units historically have observed weather/climate elements as part of their overall mission. Many of these measurements come from station networks managed by other agencies, with observations taken or overseen by NPS personnel, in some cases, or by collaborators from the other agencies. National Park Service units that are small, lack sufficient resources, or lack sites presenting adequate exposure may benefit by utilizing weather/climate measurements collected from nearby stations.

2.0. Climate Background

Climate is a primary factor controlling the structure and function of ecosystems in the SFCN. An understanding of both current climate patterns and climate history in the SFCN is important to understanding and interpreting change and patterns in ecosystem attributes within the SFCN (Patterson et al. 2005). It is essential that the SFCN park units have an effective climate monitoring system to track climate changes and to aid in management decisions relating to these changes. In order to do this, it is essential to understand the climate characteristics of the SFCN, as discussed in this chapter.

2.1. Climate and the SFCN Environment

Climate in the SFCN is influenced strongly by the network's proximity to water and is characterized by hot, wet summers (the wet season) and warm, drier winters (the dry season). These "seasons" within the SFCN are actually determined more by precipitation than by temperature.

The Gulf of Mexico and the Atlantic Ocean have moderating effects on the SFCN park units in south Florida. While temperatures in the interior of the Florida peninsula can frequently climb to near 40°C, the south Florida park units are usually a few degrees cooler due to their closer proximity to water. Florida has some of the highest statewide average precipitation totals of any state. Much of this precipitation is due to afternoon thunderstorms which are common throughout the wet season (late spring until early autumn). These thunderstorms are sometimes associated with larger-scale storm systems but are generally associated with diurnal land-sea breeze circulations, with relatively cooler, moist ocean air moving onshore and colliding with relatively warmer air over the Florida peninsula. These thunderstorms are common in the afternoon hours and often bring heavy downpours, high winds and sometimes tornadoes. Hail is not an uncommon occurrence in some of the more severe thunderstorms.

Drought is a recurring issue for SFCN park units, particularly in south Florida. Drought episodes are connected to increased fire activity in the region and decreased freshwater input vital for bay ecosystems (Rudnick 2004).

Major weather events such as hurricanes, tropical storms, large wind and large wave events are natural but substantial sources of disturbance for ecological communities throughout the Caribbean. These events can often introduce patchy or large-scale destruction to coral reefs, seagrass beds, and vegetation. Storms waves and surge remove or redistribute sand along beaches; create and alter sand bars, coastal levees, and shell deposits; create and refill salt ponds; open cut-off ponds and lakes back to the sea, and so on. Seawater intrusion and sediment deposition from high storm surges can impact freshwater habitats well inland. Storms also create debris such as fallen trees, houses, and loose boats, which can exacerbate wave damage to habitats. Exotic flora and fauna can be accidentally released and dispersed to new areas where they rapidly invade the newly disturbed habitats (Waddell 2005).

The threat of hurricanes to SFCN parks during the summer and fall has been illustrated dramatically in recent years. In 2004, for example, Florida was hit by four hurricanes, including Hurricanes Charley (August 13), Frances (September 4-5), Ivan (September 16), and Jeanne

(September 25-26). Hurricane Andrew, which struck southern Florida in 1992, caused widespread damage at BISC and also damaged pine trees on Long Pine Key which then suffered subsequent beetle and weevil outbreaks (Lodge 2005). In 1989, Hurricane Hugo alone caused substantial damage to living coral cover structures in SFCN park units on the Virgin Islands (Drayton et al. 2004). Although it is still yet uncertain if the intensity of hurricanes in the Atlantic Ocean Basin is increasing (Bove et al. 1998; Henderson-Sellers et al. 1998; NAST 2001; Trenberth 2005), it is likely that with potential sea level rises, future tropical storms and hurricanes will have an increasingly damaging affect on the SFCN ecosystems.

The SFCN is not known for cold, wintry conditions. However, frost events can occasionally impact Florida park units and these events are actually instrumental in determining the general structure of plant communities in Florida park units like BICY and EVER. Frost influences, for example, the extent of mangrove communities in south Florida park units (USFWS 1999). Even snow has occurred in southern Florida, with a rare snowfall occurring in January 1977. This event brought snow to Miami Beach for the only time in recorded history.

Much of the effects of global climate change on the SFCN are still speculative and it is difficult to separate out the effects of a global shift from natural climatic cycles. However, some hypothesized effects that could impact SFCN park units include (Patterson et al. 2005): 1) sea level rises; 2) increased ocean temperatures and associated coral bleaching and death; 3) northward expansion of sub-tropical and tropical flora in south Florida; 4) modified migratory patterns of birds and other fauna; and 5) possible increases in the frequency of extreme weather/climate events, including major hurricanes and droughts.

Sea-level rises, in particular, are of concern for SFCN park units. With slow sea level rise, deposition and accretion processes can keep up with these rises and thus maintain island and shoreline habitats. However, some studies indicate that the rate of sea level rise has increased over the past century to at least 1 foot per century, possibly as a result of global climate change (Lodge 2005). If this is indeed the case, valuable island and shoreline habitats would be inundated. In areas such as BISC and DRTO, this may mean loss of much of the terrestrial park area over the next couple of centuries. Park units like EVER and eventually BICY would see a substantial loss of land area, due to gradual and/or sporadic inward encroachment of mangroves into brackish and freshwater areas coupled with conversion of freshwater marsh to brackish and saline marsh. The Virgin Island parks will probably experience less impact due to sea level rise than the low-lying south Florida parks. The steeper islands of VIIS and BUIS may lose some low-lying areas, but overall most of the park areas will be unaffected. In ocean environments, sea level rise may affect the deepest coral reefs if they fall below the light zone at a rate faster than their growth.

2.2. Spatial Variability

The SFCN is in a warm to hot, humid subtropical environment. As a result, annual precipitation totals are generally quite high across the SFCN. In the park units around the Virgin Islands, annual precipitation totals range from 900-1400 mm per year, with the steep topography of St. John, Buck, and St. Croix Islands creating orographic effects with drier, east-facing slopes and moister west-facing slopes (Patterson et al. 2005). In south Florida, interior locations are generally the driest, with coastal locations receiving somewhat higher precipitation totals (Figure

2.1). The wettest locations are on the southeastern Florida peninsula, including portions of BISC, with mean annual precipitation exceeding 1500 mm. The driest areas, including DRTO and southernmost EVER, receive under 1200 mm on average each year.

As has been discussed previously, the SFCN experiences a marked dry cycle during the winter and early springs months, with a wet cycle from late spring through early fall. This pattern can be clearly seen for SFCN park units (Figure 2.2). The wet season includes precipitation maxima both in late spring and in late summer/early fall. The latter maxima is more prominent for locations within the SFCN that are not on the Florida Peninsula, including DRTO and the Virgin Islands park units (e.g., see Figure 2.2b,c). On the Florida Peninsula, the primary wet-season precipitation maximum occurs earlier in the summer. This wet-season precipitation is greatest along the Gulf Coast, with lesser amounts to the south and east, especially for DRTO and southern EVER (Figure 2.3).

Temperatures in the SFCN are generally characterized by small year-round variations, especially in the Caribbean Sea. The park units on the Virgin Islands have daily temperatures that range from lows between 23-27°C and highs between 29-32°C. The Florida peninsula has the greatest spatial and temporal temperature variations in the SFCN. Mean annual temperatures on the Florida peninsula generally follow a latitudinal gradient, with cooler conditions to the north (Figure 2.4). Mean annual temperatures within Florida park units range from under 23°C to near 25°C. Winter temperatures tend to follow this same latitudinal gradient. January minimum temperatures (Figure 2.5) range from under 12°C in BICY and northern portions of EVER to over 15°C in DRTO and southern EVER. Summer temperatures on the Florida peninsula tend to be a function of distance from the coast, with interior locations being the warmest. In BICY, mean July maximum temperatures exceed 32°C (Figure 2.6). However, coastal areas like BISC and southwestern EVER see cooler conditions, with mean July maximum temperatures below 31°C.

2.3. Temporal Variability

Climate trend analyses suggest that the SFCN region may become warmer and wetter in the next century, with corresponding impacts such as sea level rises (NAST 2001). The frequency of extreme climate events may also increase, although this is still very uncertain. An investigation of precipitation in southern Florida during the past century (Figure 2.7) reveals no obvious trend. Temperatures across southern Florida have shown an overall warming during the past century, with substantial warming in the past 2-3 decades (Figure 2.8).

The El Niño Southern Oscillation (ENSO) influences interannual climate variability in the SFCN (NAST 2001). Warm ENSO phases (El Niño events) tend to bring cooler and wetter winter conditions across the Florida peninsula, with increased occurrences of severe thunderstorm outbreaks. Occurrences of hurricanes and other tropical storm activity also tend to decrease throughout the SFCN during warm ENSO phases (Gray 1984a; 1984b; Goldenberg and Shapiro 1996; Bove et al. 1998).

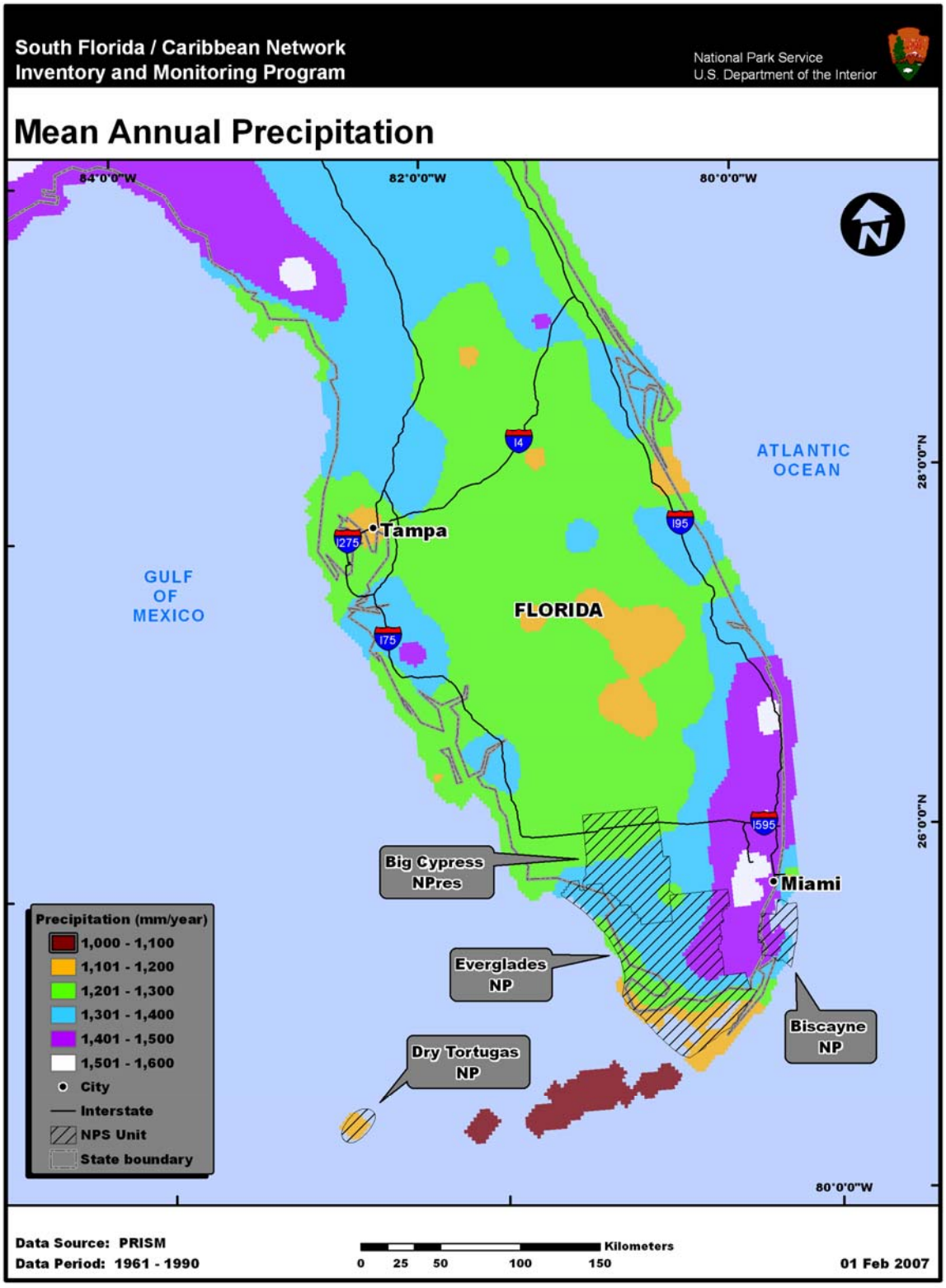
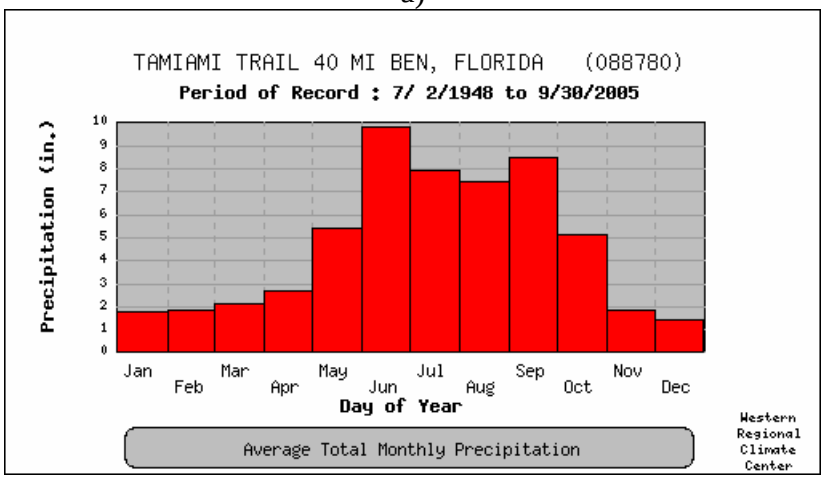
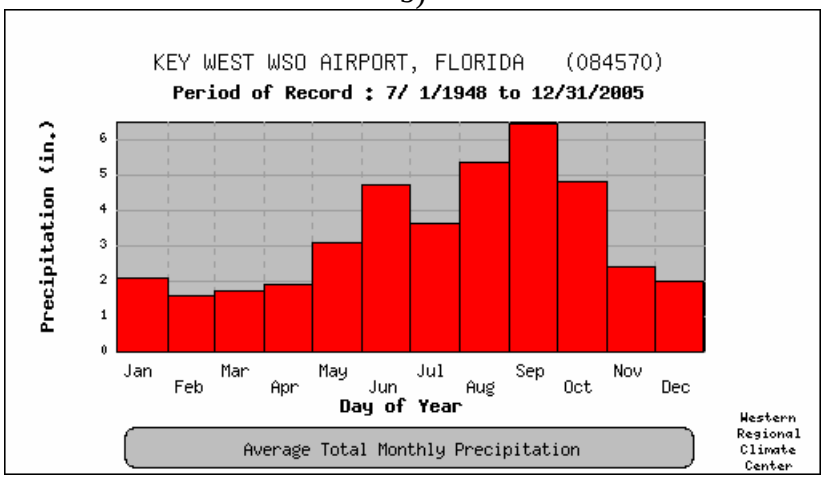


Figure 2.1. Mean annual precipitation, 1961-1990, for the SFCN.

a)



b)



c)

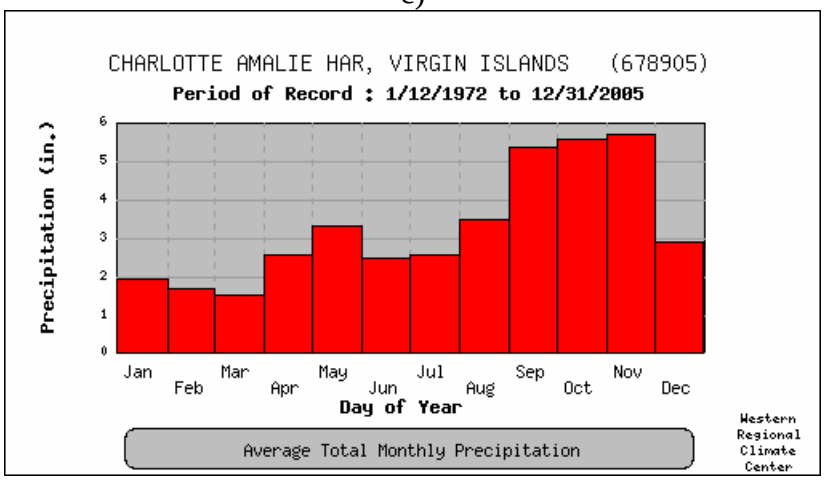


Figure 2.2. Mean monthly precipitation at selected stations in the SFCN. Locations include Tamiami Trail 40 Mi. Ben (a) near EVER, Key West Airport (b) east of DRTO (b), and Charlotte Amalie Har. (c) near BUIS and SARI.

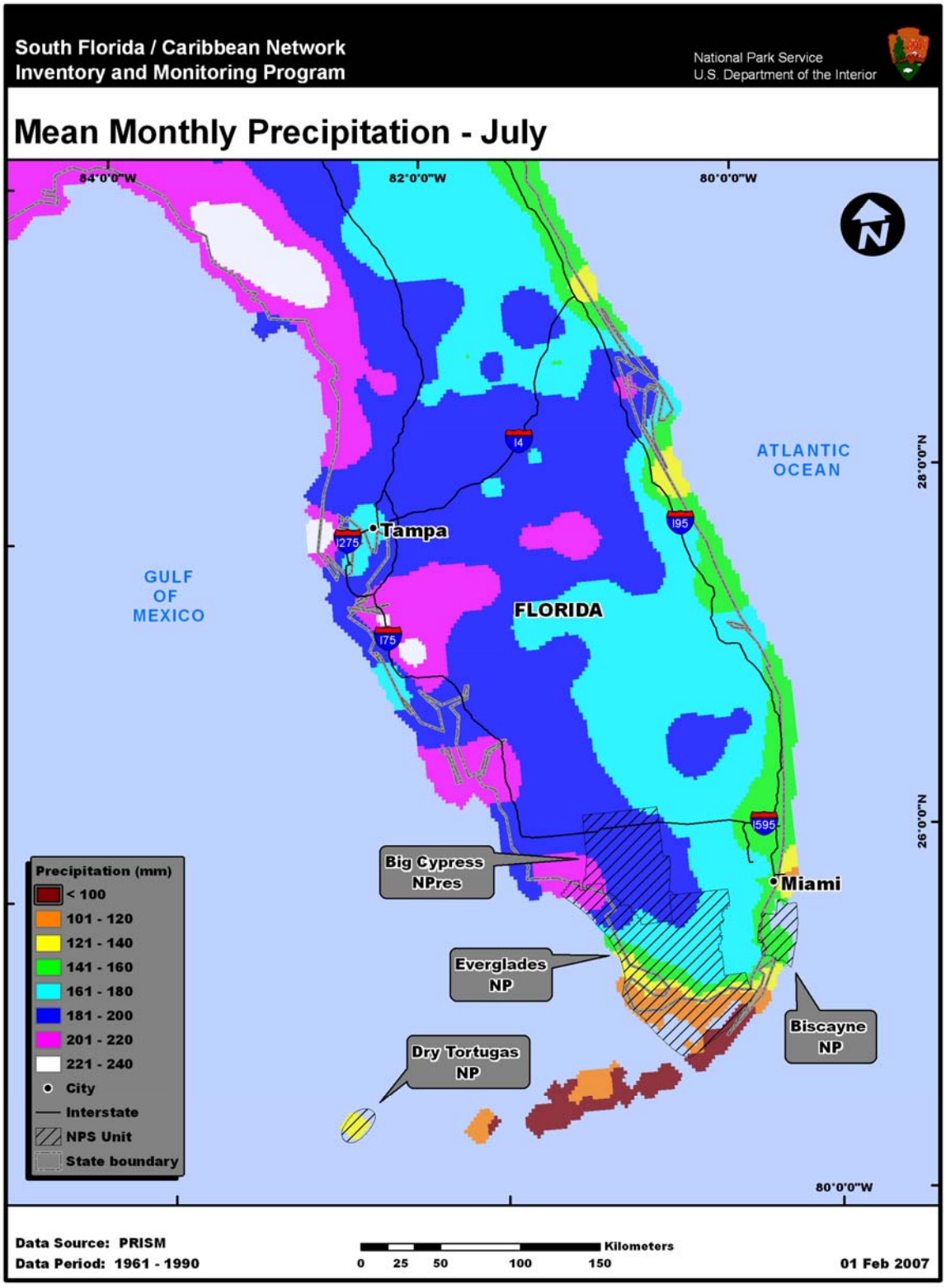


Figure 2.3. Mean July precipitation, 1961-1990, for the SFCN.

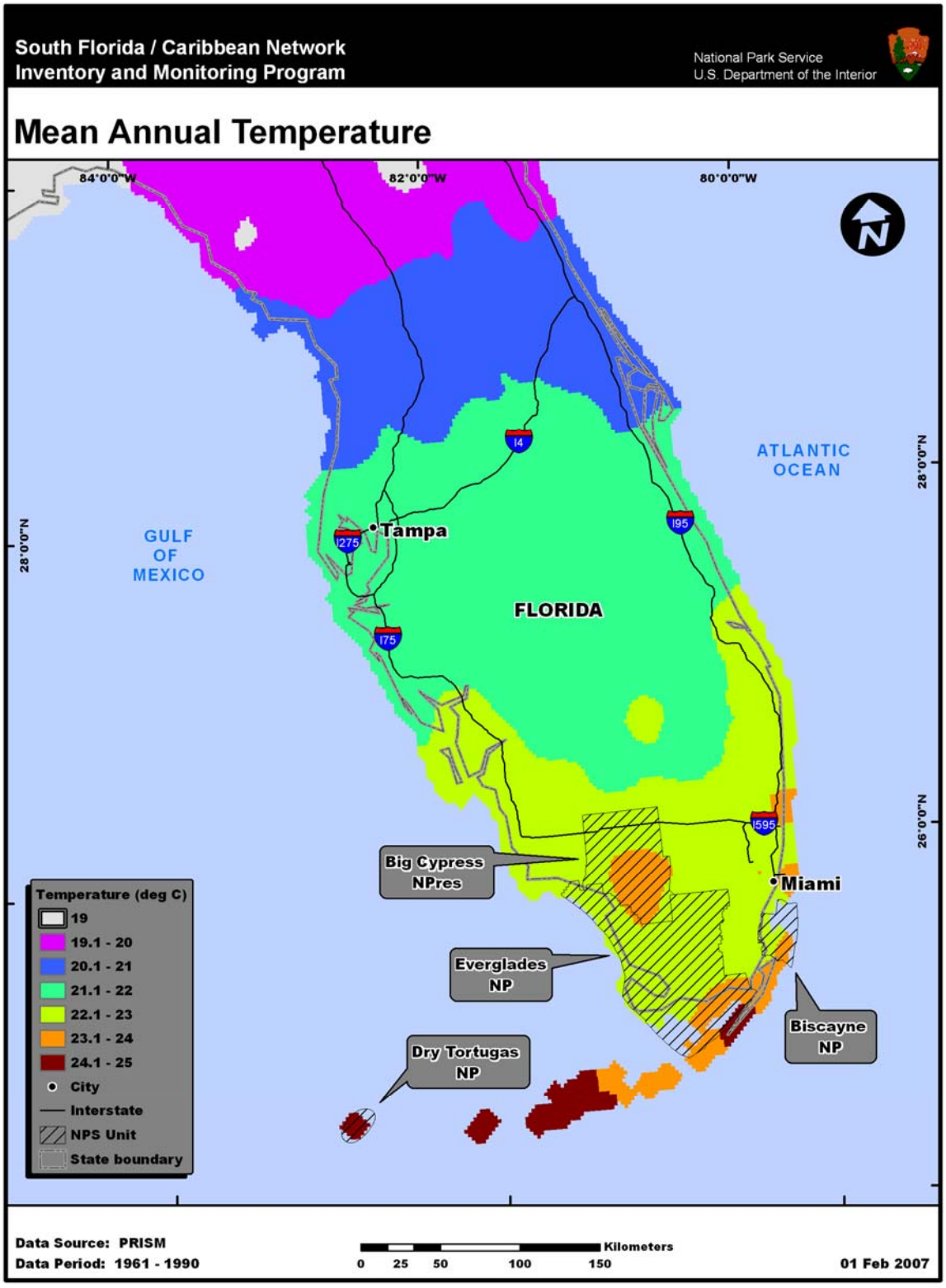


Figure 2.4. Mean annual temperature, 1961-1990, for the SFCN.

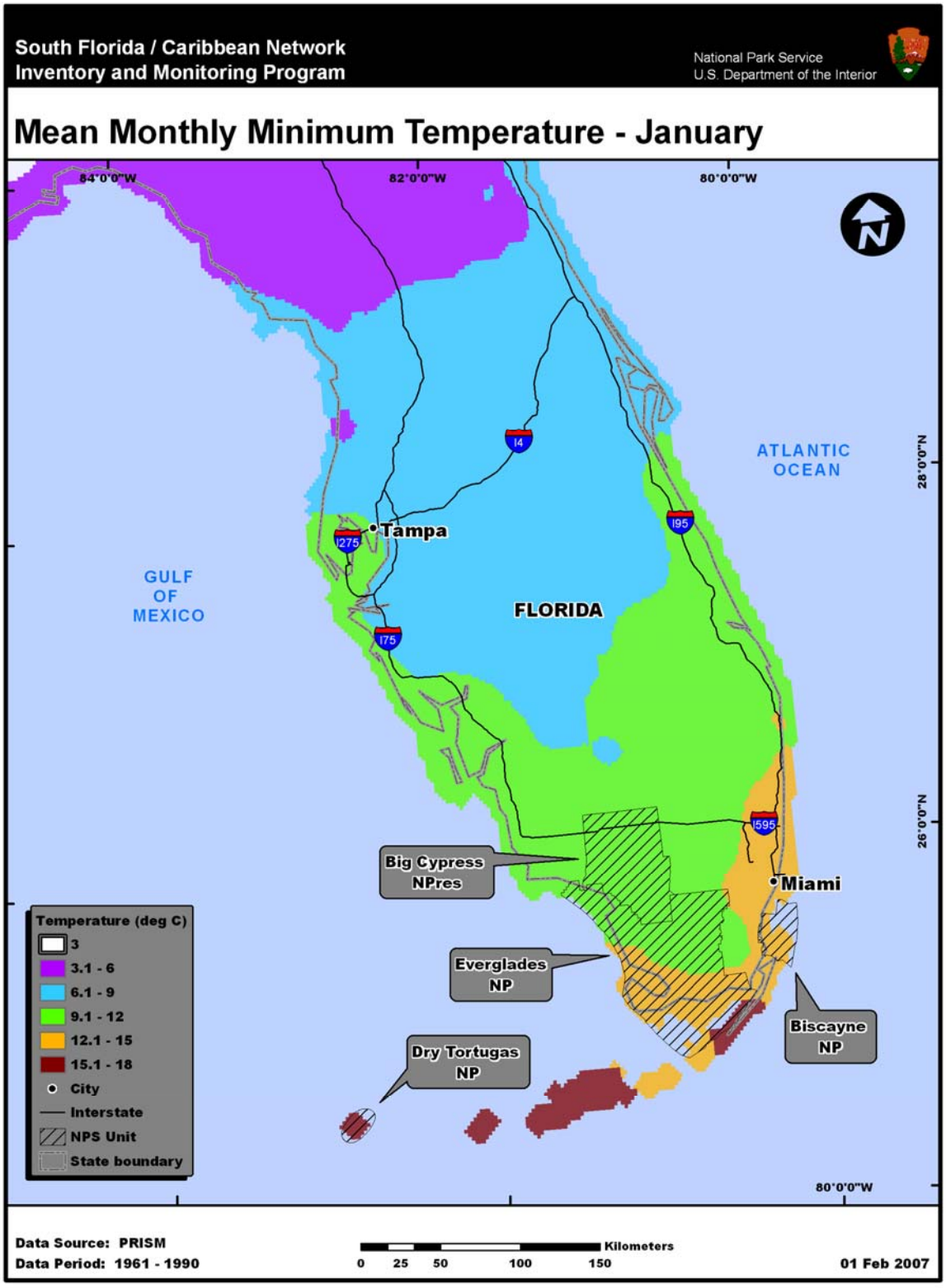


Figure 2.5. Mean January minimum temperature, 1961-1990, for the SFCN.

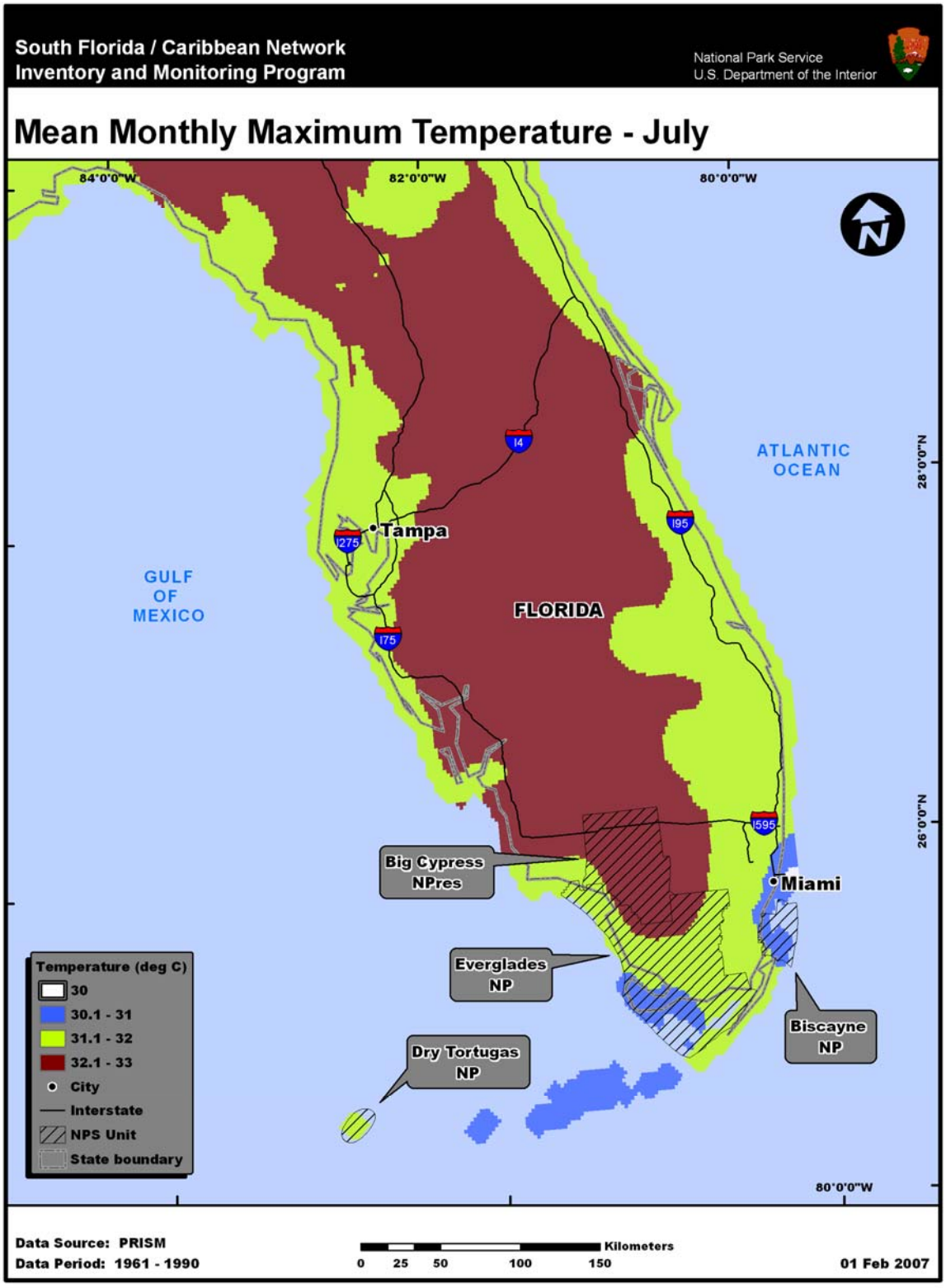


Figure 2.6. Mean July maximum temperature, 1961-1990, for the SFCN.

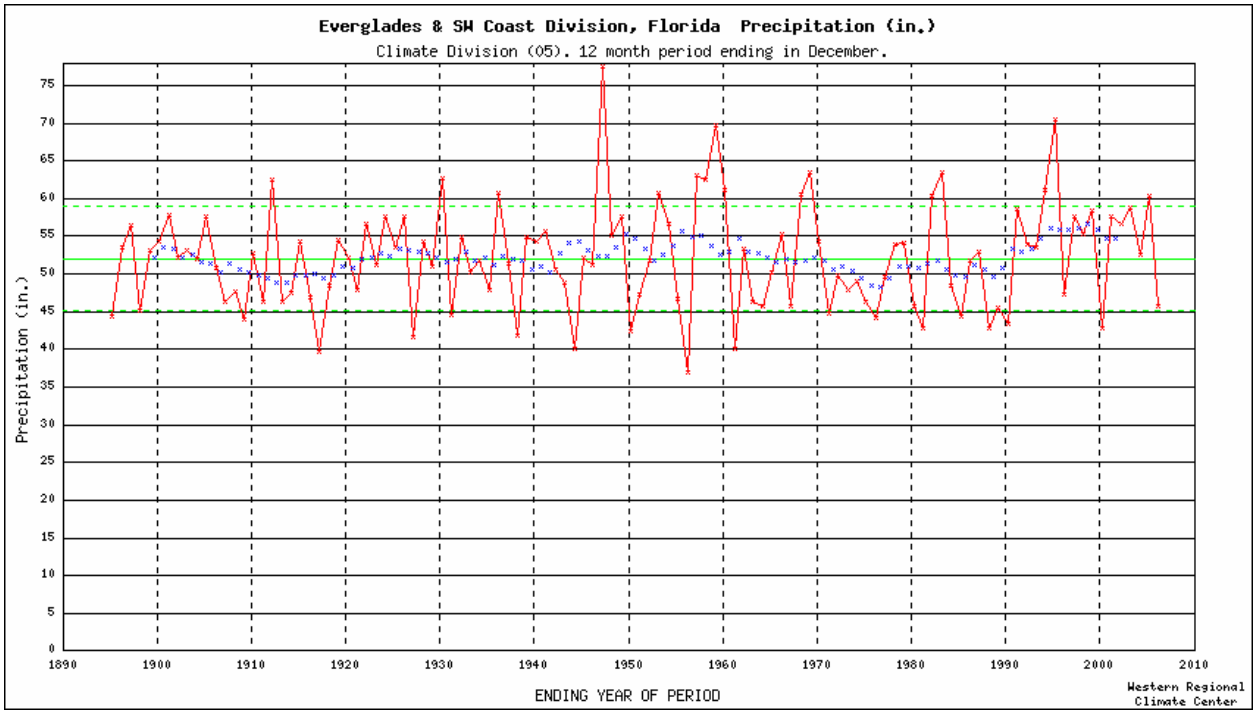


Figure 2.7. Precipitation time series, 1895-2005, for southern Florida, including twelve-month precipitation (ending in December) (red), 10-year running mean (blue), mean (green), and plus/minus one standard deviation (green dotted).

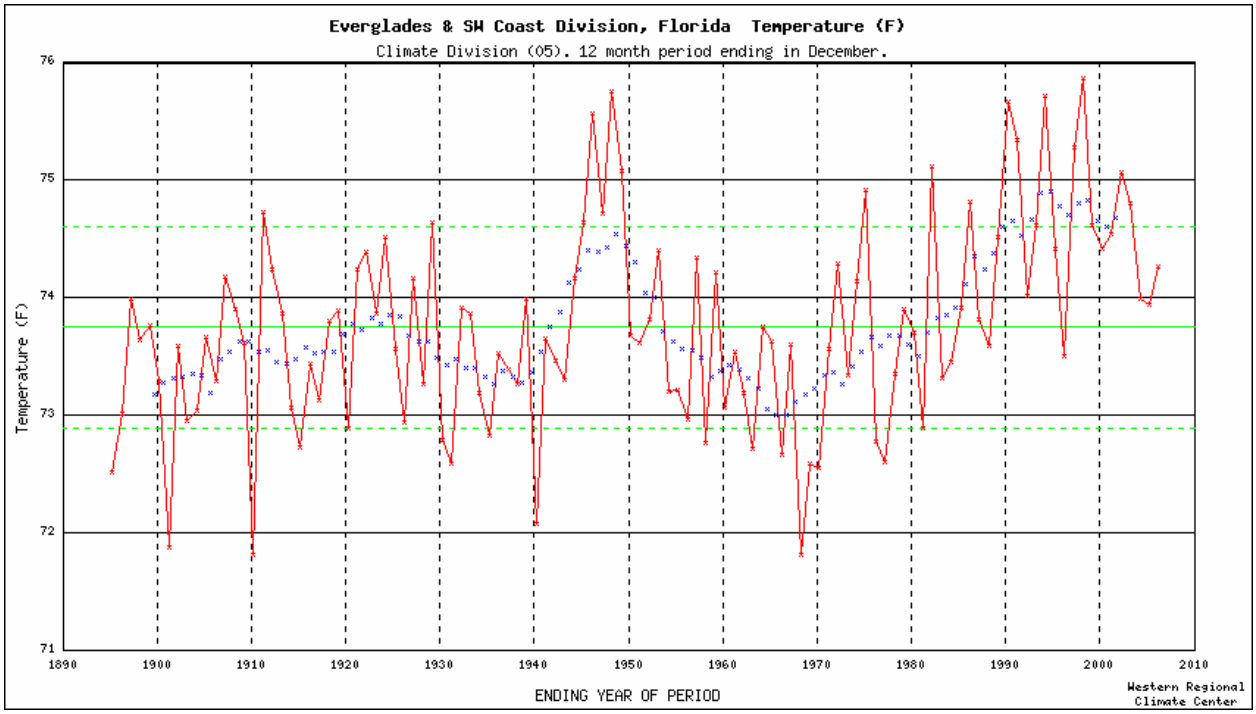


Figure 2.8. Temperature time series, 1895-2005, for southern Florida, including twelve-month average temperature (ending in December) (red), 10-year running mean (blue), mean (green), and plus/minus one standard deviation (green dotted).

2.4. Parameter Regression on Independent Slopes Model

The climate maps presented in this report were generated using the Parameter Regression on Independent Slopes Model (PRISM). This model was developed to address the extreme spatial and elevation gradients exhibited by the climate of the U.S. (Daly et al. 1994; 2002; Gibson et al. 2002; Doggett et al. 2004). The maps produced through PRISM have undergone rigorous evaluation in the U.S. This model was developed originally to provide climate information at scales matching available land-cover maps to assist in ecologic modeling. The PRISM technique accounts for the scale-dependent effects of topography on mean values of climate elements. Elevation provides the first-order constraint for the mapped climate fields, with slope and orientation (aspect) providing second-order constraints. The model has been enhanced gradually to address inversions, coast/land gradients, and climate patterns in small-scale trapping basins. Monthly climate fields are generated by PRISM to account for seasonal variations in elevation gradients in climate elements. These monthly climate fields then can be combined into seasonal and annual climate fields. Since PRISM maps are grid maps, they do not replicate point values but rather, for a given grid cell, represent the grid-cell average of the climate variable in question at the average elevation for that cell. The model relies on observed surface and upper-air measurements to estimate spatial climate fields.

3.0. Methods

Having discussed the climatic characteristics of the SFCN, we now present the procedures that were used to obtain information for weather/climate stations within the SFCN. This information was obtained from various sources, as mentioned in the following paragraphs. Retrieval of station metadata constituted a major component of this work.

3.1. Metadata Retrieval

A key component of station inventories is determining the kinds of observations that have been conducted over time, by whom, and in what manner; when each type of observation began and ended; and whether these observations are still being conducted. Metadata about the observational process (Table 3.1) generally consist of a series of vignettes that apply to time intervals and, therefore, constitute a *history* rather than a single snapshot. An expanded list of relevant metadata fields for this inventory is provided in Appendix E. This report has relied on metadata records from three sources: (a) Western Regional Climate Center (WRCC), (b) NPS personnel, and (c) other knowledgeable personnel, such as state climate office staff.

The initial metadata sources for this report were stored at WRCC. This regional climate center (RCC) acts as a working repository of many western climate records, including the main networks outlined in this section. The WRCC conducts live and periodic data collection (ingests) from all major national and western weather/climate networks. These networks include the COOP network, the Surface Airways Observation network (SAO) operated by NWS and the Federal Aviation Administration (FAA), the interagency RAWS network, and various smaller networks. The WRCC is expanding its capability to ingest information from other networks as resources permit and usefulness dictates. This center has relied heavily on historic archives (in many cases supplemented with live ingests) to assess the quantity (not necessarily quality) of data available for NPS I&M network applications.

The primary source of metadata at WRCC is the Applied Climate Information System (ACIS), a joint effort among RCCs and other NOAA entities. Metadata for SFCN weather/climate stations identified from the ACIS database are available in file “SFCN_from_ACIS.tar.gz” (see Appendix F). Historic metadata pertaining to major climate- and weather-observing systems in the U.S. are stored in ACIS where metadata are linked to the observed data. A distributed system, ACIS is synchronized among the RCCs. Mainstream software is utilized, including Postgress, Python™, and Java™ programming languages; CORBA®-compliant network software; and industry-standard, nonproprietary hardware and software. Metadata and data for all major national climate and weather networks have been entered into the ACIS database. For this project, the available metadata from many smaller networks also have been entered but in most cases the actual data have not yet been entered. Data sets are in the NetCDF (Network Common Data Form) format, but the design allows for integration with legacy systems, including non-NetCDF files (used at WRCC) and additional metadata (added for this project). The ACIS also supports a suite of products to visualize or summarize data from these data sets. National climate-monitoring maps are updated daily using the ACIS data feed. The developmental phases of ACIS have utilized metadata supplied by the NCDC and NWS with many tens of thousands of entries, screened as well as possible for duplications, mistakes, and omissions.

Table 3.1. Primary metadata fields for SFCN weather/climate stations. Explanations are provided as appropriate.

Metadata Field	Notes
Station name	Station name associated with network listed in "Climate Network."
Latitude	Numerical value (units: see coordinate units).
Longitude	Numerical value (units: see coordinate units).
Coordinate units	Latitude/longitude (units: decimal degrees, degree-minute-second, etc.).
Datum	Datum used as basis for coordinates: WGS 84, NAD 83, etc.
Elevation	Elevation of station above mean sea level (m).
Slope	Slope of ground surface below station (degrees).
Aspect	Azimuth that ground surface below station faces.
Climate division	NOAA climate division where station is located. Climate divisions are NOAA-specified zones sharing similar climate and hydrology characteristics.
Country	Country where station is located.
State	State where station is located.
County	County where station is located.
Weather/climate network	Primary weather/climate network the station belongs to (COOP, RAWS, etc.).
NPS unit code	Four-letter code identifying park unit where station resides.
NPS unit name	Full name of park unit.
NPS unit type	National park, national monument, etc.
UTM zone	If UTM is the only coordinate system available.
Location notes	Useful information not already included in "station narrative."
Climate variables	Temperature, precipitation, etc.
Installation date	Date of station installation.
Removal date	Date of station removal.
Station photograph	Digital image of station.
Photograph date	Date photograph was taken.
Photographer	Name of person who took the photograph.
Station narrative	Anything related to general site description; may include site exposure, characteristics of surrounding vegetation, driving directions, etc.
Contact name	Name of the person involved with station operation.
Organization	Group or agency affiliation of contact person.
Contact type	Designation that identifies contact person as the station owner, observer, maintenance person, data manager, etc.
Position/job title	Official position/job title of contact person.
Address	Address of contact person.
E-mail address	E-mail address of contact person.
Phone	Phone number of contact person (and extension if available).
Contact notes	Other information needed to reach contact person.

Two types of information have been used to complete the SFCN climate station inventory.

- Station inventories: Information about observational procedures, latitude/longitude, elevation, measured elements, measurement frequency, sensor types, exposures, ground

cover and vegetation, data-processing details, network, purpose, and managing individual or agency, etc.

- Data inventories: Information about measured data values including completeness, seasonality, data gaps, representation of missing data, flagging systems, how special circumstances in the data record are denoted, etc.

This is not a straightforward process. Extensive searches are typically required to develop historic station and data inventories. Both types of inventories frequently contain information gaps and often rely on tacit and unrealistic assumptions. Sources of information for these inventories frequently are difficult to recover or are undocumented and unreliable. In many cases, the actual weather/climate data available from different sources are not linked directly to metadata records. To the extent that actual data can be acquired (rather than just metadata), it is possible to cross-check these records and perform additional assessments based on the amount and completeness of the data.

Certain types of weather/climate networks that possess any of the following attributes have not been considered for inclusion in the inventory:

- Private networks with proprietary access and/or inability to obtain or provide sufficient metadata.
- Private weather enthusiasts (often with high-quality data) whose metadata are not available and whose data are not readily accessible.
- Unofficial observers supplying data to the NWS (lack of access to current data and historic archives; lack of metadata).
- Networks having no available historic data.
- Networks having poor-quality metadata.
- Networks having poor access to metadata.
- Real-time networks having poor access to real-time data.

Previous inventory efforts at WRCC have shown that for the weather networks identified in the preceding list, in light of the need for quality data to track weather and climate, the resources required and difficulty encountered in obtaining metadata or data are prohibitively large.

3.2. Criteria for Locating Stations

To identify weather and climate stations for each park unit in the SFCN we selected only those stations located within 20 km of the SFCN park units. These buffer distances were selected in an attempt to include at least a few automated stations from major networks such as SAO, while keeping the total number of identified stations down to a reasonable value.

The station locator maps presented in Chapter 4 were designed to show clearly the spatial distributions of all major weather/climate station networks in SFCN. We recognize that other mapping formats may be more suitable for other specific needs.

4.0. Station Inventory

An objective of this report is to show the locations of weather/climate stations for the SFCN region in relation to the boundaries of the NPS park units within the SFCN. A station does not have to be within park boundaries to provide useful data and information for a park unit.

4.1. Climate and Weather Networks

Most stations in the SFCN region are associated with at least one of nine major weather/climate networks (Table 4.1). Brief descriptions of each weather/climate network are provided below (see Appendix G for greater detail).

Table 4.1. Weather/climate networks represented within the SFCN.

Acronym	Name
CASTNet	Clean Air Status and Trends Network
COOP	NWS Cooperative Observer Program
CWOP	Citizen Weather Observer Program
FAWN	Florida Automated Weather Network
GPMP	NPS Gaseous Pollutant Monitoring Program
GPS-MET	NOAA ground-based GPS meteorology network
NADP	National Atmospheric Deposition Program
RAWS	Remote Automated Weather Station network
SAO	NWS/FAA Surface Airways Observation network
SCAN	Soil Climate Analysis Network
WX4U	Weather For You network

4.1.1. Clean Air Status and Trends Network (CASTNet)

CASTNet is primarily an air-quality monitoring network managed by the EPA. Standard hourly weather and climate elements are measured and include temperature, wind, humidity, solar radiation, soil temperature, and sometimes moisture. These elements are intended to support interpretation of air-quality parameters that also are measured at CASTNet sites. Data records at CASTNet sites are generally one–two decades in length.

4.1.2. NWS Cooperative Observer Program (COOP)

The COOP network has been a foundation of the U.S. climate program for decades and continues to play an important role. Manual measurements are made by volunteers and consist of daily maximum and minimum temperatures, observation-time temperature, daily precipitation, daily snowfall, and snow depth. When blended with NWS measurements, the data set is known as SOD, or “Summary of the Day.” The quality of data from COOP sites ranges from excellent to modest.

4.1.3. Citizen Weather Observer Program (CWOP)

The CWOP network consists primarily of automated weather stations operated by private citizens who have either an Internet connection and/or a wireless Ham radio setup. Data from

CWOP stations are specifically intended for use in research, education, and homeland security activities. Although standard meteorological elements such as temperature, precipitation, and wind are measured at all CWOP stations, station characteristics do vary, including sensor types and site exposure.

4.1.4. Florida Automated Weather Network (FAWN)

The FAWN network was initiated in Florida in the late 1990s in response to funding cutbacks at NWS in the area of localized weather information for agriculture, including frost and freeze warnings. Today FAWN provides useful weather data for Florida farmers and growers, primarily for daily management decisions. FAWN is also being used as a source of weather information for the general public.

4.1.5. Gaseous Pollutant Monitoring Program (GPMP)

The GPMP network measures hourly meteorological data in support of pollutant monitoring activities. Measured elements include temperature, precipitation, humidity, wind, solar radiation, and surface wetness. These data are generally of high quality, with records extending up to two decades in length.

4.1.6. NOAA Ground-Based GPS Meteorology (GPS-MET) Network

The GPS-MET network is the first network of its kind dedicated to GPS (Global Positioning System) meteorology (see Duan et al. 1996), which utilizes the radio signals broadcast by the satellite for atmospheric remote sensing. GPS meteorology applications have evolved along two paths: ground-based (Bevis et al. 1992) and space-based (Yuan et al. 1993). For more information, please see Appendix G. The stations identified in this inventory are all ground-based. The GPS-MET network was developed in response to the need for improved moisture observations to support weather forecasting, climate monitoring, and other research activities. The primary goals of this network are to measure atmospheric water vapor using ground-based GPS receivers, facilitate the operational use of these data, and encourage usage of GPS meteorology for atmospheric research and other applications. GPS-MET is a collaboration between NOAA and several other governmental and university organizations and institutions. Ancillary meteorological observations at GPS-MET stations include temperature, relative humidity, and pressure.

4.1.7. National Atmospheric Deposition Program (NADP)

The purpose of the NADP network is to monitor primarily wet deposition at selected sites around the U.S. and its territories. The network is a collaborative effort among several agencies including USDA and USGS (U.S. Geological Survey). This network also includes Mercury Deposition Network (MDN) sites. Precipitation is the primary climate parameter measured at NADP sites.

4.1.8. Remote Automated Weather Station (RAWS) Network

The RAWS network is administered through many land management agencies, particularly the BLM and the Forest Service. Hourly meteorology elements are measured and include temperature, wind, humidity, solar radiation, barometric pressure, fuel temperature, and precipitation (when temperatures are above freezing). The fire community is the primary client for RAWS data. These sites are remote and data typically are transmitted via GOES

(Geostationary Operational Environmental Satellite). Some sites operate all winter. Most data records for RAWS sites began during or after the mid-1980s.

4.1.9. NWS/FAA Surface Airways Observation Network (SAO)

These stations are located usually at major airports and military bases. Almost all SAO sites are automated. The hourly data measured at these sites include temperature, precipitation, humidity, wind, pressure, sky cover, ceiling, visibility, and current weather. Most data records begin during or after the 1940s, and these data are generally of high quality.

4.1.10. USDA/NRCS Soil Climate Analysis Network (SCAN)

The SCAN network is administered by NRCS and is intended to be a comprehensive nationwide soil moisture and climate information system to be used in supporting natural resource assessments and other conservation activities. These stations are usually located in the agricultural areas of the U.S. All SCAN sites are automated. The parameters measured at these sites include air temperature, precipitation, humidity, wind, pressure, solar radiation, snow depth, and snow water content.

4.1.11. Weather For You Network (WX4U)

The WX4U network is a nationwide collection of weather stations run by local observers. Data quality varies with site. Standard meteorological elements are measured and usually include temperature, precipitation, wind, and humidity.

4.1.12. Weather Bureau Army Navy (WBAN)

Some stations are identified in this report as WBAN stations. This is a station identification system rather than a true weather/climate network. Stations identified with WBAN are largely historical stations that reported meteorological observations on the WBAN weather observation forms that were common during the early and middle parts of the twentieth century. The use of WBAN numbers to identify stations was one of the first attempts in the U.S. to use a coordinated station numbering scheme between several weather station networks, such as the COOP and SAO networks.

4.1.13. Other Networks

In addition to the major networks mentioned above, there are various networks that are operated for specific purposes by specific organizations or governmental agencies or scientific research projects. These networks could be present within SFCN but have not been identified in this report. Some of the commonly used networks include the following:

- NOAA upper-air stations
- Federal and state departments of transportation
- U.S. Department of Energy Surface Radiation Budget Network (Surfrad)
- Park-specific-monitoring networks and stations
- Other research or project networks having many possible owners

4.2. Station Locations

The major weather/climate networks in the SFCN (discussed in Section 4.1) have at most several stations at or inside each park unit (Table 4.2), with COOP stations being most common.

Table 4.2. Number of stations within or nearby SFCN park units. Numbers are listed by park unit and by weather/climate network. Figures in parentheses indicate the numbers of stations within park boundaries.

Network	BICY	BISC	BUIS	DRTO	EVER	SARI	VIIS
CASTNet	**0**(0)	**0**(0)	**0**(0)	**0**(0)	**1**(1)	**0**(0)	**1**(1)
COOP	**9**(1)	**13**(0)	**16**(0)	**1**(1)	**29**(6)	**22**(1)	**19**(6)
CWOP	**2**(0)	**22**(0)	**0**(0)	**0**(0)	**19**(0)	**1**(0)	**1**(0)
FAWN	**0**(0)	**1**(0)	**0**(0)	**0**(0)	**1**(0)	**0**(0)	**0**(0)
GPMP	**0**(0)	**0**(0)	**0**(0)	**0**(0)	**1**(1)	**0**(0)	**0**(0)
GPS-MET	**0**(0)	**2**(0)	**0**(0)	**0**(0)	**1**(0)	**0**(0)	**0**(0)
NADP	**0**(0)	**0**(0)	**0**(0)	**0**(0)	**1**(1)	**0**(0)	**1**(1)
RAWS	**5**(4)	**0**(0)	**1**(0)	**0**(0)	**5**(3)	**1**(0)	**0**(0)
SAO	**0**(0)	**6**(1)	**1**(0)	**1**(1)	**5**(1)	**1**(0)	**1**(0)
SCAN	**0**(0)	**0**(0)	**0**(0)	**0**(0)	**1**(0)	**0**(0)	**0**(0)
WX4U	**1**(0)	**0**(0)	**0**(0)	**0**(0)	**1**(0)	**0**(0)	**0**(0)
Other	**0**(0)	**4**(1)	**1**(0)	**0**(0)	**1**(0)	**2**(0)	**2**(0)
Total	**17**(5)	**48**(2)	**19**(0)	**2**(2)	**66**(13)	**27**(1)	**25**(8)

Lists of stations have been compiled for the SFCN. As was noted previously, a station does not have to be within the boundaries to provide useful data and information regarding the park unit in question. Some might be physically *within* the administrative or political boundaries, whereas others might be just outside, or even some distance away, but would be *nearby* in behavior and representativeness. What constitutes "useful" and "representative" are also significant questions, whose answers can vary according to application, type of element, period of record, procedural or methodological observation conventions, and the like.

4.2.1. South Florida

All of the five weather/climate stations we identified within BICY are active (Table 4.3; Figure 4.1). Only one of these is a manual COOP station (Oasis Ranger Stn.), while the remaining four stations are RAWS stations that provide automated weather data for the park unit. The COOP station "Oasis Ranger Stn." is located near Monroe Station in southern BICY and has a very complete data record starting from 1978. The RAWS station "Oasis" is at this same location and also has a very complete data record. The longest RAWS records come from the stations "Miles City" and "Ochopee", both starting in 1987. "Miles City," located in northwestern BICY, has a data gap in October 1990 but has an otherwise complete data record. "Ochopee," located in western BICY, has a complete data record except for a data gap in October 1988. The RAWS station "Raccoon Point," located in eastern BICY, has been operating since 1993, with a complete data record.

Table 4.3. Weather/climate stations for SFCN park units in southern Florida. Stations inside park units and within 20 km of the park unit boundary are included. Missing entries are indicated by "M".

Name	Lat.	Lon.	Elev. (m)	Network	Start	End	In Park?
Big Cypress National Preserve (BICY)							
Oasis Ranger Stn.	25.858	-81.032	2	COOP	6/1/1978	Present	Yes
Miles City	26.248	-81.297	5	RAWS	4/1/1987	Present	Yes
Oasis	25.850	-81.030	2	RAWS	3/1/2002	Present	Yes
Ochopee	25.917	-81.283	2	RAWS	4/1/1987	Present	Yes
Raccoon Point	25.971	-80.900	2	RAWS	3/1/1993	Present	Yes

Name	Lat.	Lon.	Elev. (m)	Network	Start	End	In Park?
Big Cypress	26.328	-80.996	5	COOP	3/27/2002	Present	No
Big Cypress Reservation	26.317	-81.000	5	COOP	8/7/1940	7/17/1969	No
Chokoloskee	25.814	-81.362	2	COOP	8/1/2005	Present	No
Everglades	25.849	-81.390	2	COOP	2/1/1924	Present	No
Immokalee	26.422	-81.410	11	COOP	5/1/1958	Present	No
Miles City Tower	26.183	-81.350	46	COOP	7/1/1956	6/16/1970	No
Sunniland	26.267	-81.350	3	COOP	9/1/1952	7/31/1956	No
Tamiami Trail 40 Mi.	25.761	-80.824	5	COOP	6/29/1940	Present	No
CW4061 Naples	26.273	-81.510	3	CWOP	M	Present	No
CW5898 Naples	26.273	-81.522	6	CWOP	M	Present	No
Ten Mile Corner	25.610	-80.850	2	RAWS	3/1/1992	Present	No
NM Naples	26.050	-81.440	9	WX4U	M	Present	No
Biscayne National Park (BISC)							
Fowey Rocks Miami	25.583	-80.100	1	SAO	7/1/1936	Present	Yes
Key Biscayne	25.667	-80.200	3	WBAN	10/12/1983	Present	Yes
Cape Florida	25.672	-80.157	2	COOP	1/1/1997	Present	No
Hialeah	25.818	-80.286	4	COOP	6/29/1940	Present	No
Homestead Exp. Stn.	25.500	-80.500	3	COOP	7/1/1910	8/1/1992	No
John Pennekamp SP	25.194	-80.349	3	COOP	6/12/2000	Present	No
Kendall 2 E	25.683	-80.283	6	COOP	1/1/1942	4/1/1974	No
Miami	25.755	-80.384	4	COOP	1/1/1996	Present	No
Miami	25.791	-80.316	9	COOP	6/1/1932	Present	No
Miami 12 SSW	25.650	-80.300	3	COOP	1/1/1931	10/1/1988	No
Miami Bayfront Park	25.783	-80.183	3	COOP	6/1/1954	4/24/1974	No
Miami Beach	25.780	-80.130	2	COOP	1/5/1927	Present	No
Miami WSO City	25.717	-80.283	5	COOP	12/1/1900	6/1/1983	No
Perrine 4 W	25.582	-80.436	3	COOP	1/1/1942	Present	No
South Miami 5 W	25.700	-80.350	24	COOP	7/1/1954	12/31/1974	No
ARVIDA Miami	25.667	-80.417	3	CWOP	M	Present	No
BRWNVL Miami	25.820	-80.236	4	CWOP	M	Present	No
CITRUS Miami	25.776	-80.230	3	CWOP	M	Present	No
CNTNNL Miami	25.573	-80.331	-3	CWOP	M	Present	No
CW1733 S. Miami	25.704	-80.329	5	CWOP	M	Present	No
CW3829 Miami	25.743	-80.326	3	CWOP	M	Present	No
CW3984 Miami	25.710	-80.252	4	CWOP	M	Present	No
CW4495 The Hammocks	25.665	-80.440	3	CWOP	M	Present	No
CW5385 Pinecrest	25.659	-80.297	6	CWOP	M	Present	No
FISHER Miami Beach	25.786	-80.132	1	CWOP	M	Present	No
K4AG-1 Miami	25.652	-80.358	5	CWOP	M	Present	No
K4AG-6 Miami	25.652	-80.359	3	CWOP	M	Present	No
K4JRG Miami	25.735	-80.422	3	CWOP	M	Present	No
K4TCV-1 Miami	25.743	-80.215	2	CWOP	M	Present	No
KG4LXH-2 Miami	25.612	-80.425	3	CWOP	M	Present	No
MADSON Miami	25.849	-80.237	3	CWOP	M	Present	No
NTLLS Miami Beach	25.814	-80.133	2	CWOP	M	Present	No
PONCE Coral Gables	25.717	-80.271	4	CWOP	M	Present	No

Name	Lat.	Lon.	Elev. (m)	Network	Start	End	In Park?
RCHMND Miami	25.630	-80.358	3	CWOP	M	Present	No
REDLND Homestead	25.536	-80.451	2	CWOP	M	Present	No
SPRNGS Miami Springs	25.815	-80.274	2	CWOP	M	Present	No
W7IUC-7 Card Sound	25.291	-80.378	2	CWOP	M	Present	No
Homestead	25.509	-80.499	0	FAWN	M	Present	No
Miami	25.730	-80.160	9	GPS-MET	M	Present	No
Richmond	25.610	-80.380	9	GPS-MET	M	Present	No
Base Miami Beach	25.767	-80.133	1	SAO	M	Present	No
Homestead AFB	25.483	-80.383	5	SAO	2/1/1943	Present	No
Miami	25.791	-80.316	9	SAO	6/1/1932	Present	No
Miami	25.648	-80.433	3	SAO	1/1/1967	Present	No
Miami WSO City	25.717	-80.283	5	SAO	12/1/1900	6/1/1983	No
Dinner	25.733	-80.233	4	WBAN	2/1/1940	4/30/1945	No
Miami	25.783	-80.283	3	WBAN	6/1/1945	12/31/1959	No
Richmond	25.617	-80.417	9	WBAN	1/1/1943	11/30/1945	No
Dry Tortugas National Park (DRTO)							
Dry Tortugas	24.628	-82.874	3	COOP	6/1/1950	Present	Yes
Dry Tortugas Light Stn.	24.633	-82.917	2	SAO	11/1/1898	Present	Yes
Everglades National Park (EVER)							
Everglades NP	25.391	-80.681	2	CASTNet	5/1/1986	Present	Yes
Chokoloskee	25.814	-81.362	2	COOP	8/1/2005	Present	Yes
Coot Bay Ranger Stn.	25.183	-80.900	0	COOP	5/1/1949	12/31/1950	Yes
Flamingo	25.150	-80.917	12	COOP	5/1/1958	8/31/1966	Yes
Flamingo Ranger Stn.	25.142	-80.914	1	COOP	1/1/1951	Present	Yes
Royal Palm Ranger Stn.	25.387	-80.594	2	COOP	5/1/1949	Present	Yes
Tamiami Trail 40 Mi.	25.761	-80.824	5	COOP	6/29/1940	Present	Yes
Everglades	25.391	-80.681	2	GPMP	9/1/1982	2/1/1997	Yes
Everglades NP-Research Center	25.390	-80.680	2	NADP	3/5/1996	Present	Yes
Cache	25.390	-80.680	2	RAWS	12/1/1999	Present	Yes
Chekika	25.625	-80.580	2	RAWS	10/1/2002	Present	Yes
Ten Mile Corner	25.610	-80.850	2	RAWS	3/1/1992	Present	Yes
Flamingo	25.133	-80.933	1	SAO	10/1/1964	Present	Yes
Craig	24.833	-80.767	3	COOP	9/1/1957	11/30/1962	No
Curry Hammock	24.743	-80.982	2	COOP	6/15/2000	Present	No
Duck Key	24.771	-80.907	2	COOP	6/1/1982	Present	No
Everglades	25.849	-81.390	2	COOP	2/1/1924	Present	No
Homestead	25.501	-80.550	3	COOP	5/24/1990	Present	No
Homestead Exp. Stn.	25.500	-80.500	3	COOP	7/1/1910	8/1/1992	No
Islamorada	24.918	-80.636	2	COOP	12/1/1998	Present	No
Islamorada 2 SW	24.900	-80.667	3	COOP	7/1/1965	9/30/1966	No
John Pennekamp SP	25.194	-80.349	3	COOP	6/12/2000	Present	No
Lignumvitae Key	24.900	-80.700	3	COOP	8/1/1948	10/31/1976	No
Long Key	24.817	-80.817	1	COOP	12/1/1962	9/8/1965	No
Miami	25.755	-80.384	4	COOP	1/1/1996	Present	No
Miami	25.791	-80.316	9	COOP	6/1/1932	Present	No

Name	Lat.	Lon.	Elev. (m)	Network	Start	End	In Park?
Miami 12 SSW	25.650	-80.300	3	COOP	1/1/1931	10/1/1988	No
Oasis Ranger Stn.	25.858	-81.032	2	COOP	6/1/1978	Present	No
Pennsuco	25.917	-80.417	3	COOP	M	5/31/1967	No
Pennsuco 5 WNW	25.930	-80.454	3	COOP	12/7/1940	7/27/2003	No
Perrine 4 W	25.582	-80.436	3	COOP	1/1/1942	Present	No
Plantation Key	24.967	-80.550	2	COOP	10/1/1961	Present	No
South Miami 5 W	25.700	-80.350	24	COOP	7/1/1954	12/31/1974	No
Tamiami Canal	25.767	-80.450	3	COOP	5/1/1941	12/31/1966	No
Tavernier	25.007	-80.521	2	COOP	6/1/1936	Present	No
Trail Glade Ranges	25.765	-80.478	4	COOP	12/1/1966	Present	No
ARVIDA Miami	25.667	-80.417	3	CWOP	M	Present	No
BELL Miami	25.833	-80.417	4	CWOP	M	Present	No
CNTNNL Miami	25.573	-80.331	-3	CWOP	M	Present	No
CW1719 Key Largo	25.119	-80.419	3	CWOP	M	Present	No
CW1733 S. Miami	25.704	-80.329	5	CWOP	M	Present	No
CW3829 Miami	25.743	-80.326	3	CWOP	M	Present	No
CW4495 The Hammocks	25.665	-80.440	3	CWOP	M	Present	No
CW4842 Tavernier	24.985	-80.547	2	CWOP	M	Present	No
DORAL Miami	25.820	-80.393	2	CWOP	M	Present	No
K4AG-1 Miami	25.652	-80.358	5	CWOP	M	Present	No
K4AG-6 Miami	25.652	-80.359	3	CWOP	M	Present	No
K4JRG Miami	25.735	-80.422	3	CWOP	M	Present	No
KG4LXH-2 Miami	25.612	-80.425	3	CWOP	M	Present	No
RCHMND Miami	25.630	-80.358	3	CWOP	M	Present	No
REDLND Homestead	25.536	-80.451	2	CWOP	M	Present	No
W7IUC-7 Card Sound	25.291	-80.378	2	CWOP	M	Present	No
WT4X-5 Grassy Key	24.759	-80.957	1	CWOP	M	Present	No
WT4X-6 Plantation Key	24.979	-80.550	2	CWOP	M	Present	No
YOUTH Hialeah Gardens	25.884	-80.362	2	CWOP	M	Present	No
Homestead	25.509	-80.499	0	FAWN	M	Present	No
Richmond	25.610	-80.380	9	GPS-MET	M	Present	No
Oasis	25.850	-81.030	2	RAWS	3/1/2002	Present	No
Ochopee	25.917	-81.283	2	RAWS	4/1/1987	Present	No
Homestead AFB	25.483	-80.383	5	SAO	2/1/1943	Present	No
Islamorada Stn.	24.950	-80.583	2	SAO	10/1/1972	Present	No
Miami	25.791	-80.316	9	SAO	6/1/1932	Present	No
Miami	25.648	-80.433	3	SAO	1/1/1967	Present	No
Everglades ARS	25.500	-80.550	3	SCAN	M	Present	No
Richmond	25.617	-80.417	9	WBAN	1/1/1943	11/30/1945	No
NM Naples	26.050	-81.440	9	WX4U	M	Present	No

A few additional sources of near-real-time weather data are found within 20 km of BICY. The RAWS station “Ten Mile Corner” is in northwestern EVER, just outside the boundary of BICY. This station has been operating since 1992. A few CWOP and WX4U stations were also identified.

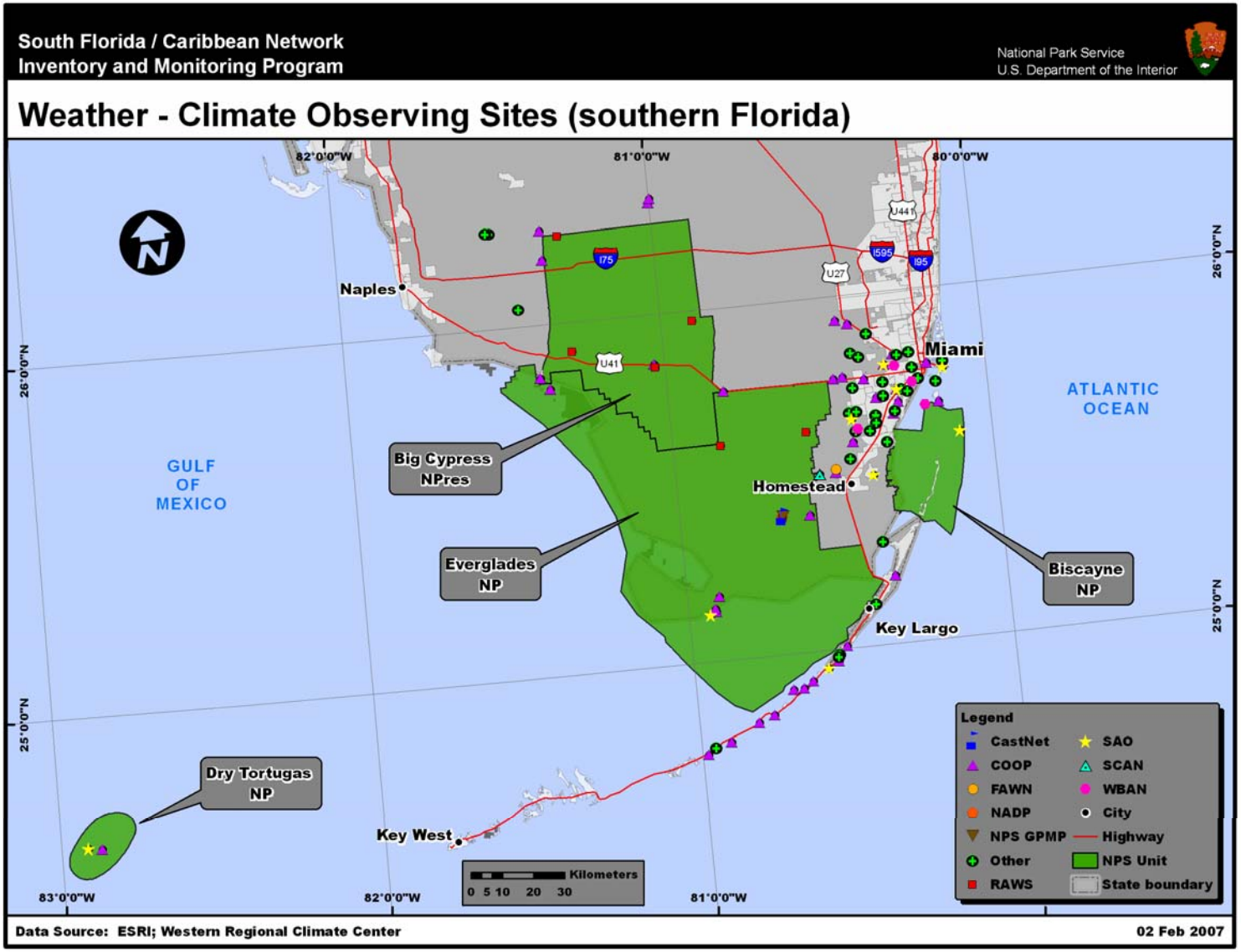


Figure 4.1. Station locations for the SFCN park units in southern Florida.

Eight COOP stations were identified within 20 km of BICY (Table 4.3). Five of these are active. The COOP station "Everglades" is located on the Gulf Coast, 1 km west of BICY, and provides the longest climate record (1924-present).The data record at "Everglades" has numerous small data gaps throughout. Another long-term record is available at the COOP station "Tamiami Trial 40 Mi.," just east of BICY along U.S. Highway 41. This station's data record goes back to 1940 and has numerous small data gaps much like those at "Everglades."

Biscayne National Park (BISC) has two weather/climate stations within its boundaries (Table 4.3). Both of these are located in northern BISC (Figure 4.1). The SAO station "Fowey Rocks Miami" provides a long-term climate record and a source of near real-time data for the park unit. The other station identified in BISC, "Key Biscayne," is a WBAN station that has been operating since 1983.

Out of the 13 COOP stations identified within 20 km of the boundaries of BISC, seven are active (Table 4.3). The longest record we identified was from the COOP station "Miami Beach," which is 13 km north of BISC and has been active since 1927. The record at this station is very complete except for a large data gap through all of 2001 and 2002. Another reliable long-term record was identified at the COOP station "Miami," which is located 18 km north of BISC. This station has been active since 1932 and has a very complete data record. The COOP station "Perrine 4 W," located 11 km west of BISC, has been operating since 1942 but has a data record that is unreliable before 1990.

Many sources of near-real-time weather data exist north and west of BISC (Figure 4.1). The Miami area hosts a large number of CWOP stations located within 20 km of BISC (Table 4.3). In addition to these, there are several SAO stations at local airports, a couple of GPS-MET stations in Miami and Richmond, and a FAWN station at Homestead, 16 km west of BISC.

We identified two stations for DRTO. The COOP station "Dry Tortugas" has a data record that goes back to 1950, with satisfactory completeness. The SAO station "Dry Tortugas Light Stn." has been operating since 1898. Besides these two stations, the closest sources of weather/climate data for DRTO are in Key West, almost 100 km to the east of DRTO.

Several local and regional weather/climate networks have stations inside EVER. Six COOP sites were identified within EVER; four of these are active. The longest record is at "Tamiami Trail 40 Mi.," in northern EVER. This station was discussed previously. Two other COOP stations with longer data records are "Flamingo Ranger Stn." (1951-present), located in southern EVER, and "Royal Palm Ranger Stn." (1949-present), located in eastern EVER. "Flamingo Ranger Stn." has a fairly complete data record, although there are numerous small data gaps. "Royal Palm Ranger Stn." has a big data gap throughout the 1960s and 1970s, but has been very reliable in recent years. A NADP station (Everglades NP-Research Center) has been operating since 1996 on Research Road in eastern EVER. Several near-real-time stations operate at this location as well. A CASTNet station (Everglades NP) has been operating since 1986, while the RAWS station "Cache" also operates here (1999-present). Other RAWS stations within EVER include "Chekika" (2002-present), in northeastern EVER, and "Ten Mile Corner" (1992-present), in northern EVER. The SAO station "Flamingo" has been operating since 1964 in southern EVER, along Florida Bay.

Like BISC, numerous CWOP stations were identified within 20 km of EVER, located primarily in the Miami vicinity. These all provide near-real-time weather data. Several other weather networks provide near-real-time data as well. The RAWS stations “Oasis” and “Ochopee,” discussed previously, are in BICY, 16 km and 6 km, respectively, north of EVER. The FAWN station “Homestead” is located 6 km east of EVER. Just west of this FAWN station is the SCAN station “Everglades ARS,” located only 1 km east of EVER. Four active SAO stations were identified within 20 km of EVER. Three of these are located in the Miami vicinity, while a fourth SAO, “Islamorada Stn.,” is located along U.S. Highway 1, 5 km south of the EVER boundary.

4.2.2. Virgin Islands

No weather/climate stations were identified within the boundaries of BUIS (Figure 4.2; Table 4.4). Sixteen COOP stations were identified within 20 km of BUIS. Five of these stations are active. The COOP station “Christiansted Fort” has the longest data record of these stations (1921-present). It is located 8 km west of BUIS. Unfortunately, this station has an unreliable data record. The COOP station “Christiansted,” located 20 km west of BUIS, has been operating since 1945. The data record at this station is fairly complete but there are scattered data gaps. A SAO station has been identified at this same location. The COOP station “Beth Upper New Works” is located 18 km from BUIS and has been operating since 1956, with a data record that is fairly complete. The COOP station “East Hill” (1956-present) is the closest active COOP station, located 4 km west of BUIS. This station measures precipitation only and its data record is fairly complete after 1972. The COOP station “Montpellier” (1979-present) is also a precipitation-only COOP station, located 12 km from BUIS. The RAWS network has a station 4 km southwest of BUIS. This station (Cotton Valley) provides near-real-time data for the region and has been operating since 2004.

One weather/climate stations was identified within the boundaries of SARI (Table 4.4; Figure 4.2). This is the COOP station “Montpellier,” discussed previously. The same active stations that were identified for BUIS were identified for SARI. In addition to these, an active CWOP station (CW3616 Frederiksted) is located 11 km from SARI and provides near-real-time data for the region.

Several stations have been identified within the boundaries of VIIS (Table 4.4; Figure 4.2). A CASTNet site (Lind Point) operated in VIIS from 1998 to 2003. A NADP station (Virgin Islands NP-Lind Point) has been operating in VIIS since 1998. Six COOP stations were identified in VIIS; however, only one of these is still active. The COOP station “Cruz Bay” has been operating since 1955. Currently, the station measures precipitation only. Temperature measurements were also taken from the 1970s through the early 1990s. There are many small data gaps throughout the data record at “Cruz Bay.” Weekend observations are usually unavailable.

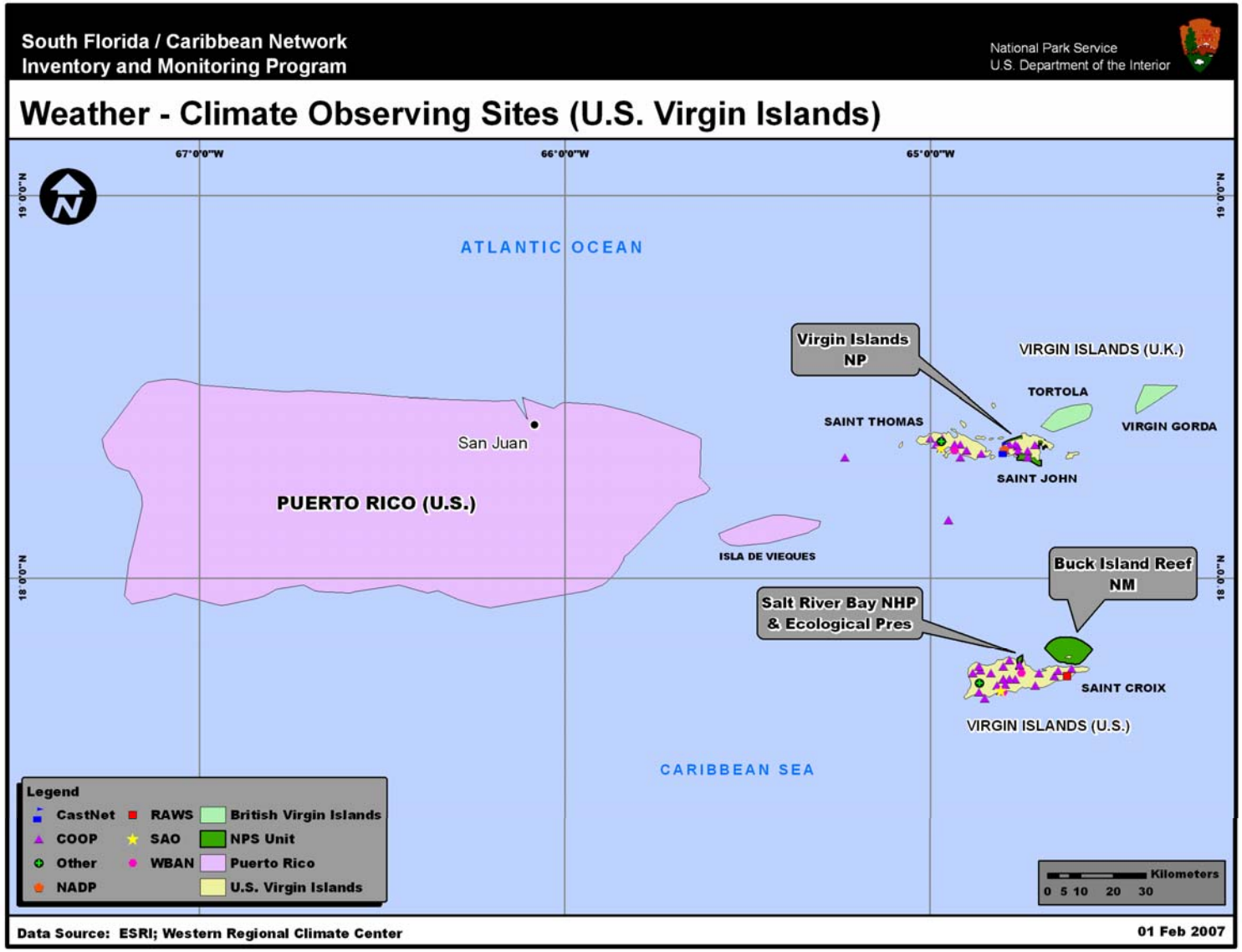


Figure 4.2. Station locations for the SFCN park units on the Virgin Islands.

Table 4.4. Weather/climate stations for the SFCN park units on the Virgin Islands. Stations inside park units and within 20 km of the park unit boundary are included. Missing entries are indicated by "M".

Name	Lat.	Lon.	Elev. (m)	Network	Start	End	In Park?
Buck Island Reef National Monument (BUIS)							
Christiansted	17.703	-64.806	19	COOP	10/1/1945	Present	No
Adventure	17.717	-64.817	36	COOP	11/1/1938	10/1/1966	No
Beth Upper New Works	17.720	-64.794	34	COOP	1/1/1956	Present	No
Bethlehem Old Works	17.733	-64.800	30	COOP	1/1/1956	1/31/1968	No
Christiansted Fort	17.749	-64.701	9	COOP	1/1/1921	Present	No
Cotton Valley 2	17.760	-64.613	43	COOP	1/1/1956	8/1/2001	No
East Hill	17.756	-64.649	37	COOP	1/1/1956	Present	No
Estate Belvedere	17.767	-64.800	140	COOP	12/1/1961	10/5/1965	No
Estate Rust-Op-Twist	17.783	-64.783	15	COOP	2/13/1956	12/31/1984	No
Estate The Sight	17.742	-64.660	40	COOP	7/1/1957	7/1/2002	No
Fredensborg	17.733	-64.783	45	COOP	1/1/1956	10/1/1966	No
Granard	17.716	-64.712	20	COOP	9/1/1957	5/1/2003	No
Jealousy	17.733	-64.800	45	COOP	1/1/1956	6/1/1966	No
Kings Hill	17.733	-64.783	64	COOP	7/1/1957	4/30/1979	No
Montpellier	17.771	-64.755	61	COOP	11/1/1979	Present	No
Strawberry Hill	17.733	-64.767	45	COOP	1/1/1956	10/1/1966	No
Cotton Valley	17.743	-64.624	122	RAWS	12/1/2004	Present	No
Christiansted	17.703	-64.806	19	SAO	10/1/1945	Present	No
Christiansted	17.700	-64.800	17	WBAN	9/1/1941	12/31/1948	No
Salt River National Historical Park and Ecological Reserve (SARI)							
Montpellier	17.771	-64.755	61	COOP	11/1/1979	Present	Yes
Adventure	17.717	-64.817	36	COOP	11/1/1938	10/1/1966	No
Annaly	17.756	-64.863	213	COOP	8/1/1957	1/17/2006	No
Beth Upper New Works	17.720	-64.794	34	COOP	1/1/1956	Present	No
Bethlehem Old Works	17.733	-64.800	30	COOP	1/1/1956	1/31/1968	No
Christiansted	17.703	-64.806	19	COOP	10/1/1945	Present	No
Christiansted Fort	17.749	-64.701	9	COOP	1/1/1921	Present	No
Cotton Valley 2	17.760	-64.613	43	COOP	1/1/1956	8/1/2001	No
East Hill	17.756	-64.649	37	COOP	1/1/1956	Present	No
Estate Belvedere	17.767	-64.800	140	COOP	12/1/1961	10/5/1965	No
Estate Rust-Op-Twist	17.783	-64.783	15	COOP	2/13/1956	12/31/1984	No
Estate The Sight	17.742	-64.660	40	COOP	7/1/1957	7/1/2002	No
Fountain	17.750	-64.833	76	COOP	1/1/1956	8/1/1993	No
Fredensborg	17.733	-64.783	45	COOP	1/1/1956	10/1/1966	No
Frederiksted 1 SE	17.700	-64.867	24	COOP	7/1/1957	11/1/1989	No
Good Hope School	17.683	-64.850	3	COOP	1/1/1970	6/30/1976	No
Granard	17.716	-64.712	20	COOP	9/1/1957	5/1/2003	No
Ham Bluff Lighthouse	17.767	-64.867	24	COOP	7/1/1946	8/1/1993	No
Jealousy	17.733	-64.800	45	COOP	1/1/1956	6/1/1966	No
Kings Hill	17.733	-64.783	64	COOP	7/1/1957	4/30/1979	No
Mount Washington	17.750	-64.883	73	COOP	12/1/1970	5/31/1972	No
Strawberry Hill	17.733	-64.767	45	COOP	1/1/1956	10/1/1966	No

Name	Lat.	Lon.	Elev. (m)	Network	Start	End	In Park?
CW3616 Frederiksted	17.723	-64.865	83	CWOP	M	Present	No
Cotton Valley	17.743	-64.624	122	RAWS	12/1/2004	Present	No
Christiansted	17.703	-64.806	19	SAO	10/1/1945	Present	No
Christiansted	17.700	-64.800	17	WBAN	9/1/1941	12/31/1948	No
St. Croix	17.750	-64.750	3	WBAN	5/12/1983	8/29/1990	No
Virgin Islands National Park (VIIS)							
Lind Point	18.336	-64.796	80	CASTNet	5/1/1998	12/1/2003	Yes
Bordeaux Mountain	18.333	-64.733	338	COOP	5/1/1971	12/31/1984	Yes
Caneel Bay	18.350	-64.783	18	COOP	11/1/1967	5/6/2002	Yes
Catherineburg	18.345	-64.761	258	COOP	3/1/1957	2/1/1997	Yes
Cruz Bay	18.335	-64.794	2	COOP	1/1/1955	Present	Yes
Lameshur Bay	18.317	-64.733	52	COOP	7/1/1958	3/1/1992	Yes
Trunk Bay Estate	18.350	-64.767	45	COOP	1/1/1956	11/30/1967	Yes
Virgin Islands NP-Lind Point	18.336	-64.796	75	NADP	4/14/1998	Present	Yes
Bonne Esperance	18.350	-64.983	207	COOP	1/1/1956	6/30/1958	No
Charlotte Amalie	18.350	-64.933	12	COOP	1/1/1955	10/31/1958	No
Charlotte Amalie	18.340	-64.970	6	COOP	10/1/1945	Present	No
Charlotte Amalie 2	18.350	-64.933	5	COOP	1/1/1958	5/1/1983	No
Charlotte Amalie Estate	18.333	-64.900	60	COOP	1/1/1931	5/31/1943	No
Coral Bay	18.349	-64.714	9	COOP	5/1/1971	Present	No
Donoe Estate	18.333	-64.900	94	COOP	1/1/1956	2/28/1964	No
Dorothea AES	18.367	-64.967	244	COOP	2/1/1956	10/1/1993	No
East End	18.334	-64.759	32	COOP	1/1/1970	Present	No
Estate Fort Mylner	18.333	-64.900	61	COOP	11/1/1957	9/1/1995	No
Frenchmans Bay	18.317	-64.917	36	COOP	12/1/1954	4/30/1979	No
Redhook Bay St. Thomas	18.326	-64.860	1	COOP	3/1/1963	Present	No
Wintberg	18.350	-64.917	197	COOP	1/1/1958	Present	No
CW3191 St. Thomas	18.357	-64.970	452	CWOP	M	Present	No
Charlotte Amalie	18.340	-64.970	6	SAO	10/1/1945	Present	No
Charlotte Amalie	18.333	-64.933	8	WBAN	1/1/1939	12/31/1943	No
St. Thomas	18.333	-64.933	63	WBAN	11/1/1935	3/31/1944	No

Thirteen COOP stations have been identified within 20 km of the boundaries of VIIS (Table 4.4). However, only five of these stations are still active. The longest data record comes from the COOP station “Charlotte Amalie,” located 18 km west of VIIS. This station has been operating since 1945. However, the data record has several large data gaps, with a notable recent gap occurring from July 1996 to February 1999. The COOP station “Coral Bay” is located just east of VIIS and has been operating since 1971. This station measures only precipitation and has a fairly complete data record. The COOP station “East End” is located just 1 km from VIIS and has been operating since 1970. Like “Coral Bay,” this station measures only precipitation. The data record at “East End” has a substantial data gap from August 1997 to March 2002. The COOP station “Redhook Bay St. Thomas” is located 6 km west of VIIS and has been operating since 1963. This station’s data record is fairly unreliable before 1980 but has been quite complete

since then. The COOP station “Wintberg” is located 12 km west of VIIS and has been operating since 1958. This station measures only precipitation. The data record at “Wintberg” is fairly complete after 1972. Sources of near-real-time data within 20 km of VIIS include the CWOP station “CW3191 St. Thomas,” located 12 km west of the park unit, and the SAO station “Charlotte Amalie” (1945-present), 18 km west of the park unit.

5.0. Conclusions and Recommendations

We have based our findings on an examination of available climate records within SFCN units, discussions with NPS staff and other collaborators, and prior knowledge of the area. Here, we offer an evaluation and general comments pertaining to the status, prospects, and needs for climate-monitoring capabilities in SFCN.

5.1. South Florida / Caribbean Inventory and Monitoring Network

The island-based SFCN park units, such as DRTO and the park units on the relatively small U.S. Virgin Islands, cannot support the same number of weather and climate stations as can larger islands or mainland locations. These park units must rely heavily on outside sources of weather/climate data. This is true particularly with regards to near-real-time stations, where little of any coverage currently exists on Virgin Islands park units. The near-real-time weather stations identified in this report are invaluable for determining current weather conditions, while the climate records available from longer-term stations on these islands are extremely valuable for tracking global-scale climatic changes. Therefore, it is important that the NPS encourage local officials who are responsible for operating these stations to continue to maintain reliable observations.

No weather/climate station coverage is available currently in central and southern BISC. This coverage gap could begin to be addressed by installing an automated station on Elliott Key, at the main ranger station. Candidate weather/climate station networks for this installation would include the FAWN and RAWS networks. Weather/climate monitoring efforts in the park unit would likely benefit from such an installation.

The importance of monitoring wet season/dry season cycles and spatiotemporal patterns in precipitation is quite evident for both BICY and EVER, where precipitation patterns play a integral role in the ecosystems in these park units. Drought monitoring, monitoring of fire conditions, and monitoring of ecosystem health all will benefit from a better understanding of regional convective precipitation patterns, which are quite variable in space and time across both BICY and EVER. In order to improve this understanding, however, the existing coverage of near-real-time weather stations in these parks would need to be increased, and weather/climate monitoring efforts in both BICY and EVER would benefit by gradually implementing this strategy. Since the RAWS network already has a presence within both BICY and EVER, a natural first step would be to install more of these stations. Potential sites in BICY could include 1) a location along Highway 839 between US Highway 41 and Interstate 75, and 2) northeastern BICY, near the rest area at the Recreation Access Point on Interstate 75. Potential sites in EVER could include 1) the Gulf Coast Visitor Center, 2) the Royal Palm Visitor Center, and 3) along Highway 9336, near access points such as the Pa-hay-okee or Mahogany Overlooks.

5.2. Spatial Variations in Mean Climate

Temperature patterns and even mean annual climate (both temperature and precipitation) are relatively uniform across the SFCN landscape, due to its subtropical-tropical marine setting. However, at shorter time scales, precipitation in the SFCN, due to its highly convective nature, has significant local variations over short horizontal distances and introduces considerable fine-

scale structure within the SFCN park units. Issues encountered in mapping mean climate are discussed in Appendix D and in Redmond et al. (2005).

For areas where new stations will be installed, if only a few new stations will be emplaced, the primary goal should be overall characterization of the main climate elements (temperature and precipitation and their joint relative, snow). This level of characterization generally requires that (a) stations should not be located in deep valley bottoms (cold air drainage pockets) or near excessively steep slopes and (b) stations should be distributed spatially in the major biomes of each park. If such stations already are present in the vicinity, then additional stations would be best used for two important and somewhat competing purposes: (a) add redundancy as backup for loss of data from current stations (or loss of the physical stations) or (b) provide added information on spatial heterogeneity in climate arising from topographic diversity.

5.3. Climate Change Detection

The marine setting of the SFCN ensures that temperatures throughout the SFCN are fairly uniform, including little variation with time. Although these stable temperatures are not as interesting for day-to-day weather observations, they do provide a useful indicator of longer-term global temperature trends. Temperatures in the SFCN are regulated strongly by water bodies such as the Atlantic Ocean, the Gulf of Mexico, and the Caribbean Sea, the heat content of which will respond to global-scale warming or cooling trends (NAST 2001). Many of the SFCN park units, most notably those in southern Florida, are located near current sea levels and thus would be directly impacted by any sea level changes associated with global-scale temperature changes (NAST 2001). Therefore, monitoring long-term temperature characteristics for the SFCN should be a high priority. Care should be taken to ensure the continued operation of any existing weather/climate stations that measure both temperature and precipitation. Long-term climate monitoring efforts in near-coastal marine ecosystems could be enhanced by either utilizing existing weather buoys or installing new buoys that monitor not only atmospheric conditions but also oceanic parameters such as sea surface temperature.

The desire for credible, accurate, complete, and long-term climate records—from any location—cannot be overemphasized. Thus, this consideration always should have a high priority. However, because of spatial diversity in climate, monitoring that fills knowledge gaps and provides information on long-term temporal variability in short-distance relationships also will be valuable.

5.4. Aesthetics

This issue arises frequently enough to deserve comment. Standards for quality climate measurements require open exposures away from heat sources, buildings, pavement, close vegetation and tall trees, and human intrusion (thus away from property lines). By their nature, sites that meet these standards are usually quite visible. In many settings (such as heavily forested areas) these sites also are quite rare, making them precisely the same places that managers wish to protect from aesthetic intrusion. The most suitable and scientifically defensible sites frequently are rejected as candidate locations for weather/climate stations. Most weather/climate stations, therefore, tend to be “hidden” but many of these hidden locations have inferior exposures. Some measure of compromise is nearly always called for in siting weather and climate stations.

The public has vast interest and curiosity in weather and climate, and within the NPS I&M networks, such measurements consistently rate near or at the top of desired public information. There seem to be many possible opportunities for exploiting and embracing this widespread interest within the interpretive mission of the NPS. One way to do this would be to highlight rather than hide these stations and educate the public about the need for adequate siting. A number of weather displays we have encountered during visits have proven inadvertently to serve as counterexamples for how measurements should not be made.

5.5. Information Access

Access to information promotes its use, which in turn promotes attention to station care and maintenance, better data, and more use. An end-to-end view that extends from sensing to decision support is far preferable to isolated and disconnected activities and aids the support infrastructure that is ultimately so necessary for successful, long-term climate monitoring.

Decisions about improvements in monitoring capacity are facilitated greatly by the ability to examine available climate information. Various methods are being created at WRCC to improve access to that information. Web pages providing historic and ongoing climate data, and information from SFCN park units can be accessed at http://www.wrcc.dri.edu/nps. In the event that this URL changes, there still will be links from the main WRCC Web page entitled "Projects" under NPS.

The WRCC has been steadily developing software to summarize data from hourly sites. This has been occurring under the aegis of the RAWS program and a growing array of product generators ranging from daily and monthly data lists to wind roses and hourly frequency distributions. All park data are available to park personnel via an access code (needed only for data listings) that can be acquired by request. The WRCC RAWS Web page is located at http://www.wrcc.dri.edu/wraws or http://www.raws.dri.edu.

Web pages have been developed to provide access not only to historic and ongoing climate data and information from SFCN park units but also to climate-monitoring efforts for SFCN. These pages can be found through http://www.wrcc.dri.edu/nps.

Additional access to more standard climate information is accessible though the previously mentioned Web pages, as well as through http://www.wrcc.dri.edu/summary. These summaries are generally for COOP stations.

5.6. Summarized Conclusions and Recommendations

- SFCN park units on smaller islands must rely heavily on outside weather/climate data sources. Therefore, it is important that the NPS encourage continued operation of these stations.
- Central and southern portions of BISC have no weather/climate station coverage. Climate monitoring efforts could be improved by installing an automated station such as FAWN or RAWS on Elliott Key, near main ranger station.

- Current climate monitoring needs in SFCN are generally tied to the need for a better understanding of precipitation characteristics, which are largely convective in nature and therefore are highly variable in both space and time.
- Understanding of spatiotemporal precipitation patterns is particularly important for BICY and EVER, whose ecosystems are strongly influenced by and dependent on precipitation processes.
- A useful strategy for improving precipitation-monitoring efforts in BICY and EVER would be to expand the existing coverage of RAWS stations. A long-term plan for implementing such a strategy would be ideal, starting with sites such as visitor centers or highway access points.

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Appendix A. Glossary

Climate—Complete and entire ensemble of statistical descriptors of temporal and spatial properties comprising the behavior of the atmosphere. These descriptors include means, variances, frequency distributions, autocorrelations, spatial correlations and other patterns of association, temporal lags, and element-to-element relationships. The descriptors have a physical basis in flows and reservoirs of energy and mass. Climate and weather phenomena shade gradually into each other and are ultimately inseparable.

Climate Element—(same as Weather Element) Attribute or property of the state of the atmosphere that is measured, estimated, or derived. Examples of climate elements include temperature, wind speed, wind direction, precipitation amount, precipitation type, relative humidity, dewpoint, solar radiation, snow depth, soil temperature at a given depth, etc. A derived element is a function of other elements (like degree days or number of days with rain) and is not measured directly with a sensor. The terms “parameter” or “variable” are not used to describe elements.

Climate Network—Group of climate stations having a common purpose; the group is often owned and maintained by a single organization.

Climate Station—Station where data are collected to track atmospheric conditions over the long-term. Often, this station operates to additional standards to verify long-term consistency. For these stations, the detailed circumstances surrounding a set of measurements (siting and exposure, instrument changes, etc.) are important.

Data—Measurements specifying the state of the physical environment. Does not include metadata.

Data Inventory—Information about overall data properties for each station within a weather or climate network. A data inventory may include start/stop dates, percentages of available data, breakdowns by climate element, counts of actual data values, counts or fractions of data types, etc. These properties must be determined by actually reading the data and thus require the data to be available, accessible, and in a readable format.

NPS I&M Network—A set of NPS park units grouped by a common theme, typically by natural resource and/or geographic region.

Metadata—Information necessary to interpret environmental data properly, organized as a history or series of snapshots—data about data. Examples include details of measurement processes, station circumstances and exposures, assumptions about the site, network purpose and background, types of observations and sensors, pre-treatment of data, access information, maintenance history and protocols, observational methods, archive locations, owner, and station start/end period.

Quality Assurance—Planned and systematic set of activities to provide adequate confidence that products and services are resulting in credible and correct information. Includes quality control.

Quality Control—Evaluation, assessment, and improvement of imperfect data by utilizing other imperfect data.

Station Inventory—Information about a set of stations obtained from metadata that accompany the network or networks. A station inventory can be compiled from direct and indirect reports prepared by others.

Weather—Instantaneous state of the atmosphere at any given time, mainly with respect to its effects on biological activities. As distinguished from climate, weather consists of the short-term (minutes to days) variations in the atmosphere. Popularly, weather is thought of in terms of temperature, precipitation, humidity, wind, sky condition, visibility, and cloud conditions.

Weather Element (same as Climate Element)—Attribute or property of the state of the atmosphere that is measured, estimated, or derived. Examples of weather elements include temperature, wind speed, wind direction, precipitation amount, precipitation type, relative humidity, dewpoint, solar radiation, snow depth, soil temperature at a given depth, etc. A derived weather element is a function of other elements (like degree days or number of days with rain) and is not measured directly. The terms “parameter” and “variable” are not used to describe weather elements.

Weather Network—Group of weather stations usually owned and maintained by a particular organization and usually for a specific purpose.

Weather Station—Station where collected data are intended for near-real-time use with less need for reference to long-term conditions. In many cases, the detailed circumstances of a set of measurements (siting and exposure, instrument changes, etc.) from weather stations are not as important as for climate stations.

Appendix B. Climate-monitoring principles

Since the late 1990s, frequent references have been made to a set of climate-monitoring principles enunciated in 1996 by Tom Karl, director of the NOAA NCDC in Asheville, North Carolina. These monitoring principles also have been referred to informally as the "Ten Commandments of Climate Monitoring." Both versions are given here. In addition, these principles have been adopted by the Global Climate Observing System (GCOS 2004).

(Compiled by Kelly Redmond, Western Regional Climate Center, Desert Research Institute, August 2000.)

B.1. Full Version (Karl et al. 1996)

B.1.1. Effects on climate records of instrument changes, observing practices, observation locations, sampling rates, etc., must be known before such changes are implemented. This can be ascertained through a period where overlapping measurements from old and new observing systems are collected or sometimes by comparing the old and new observing systems with a reference standard. Site stability for in situ measurements, both in terms of physical location and changes in the nearby environment, also should be a key criterion in site selection. Thus, many synoptic network stations, which are primarily used in weather forecasting but also provide valuable climate data, and dedicated climate stations intended to be operational for extended periods must be subject to this policy.

B.1.2. Processing algorithms and changes in these algorithms must be well documented. Documentation should be carried with the data throughout the data-archiving process.

B.1.3. Knowledge of instrument, station, and/or platform history is essential for interpreting and using the data. Changes in instrument sampling time, local environmental conditions for in situ measurements, and other factors pertinent to interpreting the observations and measurements should be recorded as a mandatory part in the observing routine and be archived with the original data.

B.1.4. In situ and other observations with a long, uninterrupted record should be maintained. Every effort should be applied to protect the data sets that have provided long-term, homogeneous observations. "Long-term" for space-based measurements is measured in decades, but for more conventional measurements, "long-term" may be a century or more. Each element in the observational system should develop a list of prioritized sites or observations based on their contribution to long-term climate monitoring.

B.1.5. Calibration, validation, and maintenance facilities are critical requirements for long-term climatic data sets. Homogeneity in the climate record must be assessed routinely, and corrective action must become part of the archived record.

B.1.6. Where feasible, some level of "low-technology" backup to "high-technology" observing systems should be developed to safeguard against unexpected operational failures.

B.1.7. Regions having insufficient data, variables and regions sensitive to change, and key

measurements lacking adequate spatial and temporal resolution should be given the highest priority in designing and implementing new climate-observing systems.

B.1.8. Network designers and instrument engineers must receive long-term climate requirements at the outset of the network design process. This is particularly important because most observing systems have been designed for purposes other than long-term climate monitoring. Instruments must possess adequate accuracy with biases small enough to document climate variations and changes.

B.1.9. Much of the development of new observational capabilities and the evidence supporting the value of these observations stem from research-oriented needs or programs. A lack of stable, long-term commitment to these observations and lack of a clear transition plan from research to operations are two frequent limitations in the development of adequate, long-term monitoring capabilities. Difficulties in securing a long-term commitment must be overcome in order to improve the climate-observing system in a timely manner with minimal interruptions.

B.1.10. Data management systems that facilitate access, use, and interpretation are essential. Freedom of access, low cost, mechanisms that facilitate use (directories, catalogs, browse capabilities, availability of metadata on station histories, algorithm accessibility and documentation, etc.) and quality control should guide data management. International cooperation is critical for successful management of data used to monitor long-term climate change and variability.

B.2. Abbreviated version, "Ten Commandments of Climate Monitoring"

B.2.1. Assess the impact of new climate-observing systems or changes to existing systems before they are implemented.

"Thou shalt properly manage network change." (assess effects of proposed changes)

B.2.2. Require a suitable period where measurement from new and old climate-observing systems will overlap.

"Thou shalt conduct parallel testing." (compare old and replacement systems)

B.2.3. Treat calibration, validation, algorithm-change, and data-homogeneity assessments with the same care as the data.

"Thou shalt collect metadata." (fully document system and operating procedures)

B.2.4. Verify capability for routinely assessing the quality and homogeneity of the data including high-resolution data for extreme events.

"Thou shalt assure data quality and continuity." (assess as part of routine operating procedures)

B.2.5. Integrate assessments like those conducted by the International Panel on Climate Change into global climate-observing priorities.

“Thou shalt anticipate the use of data.” (integrated environmental assessment; component in operational plan for system)

B.2.6. Maintain long-term weather and climate stations.

“Thou shalt worship historic significance.” (maintain homogeneous data sets from long–term, climate-observing systems)

B.2.7. Place high priority on increasing observations in regions lacking sufficient data and in regions sensitive to change and variability.

"Thou shalt acquire complementary data." (new sites to fill observational gaps)

B.2.8. Provide network operators, designers, and instrument engineers with long-term requirements at the outset of the design and implementation phases for new systems.

“Thou shalt specify requirements for climate observation systems.” (application and usage of observational data)

B.2.9. Carefully consider the transition from research-observing system to long-term operation.

“Thou shalt have continuity of purpose.” (stable long-term commitments)

B.2.10. Focus on data-management systems that facilitate access, use, and interpretation of weather data and metadata.

“Thou shalt provide access to data and metadata.” (readily available weather and climate information)

B.3. Literature Cited

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Appendix C. Factors in operating a weather/ climate network

C.1. Climate versus Weather

- Climate measurements require *consistency through time.*

C.2. Network Purpose

- Anticipated or desired lifetime.
- Breadth of network mission (commitment by needed constituency).
- Dedicated constituency—no network survives without a dedicated constituency.

C.3. Site Identification and Selection

- Spanning gradients in climate or biomes with transects.
- Issues regarding representative spatial scale—site uniformity versus site clustering.
- Alignment with and contribution to network mission.
- Exposure—ability to measure representative quantities.
- Logistics—ability to service station (Always or only in favorable weather?).
- Site redundancy (positive for quality control, negative for extra resources).
- Power—is AC needed?
- Site security—is protection from vandalism needed?
- Permitting often a major impediment and usually underestimated.

C.4. Station Hardware

- Survival—weather is the main cause of lost weather/climate data.
- Robustness of sensors—ability to measure and record in any condition.
- Quality—distrusted records are worthless and a waste of time and money.
  - High quality—will cost up front but pays off later.
  - Low quality—may provide a lower start-up cost but will cost more later (low cost can be expensive).
- Redundancy—backup if sensors malfunction.
- Ice and snow—measurements are much more difficult than rain measurements.
- Severe environments (expense is about two–three times greater than for stations in more benign settings).

C.5. Communications

- Reliability—live data have a much larger constituency.
- One-way or two-way.
  - Retrieval of missed transmissions.
  - Ability to reprogram data logger remotely.
  - Remote troubleshooting abilities.
  - Continuing versus one-time costs.
- Back-up procedures to prevent data loss during communication outages.
- Live communications increase problems but also increase value.

C.6. Maintenance

- Main reason why networks fail (and most networks do eventually fail!).
- Key issue with nearly every network.
- Who will perform maintenance?
- Degree of commitment and motivation to contribute.
- Periodic? On-demand as needed? Preventive?
- Equipment change-out schedules and upgrades for sensors and software.
- Automated stations require skilled and experienced labor.
- Calibration—sensors often drift (climate).
- Site maintenance essential (constant vegetation, surface conditions, nearby influences).
- Typical automated station will cost about $2K per year to maintain.
- Documentation—photos, notes, visits, changes, essential for posterity.
- Planning for equipment life cycle and technological advances.

C.7. Maintaining Programmatic Continuity and Corporate Knowledge

- Long-term vision and commitment needed.
- Institutionalizing versus personalizing—developing appropriate dependencies.

C.8. Data Flow

- Centralized ingest?
- Centralized access to data and data products?
- Local version available?
- Contract out work or do it yourself?
- Quality control of data.
- Archival.
- Metadata—historic information, not a snapshot. Every station should collect metadata.
- Post-collection processing, multiple data-ingestion paths.

C.9. Products

- Most basic product consists of the data values.
- Summaries.
- Write own applications or leverage existing mechanisms?

C.10. Funding

- Prototype approaches as proof of concept.
- Linking and leveraging essential.
- Constituencies—every network needs a constituency.
- Bridging to practical and operational communities? Live data needed.
- Bridging to counterpart research efforts and initiatives—funding source.
- Creativity, resourcefulness, and persistence usually are essential to success.

C.11. Final Comments

- Deployment is by far the easiest part in operating a network.
- Maintenance is the main issue.
- Best analogy: Operating a network is like raising a child; it requires constant attention.

Source: Western Regional Climate Center (WRCC)

Appendix D. General design considerations for weather/ climate-monitoring programs

The process for designing a climate-monitoring program benefits from anticipating design and protocol issues discussed here. Much of this material is been excerpted from a report addressing the Channel Islands National Park (Redmond and McCurdy 2005), where an example is found illustrating how these factors can be applied to a specific setting. Many national park units possess some climate or meteorology feature that sets them apart from more familiar or "standard" settings.

D.1. Introduction

There are several criteria that must be used in deciding to deploy new stations and where these new stations should be sited.

- Where are existing stations located?
- Where have data been gathered in the past (discontinued locations)?
- Where would a new station fill a knowledge gap about basic, long-term climatic averages for an area of interest?
- Where would a new station fill a knowledge gap about how climate behaves over time?
- As a special case for behavior over time, what locations might be expected to show a more sensitive response to climate change?
- How do answers to the preceding questions depend on the climate element? Are answers the same for precipitation, temperature, wind, snowfall, humidity, etc.?
- What role should manual measurements play? How should manual measurements interface with automated measurements?
- Are there special technical or management issues, either present or anticipated in the next 5–15 years, requiring added climate information?
- What unique information is provided in addition to information from existing sites? "Redundancy is bad."
- What nearby information is available to estimate missing observations because observing systems always experience gaps and lose data? "Redundancy is good."
- How would logistics and maintenance affect these decisions?

In relation to the preceding questions, there are several topics that should be considered. The following topics are not listed in a particular order.

D.1.1. Network Purpose

Humans seem to have an almost reflexive need to measure temperature and precipitation, along with other climate elements. These reasons span a broad range from utilitarian to curiosity-driven. Although there are well-known recurrent patterns of need and data use, new uses are always appearing. The number of uses ranges in the thousands. Attempts have been made to categorize such uses (see NRC 1998; NRC 2001). Because climate measurements are accumulated over a long time, they should be treated as multi-purpose and should be undertaken in a manner that serves the widest possible applications. Some applications remain constant, while others rise and fall in importance. An insistent issue today may subside, while the next pressing issue of tomorrow barely may be anticipated. The notion that humans might affect the

climate of the entire Earth was nearly unimaginable when the national USDA (later NOAA) cooperative weather network began in the late 1800s. Abundant experience has shown, however, that there always will be a demand for a history record of climate measurements and their properties. Experience also shows that there is an expectation that climate measurements will be taken and made available to the general public.

An exhaustive list of uses for data would fill many pages and still be incomplete. In broad terms, however, there are needs to document environmental conditions that disrupt or otherwise affect park operations (e.g., storms and droughts). Design and construction standards are determined by climatological event frequencies that exceed certain thresholds. Climate is a determinant that sometimes attracts and sometimes discourages visitors. Climate may play a large part in the park experience (e.g., Death Valley and heat are nearly synonymous). Some park units are large enough to encompass spatial or elevation diversity in climate and the sequence of events can vary considerably inside or close to park boundaries. That is, temporal trends and statistics may not be the same everywhere, and this spatial structure should be sampled. The granularity of this structure depends on the presence of topography or large climate gradients or both, such as that found along the U.S. West Coast in summer with the rapid transition from the marine layer to the hot interior.

Plant and animal communities and entire ecosystems react to every nuance in the physical environment. No aspect of weather and climate goes undetected in the natural world. Wilson (1998) proposed “an informal rule of biological evolution” that applies here: “If an organic sensor can be imagined that is capable of detecting any particular environmental signal, a species exists somewhere that possesses this sensor.” Every weather and climate event, whether dull or extraordinary to humans, matters to some organism. Dramatic events and creeping incremental change both have consequences to living systems. Extreme events or disturbances can “reset the clock” or “shake up the system” and lead to reverberations that last for years to centuries or longer. Slow change can carry complex nonlinear systems (e.g., any living assemblage) into states where chaotic transitions and new behavior occur. These changes are seldom predictable, typically are observed after the fact, and understood only in retrospect. Climate changes may not be exciting, but as a well-known atmospheric scientist, Mike Wallace, from the University of Washington once noted, “subtle does not mean unimportant.”

Thus, individuals who observe the climate should be able to record observations accurately and depict both rapid and slow changes. In particular, an array of artificial influences easily can confound detection of slow changes. The record as provided can contain both real climate variability (that took place in the atmosphere) and fake climate variability (that arose directly from the way atmospheric changes were observed and recorded). As an example, trees growing near a climate station with an excellent anemometer will make it appear that the wind gradually slowed down over many years. Great care must be taken to protect against sources of fake climate variability on the longer-time scales of years to decades. Processes leading to the observed climate are not stationary; rather these processes draw from probability distributions that vary with time. For this reason, climatic time series do not exhibit statistical stationarity. The implications are manifold. There are no true climatic “normals” to which climate inevitably must return. Rather, there are broad ranges of climatic conditions. Climate does not demonstrate exact repetition but instead continual fluctuation and sometimes approximate repetition. In addition,

there is always new behavior waiting to occur. Consequently, the business of climate monitoring is never finished, and there is no point where we can state confidently that "enough" is known.

D.1.2. Robustness

The most frequent cause for loss of weather data is the weather itself, the very thing we wish to record. The design of climate and weather observing programs should consider the meteorological equivalent of "peaking power" employed by utilities. Because environmental disturbances have significant effects on ecologic systems, sensors, data loggers, and communications networks should be able to function during the most severe conditions that realistically can be anticipated over the next 50–100 years. Systems designed in this manner are less likely to fail under more ordinary conditions, as well as more likely to transmit continuous, quality data for both tranquil and active periods.

D.1.3. Weather versus Climate

For "weather" measurements, pertaining to what is approximately happening here and now, small moves and changes in exposure are not as critical. For "climate" measurements, where values from different points in time are compared, siting and exposure are critical factors, and it is vitally important that the observing circumstances remain essentially unchanged over the duration of the station record.

Station moves can affect different elements to differing degrees. Even small moves of several meters, especially vertically, can affect temperature records. Hills and knolls act differently from the bottoms of small swales, pockets, or drainage channels (Whiteman 2000; Geiger et al. 2003). Precipitation is probably less subject to change with moves of 50–100 m than other elements (that is, precipitation has less intrinsic variation in small spaces) except if wind flow over the gauge is affected.

D.1.4. Physical Setting

Siting and exposure, and their continuity and consistency through time, significantly influence the climate records produced by a station. These two terms have overlapping connotations. We use the term "siting" in a more general sense, reserving the term "exposure" generally for the particular circumstances affecting the ability of an instrument to record measurements that are representative of the desired spatial or temporal scale.

D.1.5. Measurement Intervals

Climatic processes occur continuously in time, but our measurement systems usually record in discrete chunks of time: for example, seconds, hours, or days. These measurements often are referred to as "systematic" measurements. Interval averages may hide active or interesting periods of highly intense activity. Alternatively, some systems record "events" when a certain threshold of activity is exceeded (examples: another millimeter of precipitation has fallen, another kilometer of wind has moved past, the temperature has changed by a degree, a gust higher than 9.9 m/s has been measured). When this occurs, measurements from all sensors are reported. These measurements are known as "breakpoint" data. In relatively unchanging conditions (long calm periods or rainless weeks, for example), event recorders should send a signal that they are still "alive and well." If systematic recorders are programmed to note and periodically report the highest, lowest, and mean value within each time interval, the likelihood

is reduced that interesting behavior will be glossed over or lost. With the capacity of modern data loggers, it is recommended to record and report extremes within the basic time increment (e.g., hourly or 10 minutes). This approach also assists quality-control procedures.

There is usually a trade-off between data volume and time increment, and most automated systems now are set to record approximately hourly. A number of field stations maintained by WRCC are programmed to record in 5- or 10-minute increments, which readily serve to construct an hourly value. However, this approach produces 6–12 times as much data as hourly data. These systems typically do not record details of events at sub-interval time scales, but they easily can record peak values, or counts of threshold exceedance, within the time intervals.

Thus, for each time interval at an automated station, we recommend that several kinds of information—mean or sum, extreme maximum and minimum, and sometimes standard deviation—be recorded. These measurements are useful for quality control and other purposes. Modern data loggers and office computers have quite high capacity. Diagnostic information indicating the state of solar chargers or battery voltages and their extremes is of great value. This topic will be discussed in greater detail in a succeeding section.

Automation also has made possible adaptive or intelligent monitoring techniques where systems vary the recording rate based on detection of the behavior of interest by the software. Sub-interval behavior of interest can be masked on occasion (e.g., a 5-minute extreme downpour with high-erosive capability hidden by an innocuous hourly total). Most users prefer measurements that are systematic in time because they are much easier to summarize and manipulate.

For breakpoint data produced by event reporters, there also is a need to send periodically a signal that the station is still functioning, even though there is nothing more to report. “No report” does not necessarily mean “no data,” and it is important to distinguish between the actual observation that was recorded and the content of that observation (e.g., an observation of “0.00” is not the same as “no observation”).

D.1.6. Mixed Time Scales

There are times when we may wish to combine information from radically different scales. For example, over the past 100 years we may want to know how the frequency of 5-minute precipitation peaks has varied or how the frequency of peak 1-second wind gusts have varied. We may also want to know over this time if nearby vegetation gradually has grown up to increasingly block the wind or to slowly improve precipitation catch. Answers to these questions require knowledge over a wide range of time scales.

D.1.7. Elements

For manual measurements, the typical elements recorded included temperature extremes, precipitation, and snowfall/snow depth. Automated measurements typically include temperature, precipitation, humidity, wind speed and direction, and solar radiation. An exception to this exists in very windy locations where precipitation is difficult to measure accurately. Automated measurements of snow are improving, but manual measurements are still preferable, as long as shielding is present. Automated measurement of frozen precipitation presents numerous challenges that have not been resolved fully, and the best gauges are quite expensive ($3–8K).

Soil temperatures also are included sometimes. Soil moisture is extremely useful, but measurements are not made at many sites. In addition, care must be taken in the installation and maintenance of instruments used in measuring soil moisture. Soil properties vary tremendously in short distances as well, and it is often very difficult ("impossible") to accurately document these variations (without digging up all the soil!). In cooler climates, ultrasonic sensors that detect snow depth are becoming commonplace.

D.1.8. Wind Standards

Wind varies the most in the shortest distance, since it always decreases to zero near the ground and increases rapidly (approximately logarithmically) with height near the ground. Changes in anemometer height obviously will affect distribution of wind speed as will changes in vegetation, obstructions such as buildings, etc. A site that has a 3-m (10-ft) mast clearly will be less windy than a site that has a 6-m (20-ft) or 10-m (33-ft) mast. Historically, many U.S. airports (FAA and NWS) and most current RAWS sites have used a standard 6-m (20-ft) mast for wind measurements. Some NPS RAWS sites utilize shorter masts. Over the last decade, as Automated Surface Observing Systems (ASOSs, mostly NWS) and Automated Weather Observing Systems (AWOSs, mostly FAA) have been deployed at most airports, wind masts have been raised to 8 or 10 m (26 or 33 ft), depending on airplane clearance. The World Meteorological Organization recommends 10 m as the height for wind measurements (WMO 1983; 2005), and more groups are migrating slowly to this standard. The American Association of State Climatologists (AASC 1985) have recommended that wind be measured at 3 m, a standard geared more for agricultural applications than for general purpose uses where higher levels usually are preferred. Different anemometers have different starting thresholds; therefore, areas that frequently experience very light winds may not produce wind measurements thus affecting long-term mean estimates of wind speed. For both sustained winds (averages over a short interval of 2–60 minutes) and especially for gusts, the duration of the sampling interval makes a considerable difference. For the same wind history, 1–second gusts are higher than gusts averaging 3 seconds, which in turn are greater than 5-second averages, so that the same sequence would be described with different numbers (all three systems and more are in use). Changes in the averaging procedure, or in height or exposure, can lead to "false" or "fake" climate change with no change in actual climate. Changes in any of these should be noted in the metadata.

D.1.9. Wind Nomenclature

Wind is a vector quantity having a direction and a speed. Directions can be two- or three-dimensional; they will be three-dimensional if the vertical component is important. In all common uses, winds always are denoted by the direction they blow *from* (north wind or southerly breeze). This convention exists because wind often brings weather, and thus our attention is focused upstream. However, this approach contrasts with the way ocean currents are viewed. Ocean currents usually are denoted by the direction they are moving *towards* (eastward current moves from west to east). In specialized applications (such as in atmospheric modeling), wind velocity vectors point in the direction that the wind is blowing. Thus, a southwesterly wind (from the southwest) has both northward and eastward (to the north and to the east) components. Except near mountains, wind cannot blow up or down near the ground, so the vertical component of wind often is approximated as zero, and the horizontal component is emphasized.

D.1.10. Frozen Precipitation

Frozen precipitation is more difficult to measure than liquid precipitation, especially with automated techniques. Sevruk and Harmon (1984), Goodison et al. (1998), and Yang et al. (1998; 2001) provide many of the reasons to explain this. The importance of frozen precipitation varies greatly from one setting to another. This subject was discussed in greater detail in a related inventory and monitoring report for the Alaska park units (Redmond et al. 2005).

In climates that receive frozen precipitation, a decision must be made whether or not to try to record such events accurately. This usually means that the precipitation must be turned into liquid either by falling into an antifreeze fluid solution that is then weighed or by heating the precipitation enough to melt and fall through a measuring mechanism such as a nearly-balanced tipping bucket. Accurate measurements from the first approach require expensive gauges; tipping buckets can achieve this resolution readily but are more apt to lose some or all precipitation. Improvements have been made to the heating mechanism on the NWS tipping-bucket gauge used for the ASOS to correct its numerous deficiencies making it less problematic; however, this gauge is not inexpensive. A heat supply needed to melt frozen precipitation usually requires more energy than renewable energy (solar panels or wind recharging) can provide thus AC power is needed. Periods of frozen precipitation or rime often provide less-than-optimal recharging conditions with heavy clouds, short days, low-solar-elevation angles and more horizon blocking, and cold temperatures causing additional drain on the battery.

D.1.11. Save or Lose

A second consideration with precipitation is determining if the measurement should be saved (as in weighing systems) or lost (as in tipping-bucket systems). With tipping buckets, after the water has passed through the tipping mechanism, it usually just drops to the ground. Thus, there is no checksum to ensure that the sum of all the tips adds up to what has been saved in a reservoir at some location. By contrast, the weighing gauges continually accumulate until the reservoir is emptied, the reported value is the total reservoir content (for example, the height of the liquid column in a tube), and the incremental precipitation is the difference in depth between two known times. These weighing gauges do not always have the same fine resolution. Some gauges only record to the nearest centimeter, which is usually acceptable for hydrology but not necessarily for other needs. (For reference, a millimeter of precipitation can get a person in street clothes quite wet.) Other weighing gauges are capable of measuring to the 0.25-mm (0.01-in.) resolution but do not have as much capacity and must be emptied more often. Day/night and storm-related thermal expansion and contraction and sometimes wind shaking can cause fluid pressure from accumulated totals to go up and down by small increments, leading to “negative precipitation” followed by similarly non-real light precipitation when, in fact, no change took place in the amount of accumulated precipitation.

D.1.12. Time

Time should always be in local standard time (LST), and daylight savings time (DST) should never be used under any circumstances with automated equipment and timers. Using DST leads to one duplicate hour, one missing hour, and a season of displaced values, as well as needless confusion and a data-management nightmare. Absolute time, such as Greenwich Mean Time (GMT) or Coordinated Universal Time (UTC), also can be used because these formats are unambiguously translatable. Since measurements only provide information about what already

has occurred or *is* occurring and not what *will* occur, they should always be assigned to the *ending time* of the associated interval with hour 24 marking the end of the last hour of the day. In this system, midnight always represents the end of the day, not the start. To demonstrate the importance of this differentiation, we have encountered situations where police officers seeking corroborating weather data could not recall whether the time on their crime report from a year ago was the starting midnight or the ending midnight! Station positions should be known to within a few meters, easily accomplished with GPS, so that time zones and solar angles can be determined accurately.

D.1.13. Automated versus Manual

Most of this report has addressed automated measurements. Historically, most measurements are manual and typically collected once a day. In many cases, manual measurements continue because of habit, usefulness, and desire for continuity over time. Manual measurements are extremely useful and when possible should be encouraged. However, automated measurements are becoming more common. For either, it is important to record time in a logically consistent manner.

It should not be automatically assumed that newer data and measurements are "better" than older data or that manual data are "worse" than automated data. Older or simpler manual measurements are often of very high quality even if they sometimes are not in the most convenient digital format.

There is widespread desire to use automated systems to reduce human involvement. This is admirable and understandable, but every automated weather/climate station or network requires significant human attention and maintenance. A telling example concerns the Oklahoma Mesonet (see Brock et al. 1995, and bibliography at http://www.mesonet.ou.edu), a network of about 115 high–quality, automated meteorological stations spread over Oklahoma, where about 80 percent of the annual ($2–3M) budget is nonetheless allocated to humans with only about 20 percent allocated to equipment.

D.1.14. Manual Conventions

Manual measurements typically are made once a day. Elements usually consist of maximum and minimum temperature, temperature at observation time, precipitation, snowfall, snow depth, and sometimes evaporation, wind, or other information. Since it is not actually known when extremes occurred, the only logical approach, and the nationwide convention, is to ascribe the entire measurement to the time-interval date and to enter it on the form in that way. For morning observers (for example, 8 am to 8 am), this means that the maximum temperature written for today often is from yesterday afternoon and sometimes the minimum temperature for the 24-hr period actually occurred yesterday morning. However, this is understood and expected. It is often a surprise to observers to see how many maximum temperatures do not occur in the afternoon and how many minimum temperatures do not occur in the predawn hours. This is especially true in environments that are colder, higher, northerly, cloudy, mountainous, or coastal. As long as this convention is strictly followed every day, it has been shown that truly excellent climate records can result (Redmond 1992). Manual observers should reset equipment only one time per day at the official observing time. Making more than one measurement a day is discouraged strongly; this practice results in a hybrid record that is too difficult to interpret. The only

exception is for total daily snowfall. New snowfall can be measured up to four times per day with no observations closer than six hours. It is well known that more frequent measurement of snow increases the annual total because compaction is a continuous process.

Two main purposes for climate observations are to establish the long-term averages for given locations and to track variations in climate. Broadly speaking, these purposes address topics of absolute and relative climate behavior. Once absolute behavior has been "established" (a task that is never finished because long-term averages continue to vary in time)—temporal variability quickly becomes the item of most interest.

D.2. Representativeness

Having discussed important factors to consider when new sites are installed, we now turn our attention to site "representativeness." In popular usage, we often encounter the notion that a site is "representative" of another site if it receives the same annual precipitation or records the same annual temperature or if some other element-specific, long-term average has a similar value. This notion of representativeness has a certain limited validity, but there are other aspects of this idea that need to be considered.

A climate monitoring site also can be said to be representative if climate records from that site show sufficiently strong temporal correlations with a large number of locations over a sufficiently large area. If station A receives 20 cm a year and station B receives 200 cm a year, these climates obviously receive quite differing amounts of precipitation. However, if their monthly, seasonal, or annual correlations are high (for example, 0.80 or higher for a particular time scale), one site can be used as a surrogate for estimating values at the other if measurements for a particular month, season, or year are missing. That is, a wet or dry month at one station is also a wet or dry month (relative to its own mean) at the comparison station. Note that high correlations on one time scale do not imply automatically that high correlations will occur on other time scales.

Likewise, two stations having similar mean climates (for example, similar annual precipitation) might not co-vary in close synchrony (for example, coastal versus interior). This may be considered a matter of climate "affiliation" for a particular location.

Thus, the representativeness of a site can refer either to the basic climatic averages for a given duration (or time window within the annual cycle) or to the extent that the site co-varies in time with respect to all surrounding locations. One site can be representative of another in the first sense but not the second, or vice versa, or neither, or both—all combinations are possible.

If two sites are perfectly correlated then, in a sense, they are "redundant." However, redundancy has value because all sites will experience missing data especially with automated equipment in rugged environments and harsh climates where outages and other problems nearly can be guaranteed. In many cases, those outages are caused by the weather, particularly by unusual weather and the very conditions we most wish to know about. Methods for filling in those values will require proxy information from this or other nearby networks. Thus, redundancy is a virtue rather than a vice.

In general, the cooperative stations managed by the NWS have produced much longer records than automated stations like RAWS stations. The RAWS stations often have problems with precipitation or with missing data, so that low correlations may be data problems rather than climatic dissimilarity. The RAWS records also are relatively short, so correlations should be interpreted with care. In performing and interpreting such analyses, however, we must remember that there are physical climate reasons and observational reasons why stations within a short distance (even a few tens or hundreds of meters) may not correlate well.

D.2.1. Temporal Behavior

It is possible that high correlations will occur between station pairs during certain portions of the year (i.e., January) but low correlations may occur during other portions of the year (e.g., September or October). The relative contributions of these seasons to the annual total (for precipitation) or average (for temperature) and the correlations for each month are both factors in the correlation of an aggregated time window of longer duration that encompasses those seasons (e.g., one of the year definitions such as calendar year or water year). A complete and careful evaluation ideally would include such a correlation analysis but requires more resources and data. Note that it also is possible and frequently is observed that temperatures are highly correlated while precipitation is not or vice versa, and these relations can change according to the time of year. If two stations are well correlated for all climate elements for all portions of the year, then they can be considered redundant.

With scarce resources, the initial strategy should be to try to identify locations that do not correlate particularly well, so that each new site measures something new that cannot be guessed easily from the behavior of surrounding sites. (An important caveat here is that lack of such correlation could be a result of physical climate behavior and not a result of faults with the actual measuring process; i.e., by unrepresentative or simply poor-quality data. Unfortunately, we seldom have perfect climate data.) As additional sites are added, we usually wish for some combination of unique and redundant sites to meet what amounts to essentially orthogonal constraints: new information and more reliably-furnished information.

A common consideration is whether to observe on a ridge or in a valley, given the resources to place a single station within a particular area of a few square kilometers. Ridge and valley stations will correlate very well for temperatures when lapse conditions prevail, particularly summer daytime temperatures. In summer at night or winter at daylight, the picture will be more mixed and correlations will be lower. In winter at night when inversions are common and even the rule, correlations may be zero or even negative and perhaps even more divergent as the two sites are on opposite sides of the inversion. If we had the luxury of locating stations everywhere, we would find that ridge tops generally correlate very well with other ridge tops and similarly valleys with other valleys, but ridge tops correlate well with valleys only under certain circumstances. Beyond this, valleys and ridges having similar orientations usually will correlate better with each other than those with perpendicular orientations, depending on their orientation with respect to large-scale wind flow and solar angles.

Unfortunately, we do not have stations everywhere, so we are forced to use the few comparisons that we have and include a large dose of intelligent reasoning, using what we have observed elsewhere. In performing and interpreting such analyses, we must remember that there are

physical climatic reasons and observational reasons why stations within a short distance (even a few tens or hundreds of meters) may not correlate well.

Examples of correlation analyses include those for the Channel Islands and for southwest Alaska, which can be found in Redmond and McCurdy (2005) and Redmond et al. (2005). These examples illustrate what can be learned from correlation analyses. Spatial correlations generally vary by time of year. Thus, results should be displayed in the form of annual correlation cycles—for monthly mean temperature and monthly total precipitation and perhaps other climate elements like wind or humidity—between station pairs selected for climatic setting and data availability and quality.

In general, the COOP stations managed by the NWS have produced much longer records than have automated stations like RAWS stations. The RAWS stations also often have problems with precipitation, especially in winter or with missing data, so that low correlations may be data problems rather than climate dissimilarity. The RAWS records are much shorter, so correlations should be interpreted with care, but these stations are more likely to be in places of interest for remote or under-sampled regions.

D.2.2. Spatial Behavior

A number of techniques exist to interpolate from isolated point values to a spatial domain. For example, a common technique is simple inverse distance weighting. Critical to the success of the simplest of such techniques is that some other property of the spatial domain, one that is influential for the mapped element, does not vary significantly. Topography greatly influences precipitation, temperature, wind, humidity, and most other meteorological elements. Thus, this criterion clearly is not met in any region having extreme topographic diversity. In such circumstances, simple Cartesian distance may have little to do with how rapidly correlation deteriorates from one site to the next, and in fact, the correlations can decrease readily from a mountain to a valley and then increase again on the next mountain. Such structure in the fields of spatial correlation is not seen in the relatively (statistically) well-behaved flat areas like those in the eastern U.S.

To account for dominating effects such as topography and inland–coastal differences that exist in certain regions, some kind of additional knowledge must be brought to bear to produce meaningful, physically plausible, and observationally based interpolations. Historically, this has proven to be an extremely difficult problem, especially to perform objective and repeatable analyses. An analysis performed for southwest Alaska (Redmond et al. 2005) concluded that the PRISM (Parameter Regression on Independent Slopes Model) maps (Daly et al. 1994; Daly et al. 2002; Gibson et al. 2002; Doggett et al. 2004) were probably the best available. An analysis by Simpson et al. (2005) further discussed many issues in the mapping of Alaska's climate and resulted in the same conclusion about PRISM.

D.2.3. Climate-Change Detection

Although general purpose climate stations should be situated to address all aspects of climate variability, it is desirable that they also be in locations that are more sensitive to climate change from natural or anthropogenic influences should it begin to occur. The question here is how well

we know such sensitivities. The climate-change issue is quite complex because it encompasses more than just greenhouse gasses.

Sites that are in locations or climates particularly vulnerable to climate change should be favored. How this vulnerability is determined is a considerably challenging research issue. Candidate locations or situations are those that lie on the border between two major biomes or just inside the edge of one or the other. In these cases, a slight movement of the boundary in anticipated direction (toward "warmer," for example) would be much easier to detect as the boundary moves past the site and a different set of biota begin to be established. Such a vegetative or ecologic response would be more visible and would take less time to establish as a real change than would a smaller change in the center of the distribution range of a marker or key species.

D.2.4. Element-Specific Differences

The various climate elements (temperature, precipitation, cloudiness, snowfall, humidity, wind speed and direction, solar radiation) do not vary through time in the same sequence or manner nor should they necessarily be expected to vary in this manner. The spatial patterns of variability should not be expected to be the same for all elements. These patterns also should not be expected to be similar for all months or seasons. The suitability of individual sites for measurement also varies from one element to another. A site that has a favorable exposure for temperature or wind may not have a favorable exposure for precipitation or snowfall. A site that experiences proper air movement may be situated in a topographic channel, such as a river valley or a pass, which restricts the range of wind directions and affects the distribution of speed-direction categories.

D.2.5. Logistics and Practical Factors

Even with the most advanced scientific rationale, sites in some remote or climatically challenging settings may not be suitable because of the difficulty in servicing and maintaining equipment. Contributing to these challenges are scheduling difficulties, animal behavior, snow burial, icing, snow behavior, access and logistical problems, and the weather itself. Remote and elevated sites usually require far more attention and expense than a rain-dominated, easily accessible valley location.

For climate purposes, station exposure and the local environment should be maintained in their original state (vegetation especially), so that changes seen are the result of regional climate variations and not of trees growing up, bushes crowding a site, surface albedo changing, fire clearing, etc. Repeat photography has shown many examples of slow environmental change in the vicinity of a station in rather short time frames (5–20 years), and this technique should be employed routinely and frequently at all locations. In the end, logistics, maintenance, and other practical factors almost always determine the success of weather- and climate-monitoring activities.

D.2.6. Personnel Factors

Many past experiences (almost exclusively negative) strongly support the necessity to place primary responsibility for station deployment and maintenance in the hands of seasoned, highly qualified, trained, and meticulously careful personnel, the more experienced the better. Over

time, even in “benign” climates but especially where harsher conditions prevail, every conceivable problem will occur and both the usual and unusual should be anticipated: weather, animals, plants, salt, sensor and communication failure, windblown debris, corrosion, power failures, vibrations, avalanches, snow loading and creep, corruption of the data logger program, etc. An ability to anticipate and forestall such problems, a knack for innovation and improvisation, knowledge of electronics, practical and organizational skills, and presence of mind to bring the various small but vital parts, spares, tools, and diagnostic troubleshooting equipment are highly valued qualities. Especially when logistics are so expensive, a premium should be placed on using experienced personnel, since the slightest and seemingly most minor mistake can render a station useless or, even worse, uncertain. Exclusive reliance on individuals without this background can be costly and almost always will result eventually in unnecessary loss of data. Skilled labor and an apprenticeship system to develop new skilled labor will greatly reduce (but not eliminate) the types of problems that can occur in operating a climate network.

D.3. Site Selection

In addition to considerations identified previously in this appendix, various factors need to be considered in selecting sites for new or augmented instrumentation.

D.3.1. Equipment and Exposure Factors

D.3.1.1. Measurement Suite: All sites should measure temperature, humidity, wind, solar radiation, and snow depth. Precipitation measurements are more difficult but probably should be attempted with the understanding that winter measurements may be of limited or no value unless an all-weather gauge has been installed. Even if an all-weather gauge has been installed, it is desirable to have a second gauge present that operates on a different principle–for example, a fluid-based system in tandem with a higher–resolution, tipping bucket gauge for summertime. Without heating, a tipping bucket gauge usually is of use only when temperatures are above freezing and when temperatures have not been below freezing for some time, so that accumulated ice and snow is not melting and being recorded as present precipitation. Gauge undercatch is a significant issue in snowy climates, so shielding should be considered for all gauges designed to work over the winter months. It is very important to note the presence or absence of shielding, the type of shielding, and the dates of installation or removal of the shielding.

D.3.1.2. Overall Exposure: The ideal, general all-purpose site has gentle slopes, is open to the sun and the wind, has a natural vegetative cover, avoids strong local (less than 200 m) influences, and represents a reasonable compromise among all climate elements. The best temperature sites are not the best precipitation sites, and the same is true for other elements. Steep topography in the immediate vicinity should be avoided unless settings where precipitation is affected by steep topography are being deliberately sought or a mountaintop or ridgeline is the desired location. The potential for disturbance should be considered: fire and flood risk, earth movement, wind-borne debris, volcanic deposits or lahars, vandalism, animal tampering, and general human encroachment are all factors.

D.3.1.3. Elevation: Mountain climates do not vary in time in exactly the same manner as adjoining valley climates. This concept is emphasized when temperature inversions are present to a greater degree and during precipitation when winds rise up the slopes at the same angle.

There is considerable concern that mountain climates will be (or already are) changing and perhaps changing differently than lowland climates, which has direct and indirect consequences for plant and animal life in the more extreme zones. Elevations of special significance are those that are near the mean rain/snow line for winter, near the tree line, and near the mean annual freezing level (all of these may not be quite the same). Because the lapse rates in wet climates often are nearly moist-adiabatic during the main precipitation seasons, measurements at one elevation may be extrapolated to nearby elevations. In drier climates and in the winter, temperature and to a lesser extent wind will show various elevation profiles.

D.3.1.4. Transects: The concept of observing transects that span climatic gradients is sound. This is not always straightforward in topographically uneven terrain, but these transects could still be arranged by setting up station(s) along the coast; in or near passes atop the main coastal interior drainage divide; and inland at one, two, or three distances into the interior lowlands. Transects need not—and by dint of topographic constraints probably cannot—be straight lines, but the closer that a line can be approximated the better. The main point is to systematically sample the key points of a behavioral transition without deviating too radically from linearity.

D.3.1.5. Other Topographic Considerations: There are various considerations with respect to local topography. Local topography can influence wind (channeling, upslope/downslope, etc.), precipitation (orographic enhancement, downslope evaporation, catch efficiency, etc.), and temperature (frost pockets, hilltops, aspect, mixing or decoupling from the overlying atmosphere, bowls, radiative effects, etc.), to different degrees at differing scales. In general, for measurements to be areally representative, it is better to avoid these local effects to the extent that they can be identified before station deployment (once deployed, it is desirable not to move a station). The primary purpose of a climate-monitoring network should be to serve as an infrastructure in the form of a set of benchmark stations for comparing other stations. Sometimes, however, it is exactly these local phenomena that we want to capture. Living organisms, especially plants, are affected by their immediate environment, whether it is representative of a larger setting or not. Specific measurements of limited scope and duration made for these purposes then can be tied to the main benchmarks. This experience is useful also in determining the complexity needed in the benchmark monitoring process in order to capture particular phenomena at particular space and time scales.

Sites that drain (cold air) well generally are better than sites that allow cold air to pool. Slightly sloped areas (1 degree is fine) or small benches from tens to hundreds of meters above streams are often favorable locations. Furthermore, these sites often tend to be out of the path of hazards (like floods) and to have rocky outcroppings where controlling vegetation will not be a major concern. Benches or wide spots on the rise between two forks of a river system are often the only flat areas and sometimes jut out to give greater exposure to winds from more directions.

D.3.1.6. Prior History: The starting point in designing a program is to determine what kinds of observations have been collected over time, by whom, in what manner, and if these observation are continuing to the present time. It also may be of value to “re-occupy” the former site of a station that is now inactive to provide some measure of continuity or a reference point from the past. This can be of value even if continuous observations were not made during the entire intervening period.

D.3.2. Element-Specific Factors

D.3.2.1. Temperature: An open exposure with uninhibited air movement is the preferred setting. The most common measurement is made at approximately eye level, 1.5–2.0 m. In snowy locations sensors should be at least one meter higher than the deepest snowpack expected in the next 50 years or perhaps 2–3 times the depth of the average maximum annual depth. Sensors should be shielded above and below from solar radiation (bouncing off snow), from sunrise/sunset horizontal input, and from vertical rock faces. Sensors should be clamped tightly, so that they do not swivel away from level stacks of radiation plates. Nearby vegetation should be kept away from the sensors (several meters). Growing vegetation should be cut to original conditions. Small hollows and swales can cool tremendously at night, and it is best avoid these areas. Side slopes of perhaps a degree or two of angle facilitate air movement and drainage and, in effect, sample a large area during nighttime hours. The very bottom of a valley should be avoided. Temperature can change substantially from moves of only a few meters. Situations have been observed where flat and seemingly uniform conditions (like airport runways) appear to demonstrate different climate behaviors over short distances of a few tens or hundreds of meters (differences of 5–10°C). When snow is on the ground, these microclimatic differences can be stronger, and differences of 2–5°C can occur in the short distance between the thermometer and the snow surface on calm evenings.

D.3.2.2. Precipitation (liquid): Calm locations with vegetative or artificial shielding are preferred. Wind will adversely impact readings; therefore, the less the better. Wind effects on precipitation are far less for rain than for snow. Devices that "save" precipitation present advantages, but most gauges are built to dump precipitation as it falls or to empty periodically. Automated gauges give both the amount and the timing. Simple backups that record only the total precipitation since the last visit have a certain advantage (for example, storage gauges or lengths of PVC pipe perhaps with bladders on the bottom). The following question should be asked: Does the total precipitation from an automated gauge add up to the measured total in a simple bucket (evaporation is prevented with an appropriate substance such as mineral oil)? Drip from overhanging foliage and trees can augment precipitation totals.

D.3.2.3. Precipitation (frozen): Calm locations or shielding are a must. Undercatch for rain is only about 5 percent, but with winds of only 2–4 m/s, gauges may catch only 30–70 percent of the actual snow falling depending on density of the flakes. To catch 100 percent of the snow, the standard configuration for shielding is employed by the CRN (Climate Reference Network): the DFIR (Double-Fence Intercomparison Reference) shield with 2.4-m (8-ft.) vertical, wooden slatted fences in two concentric octagons with diameters of 8 m and 4 m (26 ft and 13 ft, respectively) and an inner Alter shield (flapping vanes). Numerous tests have shown this is the only way to achieve complete catch of snowfall (e.g., Yang et al. 1998; 2001). The DFIR shield is large and bulky; it is recommended that all precipitation gauges have at least Alter shields on them.

Near oceans, much snow is heavy and falls more vertically. In colder locations or storms, light flakes frequently will fly in and then out of the gauge. Clearings in forests are usually excellent sites. Snow blowing from trees that are too close can augment actual precipitation totals. Artificial shielding (vanes, etc.) placed around gauges in snowy locales always should be used if

accurate totals are desired. Moving parts tend to freeze up. Capping of gauges during heavy snowfall events is a common occurrence. When the cap becomes pointed, snow falls off to the ground and is not recorded. Caps and plugs often will not fall into the tube until hours, days, or even weeks have passed, typically during an extended period of freezing temperature or above or when sunlight finally occurs. Liquid-based measurements do not have the resolution (usually 0.3 cm [0.1 in.] rather than 0.03 cm [0.01 in.]) that tipping bucket and other gauges have but are known to be reasonably accurate in very snowy climates. Light snowfall events might not be recorded until enough of them add up to the next reporting increment. More expensive gauges like Geonors can be considered and could do quite well in snowy settings; however, they need to be emptied every 40 cm (15 in.) or so (capacity of 51 cm [20 in.]) until the new 91-cm (36-in.) capacity gauge is offered for sale. Recently, the NWS has been trying out the new (and very expensive) Ott all-weather gauge. Riming can be an issue in windy foggy environments below freezing. Rime, dew, and other forms of atmospheric condensation are not real precipitation, since they are caused by the gauge.

D.3.2.4. Snow Depth: Windswept areas tend to be blown clear of snow. Conversely, certain types of vegetation can act as a snow fence and cause artificial drifts. However, some amount of vegetation in the vicinity generally can help slow down the wind. The two most common types of snow-depth gauges are the Judd Snow Depth Sensor, produced by Judd Communications, and the snow depth gauge produced by Campbell Scientific, Inc. Opinions vary on which one is better. These gauges use ultrasound and look downward in a cone about 22 degrees in diameter. The ground should be relatively clear of vegetation and maintained in a manner so that the zero point on the calibration scale does not change.

D.3.2.5. Snow Water Equivalent: This is determined by the weight of snow on fluid-filled pads about the size of a desktop set up sometimes in groups of four or in larger hexagons several meters in diameter. These pads require flat ground some distance from nearby sources of windblown snow and shielding that is “just right”: not too close to the shielding to act as a kind of snow fence and not too far from the shielding so that blowing and drifting become a factor. Generally, these pads require fluids that possess antifreeze-like properties, as well as handling and replacement protocols.

D.3.2.6. Wind: Open exposures are needed for wind measurements. Small prominences or benches without blockage from certain sectors are preferred. A typical rule for trees is to site stations back 10 tree-heights from all tree obstructions. Sites in long, narrow valleys can obviously only exhibit two main wind directions. Gently rounded eminences are more favored. Any kind of topographic steering should be avoided to the extent possible. Avoiding major mountain chains or single isolated mountains or ridges is usually a favorable approach, if there is a choice. Sustained wind speed and the highest gusts (1-second) should be recorded. Averaging methodologies for both sustained winds and gusts can affect climate trends and should be recorded as metadata with all changes noted. Vegetation growth affects the vertical wind profile, and growth over a few years can lead to changes in mean wind speed even if the “real” wind does not change, so vegetation near the site (perhaps out to 50 m) should be maintained in a quasi-permanent status (same height and spatial distribution). Wind devices can rime up and freeze or spin out of balance. In severely rimed or windy climates, rugged anemometers, such as those made by Taylor, are worth considering. These anemometers are expensive but durable and

can withstand substantial abuse. In exposed locations, personnel should plan for winds to be at least 50 m/s and be able to measure these wind speeds. At a minimum, anemometers should be rated to 75 m/s.

D.3.2.7. Humidity: Humidity is a relatively straightforward climate element. Close proximity to lakes or other water features can affect readings. Humidity readings typically are less accurate near 100 percent and at low humidities in cold weather.

D.3.2.8. Solar Radiation: A site with an unobstructed horizon obviously is the most desirable. This generally implies a flat plateau or summit. However, in most locations trees or mountains will obstruct the sun for part of the day.

D.3.2.9. Soil Temperature: It is desirable to measure soil temperature at locations where soil is present. If soil temperature is recorded at only a single depth, the most preferred depth is 10 cm. Other common depths include 25 cm, 50 cm, 2 cm, and 100 cm. Biological activity in the soil will be proportional to temperature with important threshold effects occurring near freezing.

D.3.2.10. Soil Moisture: Soil-moisture gauges are somewhat temperamental and require care to install. The soil should be characterized by a soil expert during installation of the gauge. The readings may require a certain level of experience to interpret correctly. If accurate, readings of soil moisture are especially useful.

D.3.2.11. Distributed Observations: It can be seen readily that compromises must be struck among the considerations described in the preceding paragraphs because some are mutually exclusive.

How large can a “site” be? Generally, the equipment footprint should be kept as small as practical with all components placed next to each other (within less than 10–20 m or so). Readings from one instrument frequently are used to aid in interpreting readings from the remaining instruments.

What is a tolerable degree of separation? Some consideration may be given to locating a precipitation gauge or snow pillow among protective vegetation, while the associated temperature, wind, and humidity readings would be collected more effectively in an open and exposed location within 20–50 m. Ideally, it is advantageous to know the wind measurement precisely at the precipitation gauge, but a compromise involving a short split, and in effect a “distributed observation,” could be considered. There are no definitive rules governing this decision, but it is suggested that the site footprint be kept within approximately 50 m. There also are constraints imposed by engineering and electrical factors that affect cable lengths, signal strength, and line noise; therefore, the shorter the cable the better. Practical issues include the need to trench a channel to outlying instruments or to allow lines to lie atop the ground and associated problems with animals, humans, weathering, etc. Separating a precipitation gauge up to 100 m or so from an instrument mast may be an acceptable compromise if other factors are not limiting.

D.3.2.12. Instrument Replacement Schedules: Instruments slowly degrade, and a plan for replacing them with new, refurbished, or recalibrated instruments should be in place. After approximately five years, a systematic change-out procedure should result in replacing most sensors in a network. Certain parts, such as solar radiation sensors, are candidates for annual calibration or change-out. Anemometers tend to degrade as bearings erode or electrical contacts become uneven. Noisy bearings are an indication, and a stethoscope might aid in hearing such noises. Increased internal friction affects the threshold starting speed; once spinning, they tend to function properly. Increases in starting threshold speeds can lead to more zero-wind measurements and thus reduce the reported mean wind speed with no real change in wind properties. A field calibration kit should be developed and taken on all site visits, routine or otherwise. Rain gauges can be tested with drip testers during field visits. Protective conduit and tight water seals can prevent abrasion and moisture problems with the equipment, although seals can keep moisture in as well as out. Bulletproof casings sometimes are employed in remote settings. A supply of spare parts, at least one of each and more for less-expensive or more-delicate sensors, should be maintained to allow replacement of worn or nonfunctional instruments during field visits. In addition, this approach allows instruments to be calibrated in the relative convenience of the operational home—the larger the network, the greater the need for a parts depot.

D.3.3. Long-Term Comparability and Consistency

D.3.3.1. Consistency: The emphasis here is to hold biases constant. Every site has biases, problems, and idiosyncrasies of one sort or another. The best rule to follow is simply to try to keep biases constant through time. Since the goal is to track climate through time, keeping sensors, methodologies, and exposure constant will ensure that only true climate change is being measured. This means leaving the site in its original state or performing maintenance to keep it that way. Once a site is installed, the goal should be to never move the site even by a few meters or to allow significant changes to occur within 100 m for the next several decades.

Sites in or near rock outcroppings likely will experience less vegetative disturbance or growth through the years and will not usually retain moisture, a factor that could speed corrosion. Sites that will remain locally similar for some time are usually preferable. However, in some cases the intent of a station might be to record the local climate effects of changes within a small-scale system (for example, glacier, recently burned area, or scene of some other disturbance) that is subject to a regional climate influence. In this example, the local changes might be much larger than the regional changes.

D.3.3.2. Metadata: Since the climate of every site is affected by features in the immediate vicinity, it is vital to record this information over time and to update the record repeatedly at each service visit. Distances, angles, heights of vegetation, fine-scale topography, condition of instruments, shielding discoloration, and other factors from within a meter to several kilometers should be noted. Systematic photography should be undertaken and updated at least once every one–two years.

Photographic documentation should be taken at each site in a standard manner and repeated every two–three years. Guidelines for methodology were developed by Redmond (2004) as a

result of experience with the NOAA CRN and can be found on the WRCC NPS Web pages at http://www.wrcc.dri.edu/nps and at ftp://ftp.wrcc.dri.edu/nps/photodocumentation.pdf.

The main purpose for climate stations is to *track climatic conditions through time*. Anything that affects the interpretation of records through time must to be noted and recorded for posterity. The important factors should be clear to a person who has never visited the site, no matter how long ago the site was installed.

In regions with significant, climatic transition zones, transects are an efficient way to span several climates and make use of available resources. Discussions on this topic at greater detail can be found in Redmond and Simeral (2004) and in Redmond et al. (2005).

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Appendix E. Master metadata field list

Field Name	Field Type	Field Description
begin_date	date	Effective beginning date for a record.
begin_date_flag	char(2)	Flag describing the known accuracy of the begin date for a station.
best_elevation	float(4)	Best known elevation for a station (in feet).
clim_div_code	char(2)	Foreign key defining climate division code (primary in table: clim_div).
clim_div_key	int2	Foreign key defining climate division for a station (primary in table: clim_div.
clim_div_name	varchar(30)	English name for a climate division.
controller_info	varchar(50)	Person or organization who maintains the identifier system for a given weather or climate network.
country_key	int2	Foreign key defining country where a station resides (primary in table: none).
county_key	int2	Foreign key defining county where a station resides (primary in table: county).
county_name	varchar(31)	English name for a county.
description	text	Any description pertaining to the particular table.
end_date	date	Last effective date for a record.
end_date_flag	char(2)	Flag describing the known accuracy of station end date.
fips_country_code	char(2)	FIPS (federal information processing standards) country code.
fips_state_abbr	char(2)	FIPS state abbreviation for a station.
fips_state_code	char(2)	FIPS state code for a station.
history_flag	char(2)	Describes temporal significance of an individual record among others from the same station.
id_type_key	int2	Foreign key defining the id_type for a station (usually defined in code).
last_updated	date	Date of last update for a record.
latitude	float(8)	Latitude value.
longitude	float(8)	Longitude value.
name_type_key	int2	“3”: COOP station name, “2”: best station name.
name	varchar(30)	Station name as known at date of last update entry.
ncdc_state_code	char(2)	NCDC, two-character code identifying U.S. state.
network_code	char(8)	Eight-character abbreviation code identifying a network.
network_key	int2	Foreign key defining the network for a station (primary in table: network).
network_station_id	int4	Identifier for a station in the associated network, which is defined by id_type_key.
remark	varchar(254)	Additional information for a record.
src_quality_code	char(2)	Code describing the data quality for the data source.
state_key	int2	Foreign key defining the U.S. state where a station resides (primary in table: state).
state_name	varchar(30)	English name for a state.
station_alt_name	varchar(30)	Other English names for a station.
station_best_name	varchar(30)	Best, most well-known English name for a station.
time_zone	float4	Time zone where a station resides.
ucan_station_id	int4	Unique station identifier for every station in ACIS.
unit_key	int2	Integer value representing a unit of measure.

Field Name	Field Type	Field Description
updated_by	char(8)	Person who last updated a record.
var_major_id	int2	Defines major climate variable.
var_minor_id	int2	Defines data source within a var_major_id.
zipcode	char(5)	Zipcode where a latitude/longitude point resides.
nps_netcode	char(4)	Network four-character identifier.
nps_netname	varchar(128)	Displayed English name for a network.
parkcode	char(4)	Park four-character identifier.
parkname	varchar(128)	Displayed English name for a park/
im_network	char(4)	NPS I&M network where park belongs (a net code)/
station_id	varchar(16)	Station identifier.
station_id_type	varchar(16)	Type of station identifier.
network.subnetwork.id	varchar(16)	Identifier of a sub-network in associated network.
subnetwork_key	int2	Foreign key defining sub-network for a station.
subnetwork_name	varchar(30)	English name for a sub-network.
slope	integer	Terrain slope at the location.
aspect	integer	Terrain aspect at the station.
gps	char(1)	Indicator of latitude/longitude recorded via GPS (global positioning system).
site_description	text(0)	Physical description of site.
route_directions	text(0)	Driving route or site access directions.
station_photo_id	integer	Unique identifier associating a group of photos to a station. Group of photos all taken on same date.
photo_id	char(30)	Unique identifier for a photo.
photo_date	datetime	Date photograph taken.
photographer	varchar(64)	Name of photographer.
maintenance_date	datetime	Date of station maintenance visit.
contact_key	Integer	Unique identifier associating contact information to a station.
full_name	varchar(64)	Full name of contact person.
organization	varchar(64)	Organization of contact person.
contact_type	varchar(32)	Type of contact person (operator, administrator, etc.)
position_title	varchar(32)	Title of contact person.
address	varchar(32)	Address for contact person.
city	varchar(32)	City for contact person.
state	varchar(2)	State for contact person.
zip_code	char(10)	Zipcode for contact person.
country	varchar(32)	Country for contact person.
email	varchar(64)	E-mail for contact person.
work_phone	varchar(16)	Work phone for contact person.
contact_notes	text(254)	Other details regarding contact person.
equipment_type	char(30)	Sensor measurement type; i.e., wind speed, air temperature, etc.
eq_manufacturer	char(30)	Manufacturer of equipment.
eq_model	char(20)	Model number of equipment.
serial_num	char(20)	Serial number of equipment.
eq_description	varchar(254)	Description of equipment.
install_date	datetime	Installation date of equipment.
remove_date	datetime	Removal date of equipment.
ref_height	integer	Sensor displacement height from surface.
sampling_interval	varchar(10)	Frequency of sensor measurement.

Appendix F. Electronic supplements

F.1. ACIS metadata file for weather and climate stations associated with the SFCN: http://www.wrcc.dri.edu/nps/pub/SFCN/metadata/SFCN_from_ACIS.tar.gz.

Appendix G. Descriptions of weather/climate monitoring networks

G.1. Clean Air Status and Trends Network (CASTNet)

- Purpose of network: provide information for evaluating the effectiveness of national emission-control strategies.
- Primary management agency: EPA.
- Data website: http://epa.gov/castnet/.
- Measured weather/climate elements:
  - Air temperature.
  - Precipitation.
  - Relative humidity.
  - Wind speed.
  - Wind direction.
  - Wind gust.
  - Gust direction.
  - Solar radiation.
  - Soil moisture and temperature.
- Sampling frequency: hourly.
- Reporting frequency: hourly.
- Estimated station cost: $13000.
- Network strengths:
  - High-quality data.
  - Sites are well maintained.
- Network weaknesses:
  - Density of station coverage is low.
  - Shorter periods of record for western U.S.

The CASTNet network is primarily is an air-quality-monitoring network managed by the EPA. The elements shown here are intended to support interpretation of measured air-quality parameters such as ozone, nitrates, sulfides, etc., which also are measured at CASTNet sites.

G.2. NWS Cooperative Observer Program (COOP)

- Purpose of network:
  - Provide observational, meteorological data required to define U.S. climate and help measure long-term climate changes.
  - Provide observational, meteorological data in near real-time to support forecasting and warning mechanisms and other public service programs of the NWS.
- Primary management agency: NOAA (NWS).
- Data website: data are available from the NCDC (http://www.ncdc.noaa.gov), RCCs (e.g., WRCC, http://www.wrcc.dri.edu), and state climate offices.
- Measured weather/climate elements:
  - Maximum, minimum, and observation-time temperature.
  - Precipitation, snowfall, snow depth.

  - Pan evaporation (some stations).
- Sampling frequency: daily.
- Reporting frequency: daily or monthly (station-dependent).
- Estimated station cost: $2000 with maintenance costs of $500–900/year.
- Network strengths:
  - Decade–century records at most sites.
  - Widespread national coverage (thousands of stations).
  - Excellent data quality when well maintained.
  - Relatively inexpensive; highly cost effective.
  - Manual measurements; not automated.
- Network weaknesses:
  - Uneven exposures; many are not well-maintained.
  - Dependence on schedules for volunteer observers.
  - Slow entry of data from many stations into national archives.
  - Data subject to observational methodology; not always documented.
  - Manual measurements; not automated and not hourly.

The COOP network has long served as the main climate observation network in the U.S. Readings are usually made by volunteers using equipment supplied, installed, and maintained by the federal government. The observer in effect acts as a host for the data-gathering activities and supplies the labor; this is truly a "cooperative" effort. The SAO sites often are considered to be part of the cooperative network as well if they collect the previously mentioned types of weather/climate observations. Typical observation days are morning to morning, evening to evening, or midnight to midnight. By convention, observations are ascribed to the date the instrument was reset at the end of the observational period. For this reason, midnight observations represent the end of a day. The Historical Climate Network is a subset of the cooperative network but contains longer and more complete records.

G.3. Citizen Weather Observer Program (CWOP)

- Purpose of network: collect observations from private citizens and make these data available for homeland security and other weather applications, providing constant feedback to the observers to maintain high data quality.
- Primary management agency: NOAA MADIS program.
- Data Website: http://www.wxqa.com.
- Measured weather/climate elements:
  - Air temperature.
  - Dewpoint temperature.
  - Precipitation.
  - Wind speed and direction.
  - Barometric pressure.
- Sampling frequency: 15 minutes or less.
- Reporting frequency: 15 minutes.
- Estimated station cost: unknown.
- Network strengths:
  - Active partnership between public agencies and private citizens.

    - Large number of participant sites.
    - Regular communications between data providers and users, encouraging higher data quality.
- Network weaknesses:
    - Variable instrumentation platforms.
    - Metadata are sometimes limited.

The CWOP network is a public-private partnership with U.S. citizens and various agencies including NOAA, NASA (National Aeronautics and Space Administration), and various universities. There are over 4500 registered sites worldwide, with close to 3000 of these sites located in North America.

G.4. Florida Automated Weather Network (FAWN)

- Purpose of network: provide localized weather information, including frost and freeze warnings, for agricultural management decisions.
- Primary management agency: University of Florida Institute of Food and Agricultural Sciences.
- Data Website: http://fawn.ifas.ufl.edu.
- Measured weather/climate elements:
    - Air temperature.
    - Relative humidity.
    - Precipitation.
    - Wind speed and direction.
    - Solar radiation.
- Sampling frequency: 15 minutes or less.
- Reporting frequency: 15 minutes.
- Estimated station cost: unknown.
- Network strengths:
    - Near-real-time data.
    - Easy data access.
    - Site maintenance is excellent.
- Network weaknesses:
    - Coverage limited to Florida.
    - Record lengths are limited (1990s and later).

The FAWN network was initiated in Florida in the late 1990s in response to funding cutbacks at NWS in the area of localized weather information for agriculture, including frost and freeze warnings. Today FAWN provides useful weather data for Florida farmers and growers, primarily for daily management decisions. FAWN is also being used as a source of weather information for the general public.

G.5. NPS Gaseous Pollutant Monitoring Program (GPMP)

- Purpose of network: measurement of ozone and related meteorological elements.
- Primary management agency: NPS.
- Data website: http://www2.nature.nps.gov/air/monitoring.

- Measured weather/climate elements:
  - Air temperature.
  - Relative humidity.
  - Precipitation.
  - Wind speed and direction.
  - Solar radiation.
  - Surface wetness.
- Sampling frequency: continuous.
- Reporting frequency: hourly.
- Estimated station cost: unknown.
- Network strengths:
  - Stations are located within NPS park units.
  - Data quality is excellent, with high data standards.
  - Provides unique measurements that are not available elsewhere.
  - Records are up to 2 decades in length.
  - Site maintenance is excellent.
  - Thermometers are aspirated.
- Network weaknesses:
  - Not easy to download the entire data set or to ingest live data.
  - Period of record is short compared to other automated networks. Earliest sites date from 2004.
  - Station spacing and coverage: station installation is episodic, driven by opportunistic situations.

The NPS web site indicates that there are 33 sites with continuous ozone analysis run by NPS, with records from a few to about 16-17 years. Of these stations, 12 are labeled as GPMP sites and the rest are labeled as CASTNet sites. All of these have standard meteorological measurements, including a 10-m mast. Another nine GPMP sites are located within NPS units but run by cooperating agencies. A number of other sites (1-2 dozen) ran for differing periods in the past, generally less than 5-10 years.

G.6. NOAA Ground-Based GPS Meteorology (GPS-MET)

- Purpose of network:
  - Measure atmospheric water vapor using ground-based GPS receivers.
  - Facilitate use of these data operational and in other research and applications.
  - Provides data for weather forecasting, atmospheric modeling and prediction, climate monitoring, calibrating and validation other observing systems including radiosondes and satellites, and research.
- Primary management agency: NOAA Earth System Research Laboratory.
- Data website: http://gpsmet.noaa.gov/jsp/index.jsp.
- Measurements:
  - Dual frequency carrier phase measurements every 30 seconds
- Ancillary weather/climate observations:
  - Air temperature.

  - Relative humidity.
  - Barometric pressure.
- Reporting frequency: currently 30 min.
- Estimated station cost: $0-$10000, depending on approach. Data from dual frequency GPS receivers installed for conventional applications (e.g. high accuracy surveying) can be used without modification.
- Network strengths:
  - Frequent, high-quality measurements.
  - High reliability.
  - All-weather operability.
  - Many uses.
  - Highly leveraged.
  - Requires no calibration.
  - Measurement accuracy improves with time.
- Network weakness:
  - Point measurement.
  - Provides no direct information about the vertical distribution of water vapor.

The GPS-MET network is the first network of its kind dedicated to GPS meteorology (see Duan et al. 1996). The GPS-MET network was developed in response to the need for improved moisture observations to support weather forecasting, climate monitoring, and other research activities. GPS-MET is a collaboration between NOAA and several other governmental and university organizations and institutions.

GPS meteorology utilizes the radio signals broadcast by the satellite Global Positioning System for atmospheric remote sensing. GPS meteorology applications have evolved along two paths: ground-based (Bevis et al. 1992) and space-based (Yuan et al. 1993). Both applications make the same fundamental measurement (the apparent delay in the arrival of radio signals caused by changes in the radio-refractivity of the atmosphere along the paths of the radio signals) but they do so from different perspectives.

In ground-based GPS meteorology, a GPS receiver and antenna are placed at a fixed location on the ground and the signals from all GPS satellites in view are continuously recorded. From this information, the exact position of the GPS antenna can be determined over time with high (millimeter-level) accuracy. Subsequent measurements of the antenna position are compared with the known position, and the differences can be attributed to changes in the temperature, pressure and water vapor in the atmosphere above the antenna. By making continuous measurements of temperature and pressure at the site, the total amount of water vapor in the atmosphere at this location can be estimated with high accuracy under all weather conditions. For more information on ground based GPS meteorology the reader is referred to http://gpsmet.noaa.gov.

In space-based GPS meteorology, GPS receivers and antennas are placed on satellites in Low Earth Orbit (LEO), and the signals transmitted by a GPS satellite are continuously recorded as a GPS satellite “rises” or “sets” behind the limb of the Earth. This process is called an occultation or a limb sounding. The GPS radio signals bend more as they encounter a thicker atmosphere

and the bending (which causes an apparent increase in the length of the path of the radio signal) can be attributed to changes in temperature, pressure and water vapor along the path of the radio signal through the atmosphere that is nominally about 300 km long. The location of an occultation depends on the relative geometries of the GPS satellites in Mid Earth Orbit and the satellites in LEO. As a consequence, information about the vertical temperature, pressure and moisture structure of the Earth's atmosphere as a whole can be estimated with high accuracy, but not at any one particular place over time. The main difference between ground and space-based GPS meteorology is one of geometry. A space-based measurement can be thought of as a ground-based measurement turned on its side. For more information on space based GPS meteorology, the reader is referred to http://www.cosmic.ucar.edu/gpsmet/.

G.7. National Atmospheric Deposition Program (NADP)

- Purpose of network: measurement of precipitation chemistry and atmospheric deposition.
- Primary management agencies: USDA, but multiple collaborators.
- Data website: http://nadp.sws.uiuc.edu.
- Measured weather/climate elements:
  - Precipitation.
- Sampling frequency: daily.
- Reporting frequency: daily.
- Estimated station cost: unknown.
- Network strengths:
  - Data quality is excellent, with high data standards.
  - Site maintenance is excellent.
- Network weaknesses:
  - A very limited number of climate parameters are measured.

Stations within the NADP network monitor primarily wet deposition through precipitation chemistry at selected sites around the U.S. and its territories. The network is a collaborative effort among several agencies including USGS and USDA. Precipitation is the primary climate parameter measured at NADP sites.

G.8. Remote Automated Weather Station (RAWS) Network

- Purpose of network: provide near-real-time (hourly or near hourly) measurements of meteorological variables for use in fire weather forecasts and climatology. Data from RAWS also are used for natural resource management, flood forecasting, natural hazard management, and air-quality monitoring.
- Primary management agency: WRCC, National Interagency Fire Center.
- Data website: http://www.raws.dri.edu/index.html.
- Measured weather/climate elements:
  - Air temperature.
  - Precipitation.
  - Relative humidity.
  - Wind speed.
  - Wind direction.
  - Wind gust.

  - Gust direction.
  - Solar radiation.
  - Soil moisture and temperature.
- Sampling frequency: 1 or 10 minutes, element-dependent.
- Reporting frequency: generally hourly. Some stations report every 15 or 30 minutes.
- Estimated station cost: $12000 with satellite telemetry ($8000 without satellite telemetry); maintenance costs are around $2000/year.
- Network strengths:
  - Metadata records are usually complete.
  - Sites are located in remote areas.
  - Sites are generally well-maintained.
  - Entire period of record available on-line.
- Network weaknesses:
  - RAWS network is focused largely on fire management needs (formerly focused only on fire needs).
  - Frozen precipitation is not measured reliably.
  - Station operation is not always continuous.
  - Data transmission is completed via one-way telemetry. Data are therefore recoverable either in real-time or not at all.

The RAWS network is used by many land-management agencies, such as the BLM, NPS, Fish and Wildlife Service, Bureau of Indian Affairs, Forest Service, and other agencies. The RAWS network was one of the first automated weather station networks to be installed in the U.S. Most gauges do not have heaters, so hydrologic measurements are of little value when temperatures dip below freezing or reach freezing after frozen precipitation events. There are approximately 1100 real-time sites in this network and about 1800 historic sites (some are decommissioned or moved). The sites can transmit data all winter but may be in deep snow in some locations. The WRCC is the archive for this network and receives station data and metadata through a special connection to the National Interagency Fire Center in Boise, Idaho.

G.9. NWS/FAA Surface Airways Observation (SAO) Network

- Purpose of network: provide near-real-time (hourly or near hourly) measurements of meteorological variables and are used both for airport operations and weather forecasting.
- Primary management agency: NOAA, FAA.
- Data website: data are available from state climate offices, RCCs (e.g., WRCC, http://www.wrcc.dri.edu), and NCDC (http://www.ncdc.noaa.gov).
- Measured weather/climate elements:
  - Air temperature.
  - Dewpoint and/or relative humidity.
  - Wind speed.
  - Wind direction.
  - Wind gust.
  - Gust direction.
  - Barometric pressure.
  - Precipitation (not at many FAA sites).

  - Sky cover.
  - Ceiling (cloud height).
  - Visibility.
- Sampling frequency: element-dependent.
- Reporting frequency: element-dependent.
- Estimated station cost: $100000–$200000, with maintenance costs approximately $10000/year.
- Network strengths:
  - Records generally extend over several decades.
  - Consistent maintenance and station operations.
  - Data record is reasonably complete and usually high quality.
  - Hourly or sub-hourly data.
- Network weaknesses:
  - Nearly all sites are located at airports.
  - Data quality can be related to size of airport—smaller airports tend to have poorer datasets.
  - Influences from urbanization and other land-use changes.

These stations are managed by NOAA, U. S. Navy, U. S. Air Force, and FAA. These stations are located generally at major airports and military bases. The FAA stations often do not record precipitation, or they may provide precipitation records of reduced quality. Automated stations are typically ASOSs for the NWS or AWOSs for the FAA. Some sites only report episodically with observers paid per observation.

G.10. USDA/NRCS Soil Climate Analysis Network (SCAN)

- Purpose of network: comprehensive soil-climate network used in natural resource assessments and other conservation activities in the U.S.
- Primary management agency: USDA/NRCS.
- Data website: http://www.wcc.nrcs.usda.gov/scan/.
- Measured weather/climate elements:
  - Air temperature.
  - Precipitation.
  - Relative humidity.
  - Wind speed.
  - Wind direction.
  - Barometric pressure.
  - Solar radiation.
  - Snow water content.
  - Snow depth.
  - Soil moisture and temperature (enhanced sites only).
- Sampling frequency: 1-minute temperature; 1-hour precipitation, snow water content, and snow depth. Less than one minute for relative humidity, wind speed and direction, solar radiation, and soil moisture and temperature (all at enhanced site configurations only).
- Reporting frequency: reporting intervals are user-selectable. Commonly used intervals are every one, two, three, or six hours.

- Estimated station cost: $25000, with maintenance costs approximately $1000/year.
- Network strengths:
  - Sites are well-maintained.
  - Data are of high quality and are largely complete.
  - Very reliable automated system.
- Network weaknesses:
  - Short data records.
  - Network is still in development.

The SCAN network is intended to be a comprehensive nationwide soil moisture and climate information system to be used in supporting natural resource assessments and other conservation activities. These stations are usually located in the agricultural areas of the U.S. All SCAN sites are automated. The parameters measured at these sites include air temperature, precipitation, humidity, wind, pressure, solar radiation, snow depth, and snow water content.

G.11. Weather For You Network (WX4U)

- Purpose of network: allow volunteer weather enthusiasts around the U.S. to observe and share weather data.
- Data website: http://www.met.utah.edu/jhorel/html/mesonet.
- Measured weather/climate elements:
  - Air temperature.
  - Relative humidity and dewpoint temperature.
  - Precipitation.
  - Wind speed and direction.
  - Wind gust and direction.
  - Barometric pressure.
- Sampling frequency: 10 minutes.
- Reporting frequency: 10 minutes.
- Estimated station cost: unknown.
- Network strengths:
  - Stations are located throughout the U.S.
  - Stations provide near-real-time observations.
- Network weaknesses:
  - Instrumentation platforms can be variable.
  - Data are sometimes of questionable quality.

The WX4U network is a nationwide collection of weather stations run by local observers. Meteorological elements that are measured usually include temperature, precipitation, wind, and humidity.

The U.S. Department of the Interior (DOI) is the nation's principal conservation agency, charged with the mission "*to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian tribes and our commitments to island communities.*" More specifically, DOI protects America's treasures for future generations, provides access to our Nation's natural and cultural heritage, offers recreational opportunities, honors its trust responsibilities to American Indians and Alaskan Natives and its responsibilities to island communities, conducts scientific research, provides wise stewardship of energy and mineral resources, fosters sound use of land and water resources, and conserves and protects fish and wildlife. The work that we do affects the lives of millions of people; from the family taking a vacation in one of our national parks to the children studying in one of our Indian schools.

NPS/SFCN/NRTR—2007/037, May 2007

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APPENDIX J

CONCEPTUAL ECOLOGICAL MODELS

J.1 Introduction to SFCN Conceptual Models
J.2 SFCN Region-wide Overview
J.3 Freshwater Prairies and Marshes Ecological Zones
J.4 Forest Uplands and Wetlands Ecological Zones
J.5 Island Interior Ecological Zone
J.6 Coastal Wetlands Ecological Zone
J.7 Florida and Biscayne Bays Ecological Zone
J.8 Coastal Shelf and Deep Oceanic Ecological Zones
J.9 Marine Benthic Communities Sub-model
J.10 Park-Specific Conceptual Models
J.11 Literature Cited

APPENDIX J.1

INTRODUCTION TO SFCN CONCEPTUAL MODELS

Appendix J.1 Introduction to SFCN conceptual models

To facilitate the identification and prioritization of vital signs, SFCN divided the ecosystems in the South Florida and Caribbean parks into seven ecological zones and developed conceptual models for each as well as a region-wide overview and a marine benthic communities sub-model:

Appendix J.2 SFCN Region-wide Overview
Appendix J.3 Freshwater Prairies & Marshes Ecological Zones
Appendix J.4 Forest Uplands and Wetlands Ecological Zones
Appendix J.5 Coastal Wetlands Ecological Zone
Appendix J.6 Island Interior Ecological Zone
Appendix J.7 Florida and Biscayne Bays Ecological Zone
Appendix J.8 Coastal Shelf & Deep Oceanic Ecological Zones
Appendix J.9 Marine Benthic Communities Sub-model

These conceptual models were reviewed and used to focus discussion during the vital signs identification workshops held in January-March 2006. The comments received were incorporated into the conceptual models. Simplified summaries of the models are presented in the main report.

The biological communities in these ecological zones are assumed to be affected by similar physical drivers and the same general set of stressors. In addition, a major management challenge in some of these ecological zones is to maintain an appropriate balance of vegetation communities through management of drivers and stressors, (i.e., managing fire across the park to maintain a balance of slash pine communities as well as hardwood hammocks). These ecological zones partition the landscape into fewer categories than an approach focused on individual vegetation communities; yet, are relevant biologically, are practical to management, and facilitate subsequent program design steps. To simplify the marine models, a Marine Benthic Communities sub-model was developed that is simply referenced in each model, rather than repeating the information in each zone.

Various vegetation-fire, vegetation-hydrology, and food web model diagrams from the literature are included as figures in the ecological zone models where appropriate to help explain complex topics. The relationships among these various models are shown in Figures J.1-A and J.1-B.

Park-specific conceptual model diagrams were also created summarizing issues for each park (see Appendix J.10).

Table J.1-A. South Florida and Caribbean Ecological Zones and related network parks.

Ecological Zones	BICY	EVER	BISC	DRTO	VIIS	BUIS	SARI
Freshwater wet prairies & marshes	X	X					
Forest uplands and wetlands	X	X					
Coastal wetlands	X	X	X	X	X	X	X
Island interior		X	X	X	X	X	X
Florida and Biscayne Bays		X	X				
Coastal shelf & deep oceanic		X	X	X	X	X	X

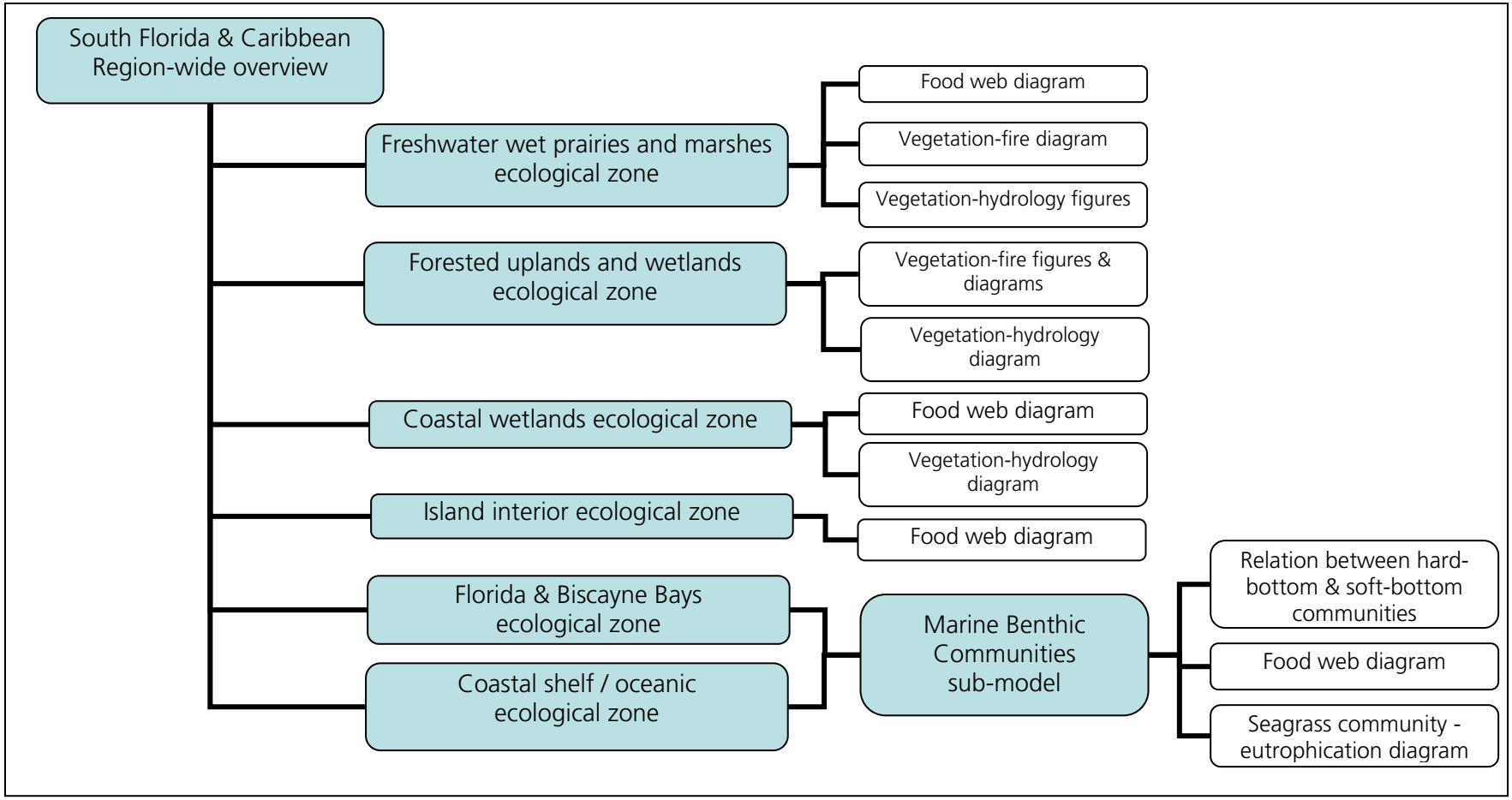


Figure J.1-A. Inter-relationships among south Florida and Caribbean Network conceptual models and sub-models. Figures in blue ▭ represent the models developed in detail in this report. ▭ represent sub-model figures included in the larger models.

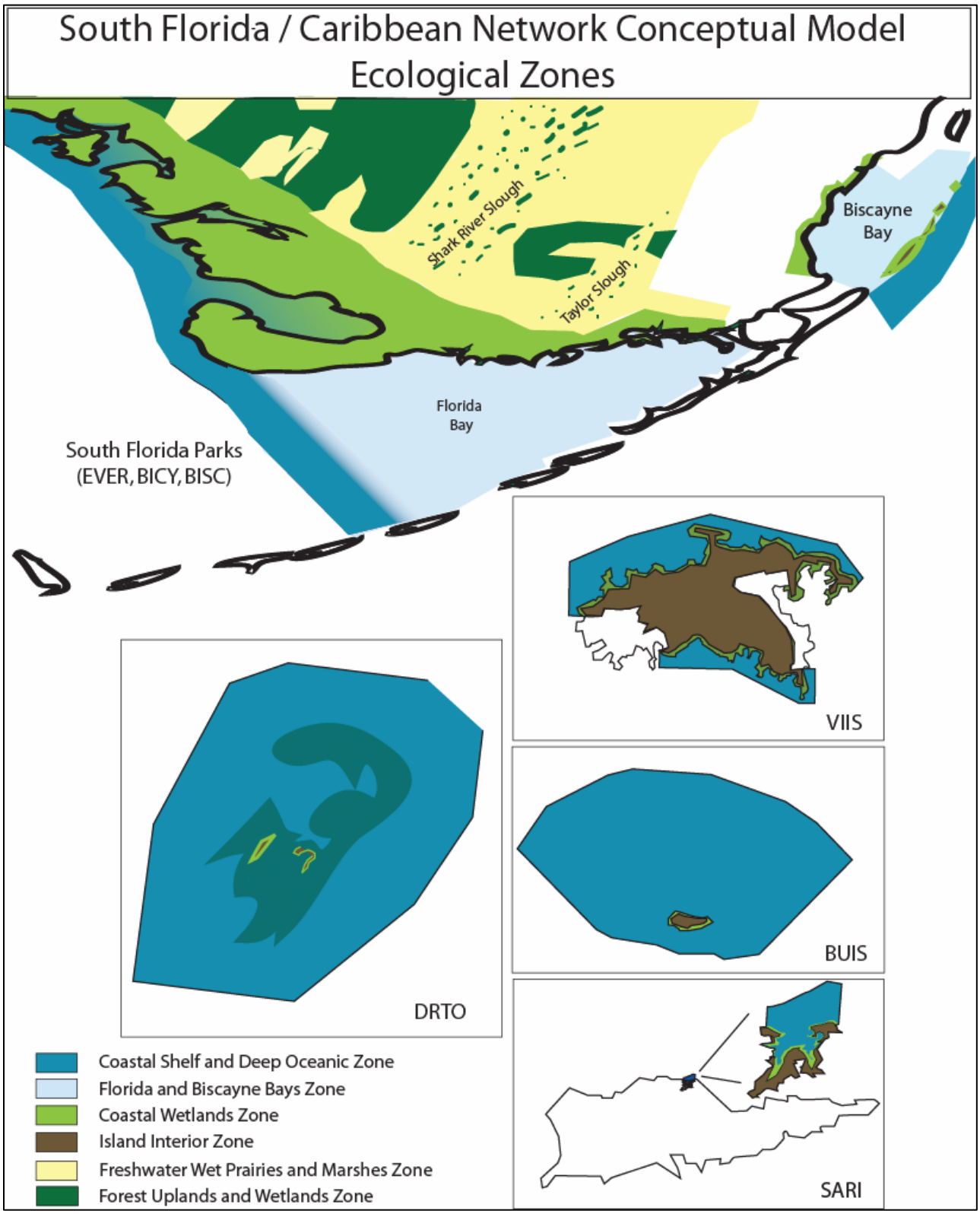


Figure J.1-B. South Florida / Caribbean Network Ecological Zones.

J.1.1 Format of conceptual models used in this document

Each of the ecological zone conceptual models consists of the following basic format:

Summary – The summary contains a general description of the ecological zone, a list of valued resources and services in the zone, a list of system drivers, stressors, and anticipated effects on the state of the environment, plus an outline for the remainder of the section.

Diagram – The diagram shows the inter-relationships between physical drivers and key background attributes, anthropogenic stressors, zone size and distribution, and biological attributes (primary producers, and consumers) (See Figure J.1-C). Different symbols are used to make the physical drivers, stressors, and biological attributes more readily apparent. Arrows show assumed important relationships between boxes, with different colors and solid/dashed lines are used to clarify which arrows come from which boxes. Dashed lines are used to clarify diagrams and are not intended to represent less important relationships.

Physical drivers, *key background attributes* and *anthropogenic stressors* – The drivers and stressors and their effects on the system are described in greater detail than food web components of the models. In general, all the drivers are described first; however, stressors that affect a specific driver are described immediately after the driver they affect. For simplicity, drivers such as *Air Quality* and *Water Quality – Nutrient level* are discussed in combination with their relevant stressors. For others, such as *Sea Level Rise*, the degree of natural physical driver vs. anthropogenic stressor is still being debated.

Anticipated effects on zone extent and biological system attributes – This section pulls together all the effects of the drivers and stressors and discusses how the biological parts of the system are expected to change as well as the overall size of the ecological zone. Some of the uncertainties involved are also included.

Potential and ongoing management actions – This section briefly summarizes potential and ongoing management actions.

Sometimes figures and sub-models such as fire-vegetation interaction figures are included to better explain complicated interactions.

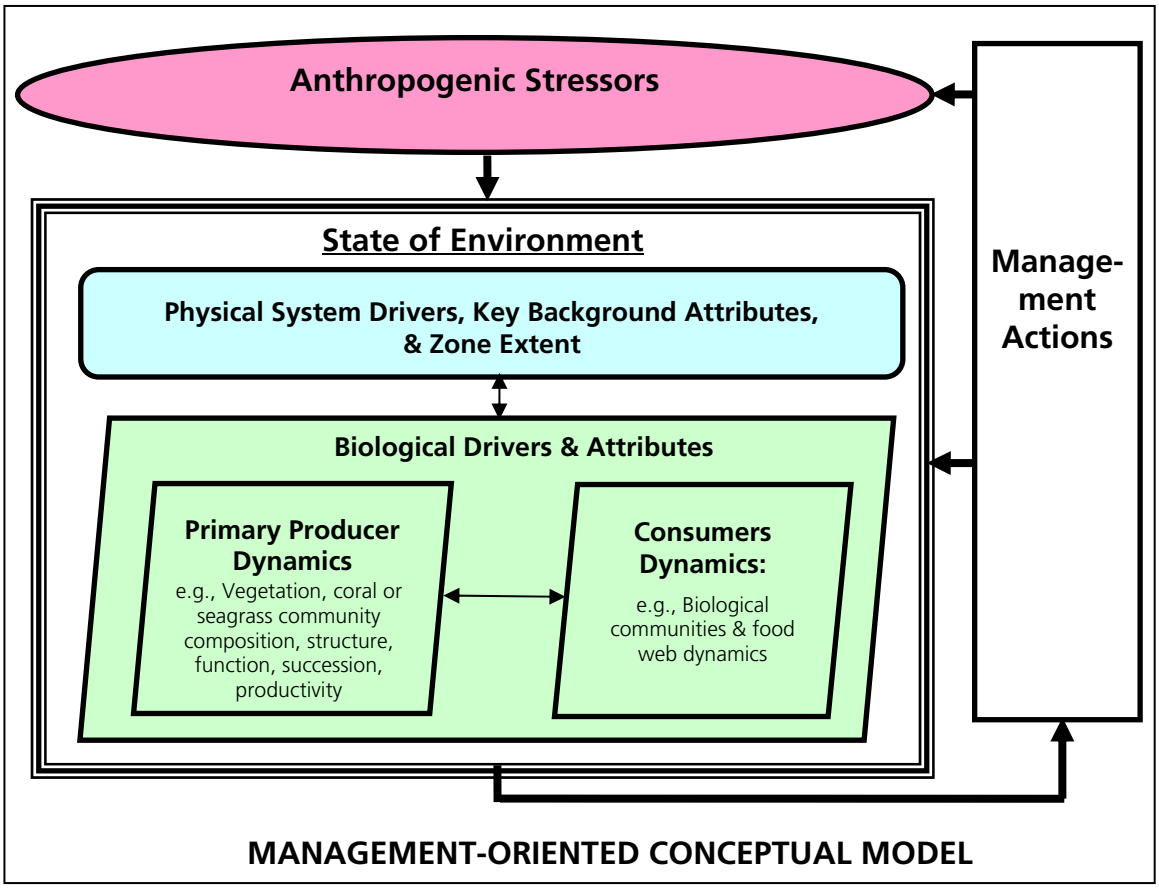


Figure J.1-C. Key components of management-oriented conceptual models. Conceptual models facilitate adaptive management by showing how system drivers, stressors and management actions are hypothesized to affect key components of the environment and their interactions. The components of conceptual models include:

- *Anthropogenic Stressors:* human-associated activities or side-effects thereof that either promote or inhibit change in the state of the environment such as water management, fire suppression, and contaminants.
- *Physical System Drivers, Key Background Attributes, & Extent of Zone:* part of the state of the environment that are important physical processes and frequently either drive or restrict change such as Hydrology, Fire Frequency and Severity, Temperature Range, or Frost Frequency. Key background attributes such as Geology and Climate fundamentally shape the system. And for nearly all of the zones, the actual size, distribution, and shape of the zone itself may change. This plays a key role in affecting the biological components of the system.
- *Biological Drivers and Attributes: Primary Producer Dynamics* and *Consumer Dynamics:* these include biotic components and interactions in the system such as food web dynamics, plant succession, keystone species, etc.
- *Management Actions:* ongoing or potential management actions in response or anticipation of changes in the State of the Environment. These are not typically included in the diagrams, but are instead listed at the end of each conceptual model.

APPENDIX J.2

SFCN REGION-WIDE OVERVIEW

J.2 SFCN Region-wide Overview

The SFCN region-wide conceptual model discusses the overview of the resources in a healthy *state of the environment*, *key physical drivers, background elements, and anthropogenic stressors*, effects of those sources of change on *biological drivers and attributes*, and a summary of potential or ongoing *management responses*.

J.2.1 Summary

The seven South Florida and Caribbean parks encompass many unique and rare habitats and species. Everglades National Park has been designated a World Heritage Site and coupled with Big Cypress is valued for its unique vegetation communities and ecosystems such as the Everglades "River of Grass," the pine rocklands, and the Big Cypress forest. The USVI parks contain the only dry tropical forest found in the national park system. The coral reefs of DRTO, BUIS, VIIS, BISC, and SARI are highly valued as both aesthetically beautiful and highly productive habitat. These parks provide habitat for at least 283 federal, state, and territorial protected species encompassing a wide range of unique species such as the West Indian manatee, Florida panther, small-toothed sawfish, five species of sea turtles, acroporiid species of coral, rare orchids, bryophytes, and succulents (see Appendix K). Both the U.S. Virgin Islands and South Florida provide important resting habitat for Neotropical migratory birds as they fly to and from North America to South America and throughout the Caribbean (see Avian Conservation Plans in Appendix L).

Both South Florida and the U.S. Virgin Islands have largely tourism driven economies, with the exception of St. Croix, VI where there are substantial industrial operations including one of the largest oil refineries in the Eastern hemisphere. These parks are valued for recreational opportunities including wildlife viewing, snorkeling, scuba diving, scenic views, hiking, kayaking, boating, fishing, camping, and additionally in BICY for off-highway vehicle recreation, hunting and oil production.

These parks and the waters outside them are highly valued by recreational fisheries (with exception of BUIS), and commercial fisheries (BISC only) for commercial fish, sport fish, lobster, shrimp, crabs and other crustaceans. BUIS, portions of DRTO, and the newly created Virgin Islands Coral Reef National Monument (VICR) are valued in a different way as they function as "no-take" marine reserves within the context of larger commercial and recreational fisheries, providing safe breeding areas and habitat for fish and invertebrate populations whose offspring can emigrate to surrounding areas. However, the concept of marine reserves is still new and marine reserve design and effectiveness in increasing fish densities and size in nearby areas are still being evaluated (Sobel and Dahlgren 2004).

The Everglades are valued for their recharging of South Florida aquifers and providing the drinking water for Miami and Everglades City. The water flowing through the Everglades into Florida Bay and eastwards to Biscayne Bay helps create the brackish habitat that supports many species and provides nursery habitat for many fish.

Seagrass beds and mangroves are highly valuable as juvenile fish and invertebrate habitats with Biscayne and Florida Bays serving as nursery habitat for many species such as pink shrimp, red drum and gray snapper. Reefs are likewise highly productive habitat for many fish and invertebrates such as lobster, grouper, and snapper. Reefs and mangroves also provide shoreline protection, buffering the land from wave erosion, storm surge and even tsunamis. Coral reefs produce the sand found on most beaches in the U. S. Virgin Islands and many in Dry Tortugas.

J.2.2 Physical Drivers, Key Background Attributes, and Anthropogenic Stressors)

The key physical drivers, anthropogenic stressors and background attributes for South Florida and Caribbean Parks are combined into key issues and discussed under the following headings (not in any priority order):

- Regional geology
- Climate & global climate change
- Major weather events
- Currents, transport & dispersal
- Coastal geomorphology & sea level rise
- Increasing human population and urbanization
- Habitat conversion
- Freshwater & estuarine hydrology and human alterations
- Fire & altered fire regimes
- Water Quality- Nutrient enrichment
- Water Quality - Sedimentation
- Water Quality - Contaminants
- Air quality
- Introduction and spread of invasive fauna, flora and disease
- Harvest & harvest methods
- Human disturbance (e.g., visitor use, boat scars, trash)

The relationship of specific anthropogenic stressors to each park, the level of knowledge about the stressor, and the conceptual models containing details are summarized in Table J.2-A.

Table J.2-A. Link between ecological community zones and anthropogenic stressors.
● versus • indicates greater versus lesser impact of stressor. Closed circles ● indicate greater certainty or knowledge than open circles ○. H indicates historical impact. For some stressors such as "sea level rise" the degree of human effects versus natural processes is still being debated but they are included for completeness.

		ECOLOGICAL COMMUNITY ZONES							PARKS						
ANTHROPOGENIC STRESSORS		Wet prairie and marsh	Forested uplands and wetlands	Island interior	Mangroves, beaches, and tidal marsh	Florida Bay	Biscayne Bay	Coastal shelf / deep oceanic	EVER	BICY	BISC	DRTO	VIIS	BUIS	SARI
Overarching stressors	Global climate change - Rising air & water temperatures, decreased frost, increased drought	○	○					○	○	○	○	○	○	○	○
	Global climate change - Increased sea level rise	○	○	●	○	○	○	○	○	○	●	●	○	○	○
	Rapid increase in human population, tourism, and urban development	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Habitat conversion & land use changes	Habitat loss due to urban development outside park	●	●	●	●				●	●	●		●		●
	Habitat fragmentation	●	●	•	•				•	●	•		•		•
	Historic agricultural or logging use effects	•	●	●	•				H	H	H		H	H	H
	Urban edge effects	•	●	●	●				•	●	●		●		●
	Development of park facilities		•	•	•				•	•	•	•	•		
	Flagler highway					●			●						
Altered hydrology	Freshwater diversions, impoundments, levees, & canals alter extent, depth, timing, duration of flows & cause water level reversals	●	●		●	○	○	○	●	●	○				
	Altered groundwater levels	○	○				○		○	○	○				
	Canals, artificial berms, rip-rap	●	●		●	●	●		●	●	●				
Altered fire regime	Fire suppression & unseasonal fires	●	●	○					●	●			○		○
Contaminants, excess nutrients & sediment	Nutrient enrichment	●	●	•	●	●	●	●	●	●	○		•	•	•
	Mercury	●	●		●	○	○		●	●	○				
	Pesticides	○	○	○	○	○	○	○	○	○	○		○		○
	Oils, other toxics, ship bottom paint	○	○	○	○	○	○	○	○	○	○	○	○	○	○
	Catastrophic oil and chemical spills				○	○	○	○	○	○	○	○	○	○	○
	Increase turbidity & sedimentation			•		•		•	•		○		●		○
	Industrial, incinerator, vehicle emissions	○	○	○	○	○	○	○	○	○	○		○		○
Invasive Species	Invasive fauna	●	●	●	●	○	○	○	●	●	●	•	●	H	●
	Invasive flora	●	●	●	●	○	○	○	●	●	●	•	●	●	●
	Invasive invertebrates	○	○	○	○	○	○	○	○	○	○	○	○	○	○
	Diseases					●	●	●	○		○	○	○	○	○
Harvest	Fishing & poor fishing methods	○	○		○	•	●	●	●	●	●	●	●	●	●
	Hunting	•	●						H	●		H	H	H	
	Illegal collection of rare flora & fauna	•	●	•	●			●	●	●	•	•	•	•	•
Disturbance, Trash, Debris, Roadkill	Incorrect fishing gear/traps					●	●	●	•	•	●	●	●	●	●
	Trash and refuse, lost fishing gear	•	•	•	●	●	●	●	•	•	●	●	●	●	●
	Artificial subsidizing of mesopredators with trash			•	•						•		•		
	Boat collisions with wildlife					●	●	○	●	○	●	○	○	○	○
	Roadkill	●	●	•	•				●	●			•		•
	Dredging outside of park				○	○	○	○	○		○				
	Boat groundings and propeller damage				•	●	●	●	●		●	●	●	●	●
	Recreational use & tourists	○	●	•	●	●	●	●	○	●	●	○	●	•	●

J.2.2a Regional geology

The underlying geology, topography and soils strongly influence the resulting vegetation communities that establish. South Florida is extremely flat with an elevation range from 0 - 4.3 m above sea level and is underlain by Holocene sediments, Key Largo Limestone, and Miami Limestone. The Big Cypress Swamp is underlain by Tamiami Formation and is slightly higher in elevation than the Everglades marshes. Water historically overflowed out of Lake Okeechobee during summer rains and flowed south and southwest in a sheet through the Everglades and Big Cypress marshes, wet prairies, sloughs and cypress woodlands and eastwards towards Biscayne Bay. The limestone is highly porous (transmissive), allowing water to easily travel underground to recharge aquifers. Historically native people, early settlers circa 1890 and Spanish sailors refilled water cast from freshwater upwelling from groundwater in the middle of Biscayne Bay. Florida Bay is a shallow carbonate mud bay that has gradually been flooded during the past 5,000 years due to rising sea level. It is bounded by the Florida Keys which are flat, sandy islands built on top of historical reefs (Pleistocene Key Largo Limestone). These Keys extend northwards to provide the eastern boundary to Biscayne Bay. The Dry Tortugas are the western-most outcropping of the Florida Keys consisting of sandy islands which have formed on top of historic coral reefs.

In contrast, the Caribbean island parks are on steep rocky islands of uplifted metamorphic rock. St. John ranges from 0-387 m above sea level and St. Croix from 0-355 m (Platenberg *et al.* 2005) with a mountainous landscape. Both islands have irregular shorelines with multiple bays and offshore cays. St. John is on a different tectonic plate from Buck Island and St. Croix and earthquakes and tremors regularly occur in this area. In 1867, an earthquake of magnitude 7.5 generated two large tsunamis that produced waves in excess of 23 ft on St. Croix (Hall 2005).

J.2.2b Climate & global climate change

Climate in SFCN parks consists of hot, wet summers and falls and warm, drier winters and springs. Peak rainfall in South Florida occurs June-November and in USVI August-November. In South Florida frost frequency decreases along a north-south gradient creating a corresponding vegetation gradient that transitions southwards from temperate to increasing sub-tropical vegetation. The Virgin Island parks are tropical with no frost occurrence. The Caribbean Sea is affected by oceanic oscillations which affect storms and climate throughout the region. The steep topography of terrestrial VIIS on St. John, BUIS, and SARI on St. Croix creates orographic effects with drier, east-facing slopes and moister west-facing slopes. Vegetation and fauna on those islands are adapted to hot, xeric, high wind environments that are frequently inundated with salt spray.

Although global climate change is a definite concern for SFCN parks, much of the effects of global climate change are still speculative and it is difficult to separate out the effects of a global shift from natural climatic cycles. However, some of these hypothesized effects that could impact South Florida and Caribbean parks include: 1)

increases in the rate of sea level rise with consequent effects on coastal geomorphology and vegetation ecotones; 2) increases in the frequency of higher than normal ocean temperatures that are outside coral tolerance limits and are associated with coral bleaching and mortality; 3) reductions in frost frequency and thereby causing northward expansion of sub-tropical flora in South Florida resulting in changes in forest and wetland community composition; 4) modifications in the migratory patterns and nesting patterns of landbirds, colonial nesting birds, and other fauna; 5) possibly changes and increases in the frequency of extreme weather events such as major hurricanes and droughts; and 6) ocean acidification due to rising CO_2 levels may lower pH enough to affect invertebrates with calcium endoskeletons such as calcareous corals.

J.2.2c Major weather events

Major weather events such as hurricanes, tropical storms, large wind or rain events and large wave events are natural but substantial sources of disturbance for both terrestrial and marine systems throughout the Caribbean, producing massive structural changes in terrestrial vegetation and in coral reefs, and changing coastal and bay bathymetry along with the distribution of beaches and coastal berms. Storms cause disturbance through strong winds, torrential rain, flooding, wave action, and storm surge resulting in patchy or large-scale disturbance to coral reefs, seagrass beds, and vegetation. Hurricanes disperse species to new areas (Oberbauer *et al*. 1996). Storm waves and surge remove or redistribute sand along beaches; create and alter sand bars, coastal levees, and shell deposits; create and refill salt ponds; and open cut-off ponds and lakes back to the sea. Hurricanes Donna, Andrew and Wilma were reported to split islands. Hurricane Wilma produced storm surges from 14.4 ft. to 18.0 ft impact on the entire western boundary of EVER (Figure J.2-A). Seawater intrusion and sediment deposition from high storm surges can impact freshwater habitats well inland. Storms also create debris such as fallen trees, houses, and loose boats, which can exacerbate wave damage to habitats. In marine communities, seagrass "blow outs" can occur and coral colonies dislodged by storms can act as "bowling balls" toppling adjacent colonies. Exotic flora and fauna can be accidentally released by storms. Even distant storms can create ocean swells that influence reefs and shorelines. While such

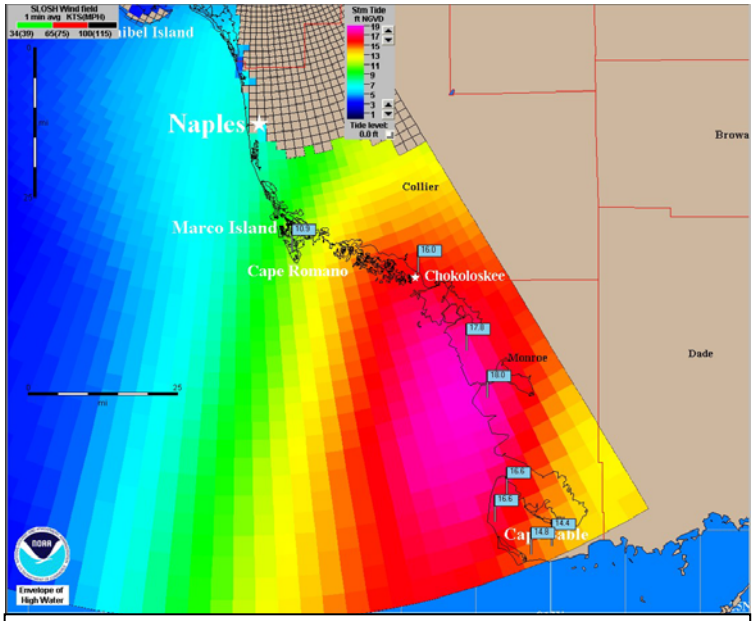


Figure J.2-A. 14-18 foot storm surge due to Hurricane Wilma impacts southwest Florida in 2005 (Downloaded from NOAA web page on 08/11/2006 http://www.srh.noaa.gov/mfl/events/?id=wilma).

events are a natural disturbance factor, these changes can greatly impact already stressed park resources, accelerate the impact of sea level rise, and eliminate whole populations of rare plants and animals. While being hotly debated (Webster *et al,* 2005; Knutson *et al.* 2004; WMO International Workshop on Tropical Cyclones 2006; Masters 2007), the hypothesis that rising sea temperatures associated with global climate change have at least the potential to increase hurricane severity is a cause for concern.

Extreme droughts are another type of major weather event that occasionally impact South Florida. Such droughts increase the probability of large catastrophic fires that burn the peat and
consequently change the topography of the landscape in addition to changing the vegetation.

Warm sea temperature events are causing great concern as they are linked to coral bleaching that stresses the coral and if continued long enough may lead to coral death. The most recent event occurred in 2005 in the U. S. Virgin Islands parks with over 85% of the corals bleaching and some species having 42% to 56% colony mortality due to a mixture of bleaching and subsequent disease outbreaks (Whelan *et al.* 2007).

J.2.2d Currents, transport & dispersal

The oceanic habitats in the seven parks are inter-connected by oceanic currents that assist the dispersal of aquatic flora and fauna species among the Caribbean islands, throughout the Gulf of Mexico, and to South Florida. The Caribbean Sea is relatively small, only 1,200 nautical miles (nm) by 500 nm, and marine systems can be adversely and beneficially affected by upstream events and conditions. Areas within the wider Caribbean are "connected" via transport of eggs and larvae in currents which generally move from east to west (Roberts 1997) although the role such dispersal plays versus local recruitment is still unclear for many species (Mora and Sale 2002). USVI reefs can receive larvae from several upstream sources, including the British Virgin Islands, St. Martin, Anguilla and Saba. Currents also transport harmful pollutants as well as larvae of fishes and other reef organisms. A dramatic example occurred in 1991 when oil began showing up on British and U. S. Virgin Island beaches two weeks after a barge sank off Eustatia island (40 miles NE of St. John). Under certain wind and current conditions, the Orinoco River plume extends to the USVI, producing visible phytoplankton blooms and bringing seeds and perhaps pollutants from South America. In another dramatic example, ash from the eruption of the volcano on Montserrat Island (200 miles south of St. John) fell on St. John and St. Croix the next day.

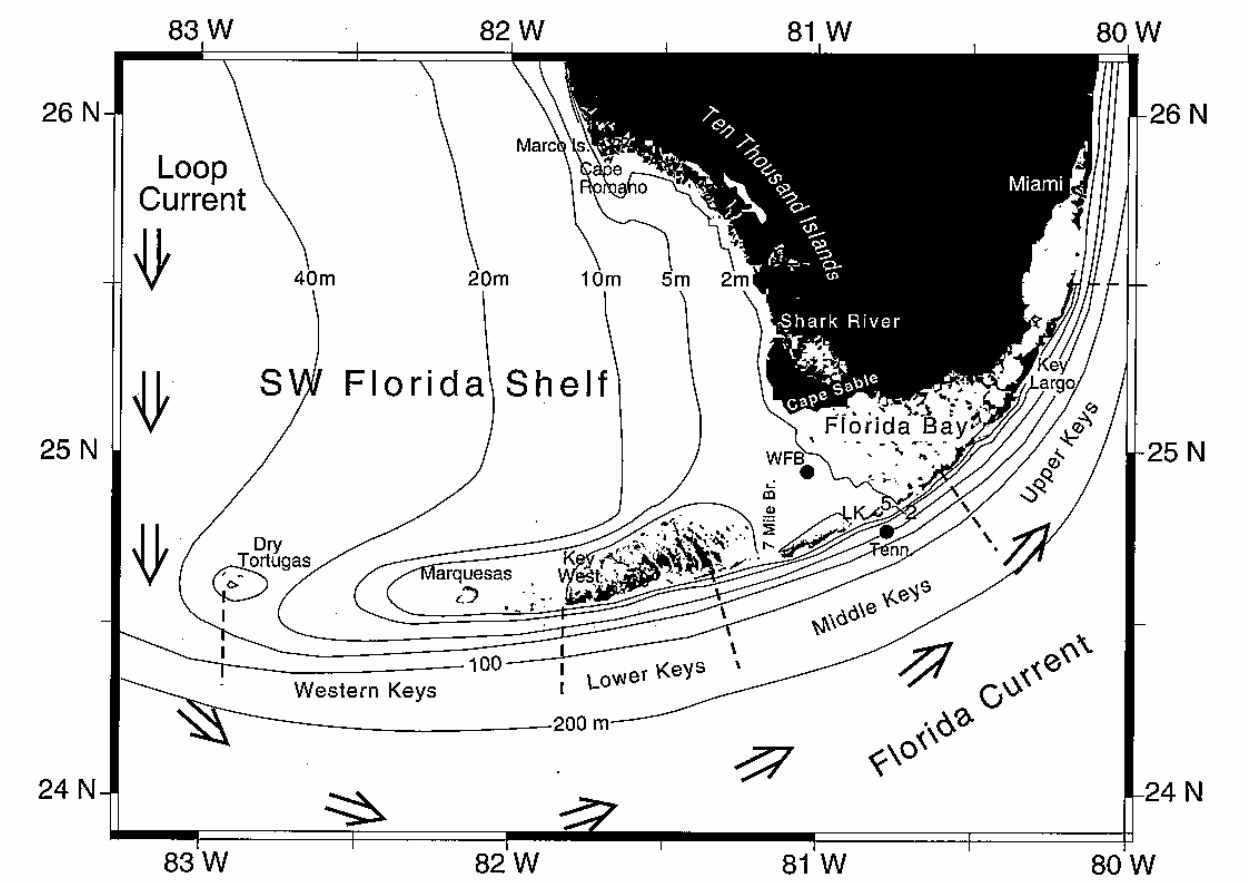


Figure J.2-B. The Loop Current varies somewhat in location in the Gulf of Mexico but generally flows south along the western coast of Florida and joins the Florida Current which travels around the Florida Keys and northward past Biscayne Bay and beyond [Figure from Lee *et al.*, 2002].

Reefs in Florida are downstream from large source areas in Central America and the Gulf of Mexico. Currents around Florida move southward along the west coast of Florida, around the Florida Keys and northwards along the eastern coast of South Florida (see Figure J.2-B). Historically, it is thought more water moved through Florida Bay eastwards from the Gulf to the Atlantic, but much of this flow is now blocked by the Flagler Railway in the Florida Keys with some flow still continuing up through Barnes Sound and Card Sound into Biscayne Bay. These currents and transport connect South Florida, with Florida Bay acting as nursery habitat for some species (pink shrimp) in the Dry Tortugas.

Pollutants can be brought south from the Tampa Bay area southwards into park waters. However, the currents also tend to sweep pollutants from the Miami River northwards away from Biscayne Bay (see Figure J.2-B).

The terrestrial portions of the parks are effectively more isolated than the bays and reefs, with marine areas acting as inhospitable barriers to movement. Ocean currents,

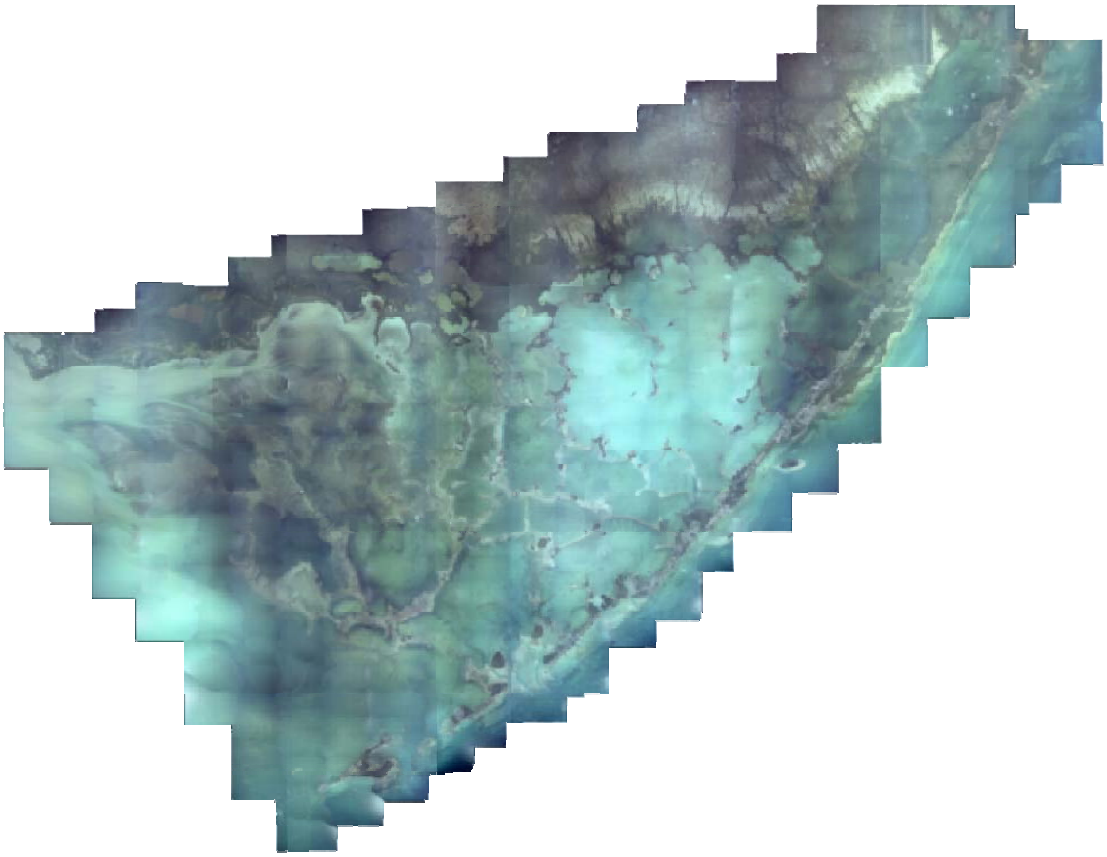


Figure J.2-C. Florida Bay in EVER aerial imagery showing basins, mudbanks, tidal channels and "White Zone." [Courtesy of Fish and Wildlife Research Institute (FWRI) and Florida Fish and Wildlife Conservation Commission (FWCC)].

wind, storms, and birds act as dispersal agents. Tropical and sub-tropical vegetation, birds, bats, and some insects have dispersed relatively easily among the islands and to South Florida. As a result, south Florida has a mix of sub-tropical and temperate species with the exception of land-bound fauna (e.g., mammals, herpetofauna) which have had greater difficulty in dispersal. South Florida land- bound fauna is largely temperate in origin (Lodge 2005). Similar difficulty in dispersal coupled with island isolation effects on populations has led the Caribbean island parks to have few native land-bound fauna even when compared with larger nearby islands such as Puerto Rico.

J.2.2e Coastal geomorphology & sea level rise

Mudbank and coastal berm dynamics are important in SFCN parks. Tropical storms and hurricanes alter mudbanks and berms and thus change how hydrology affects the system. In the extremely shallow 3-6' Florida Bay, the basins and mudbanks strongly affect circulation and salinity patterns including allowing some areas to become hypersaline (see Figure J.2-C). In some areas of Everglades, coastal berms protect freshwater marshes behind them; but when breached can suddenly be associated

with rapid changes in wetland communities. In the USVI, such berms can allow the creation of salt ponds in some years, while subsequent storms may reconnect them with the ocean. In Dry Tortugas, winter storms created a sand bar between Garden Key and Bush Key that changed local circulation and water quality patterns. A subsequent storm then removed the sand bar. These changes are part of the ongoing dynamics of the coastal environment.

Sea levels changed little between 0 AD and 1900 AD. However, the rate of sea level rise has increased over the 20th century to 1.7 mm/year, and since 1993, sea levels have been rising at a rate of around 3 mm/year. Model projections for the 21st century are for about a 4 mm/year rise with an anticipated increase in global sea levels by 2090 of 0.22 to 0.44 m above1990 levels (IPCC 2007). These estimates are conservative and its possible sea levels could rise faster. With slow sea level rise, other processes of deposition and accretion can in some areas keep up, maintaining islands and shorelines. Continuing rapid sea level rise, however, is expected to cause the gradual loss of low-elevation land area on islands and mainland areas of Florida and Caribbean parks. In areas such as BISC and DRTO, this may mean loss of much of the terrestrial park area over the next couple of centuries.

In EVER, rapid sea level rise may cause the gradual and/or sporadic inward encroachment of mangroves into brackish and freshwater areas coupled with conversion of freshwater marsh to brackish and saline marsh. Freshwater marsh collapse in the Cape Sable area is already a concern. However, mangroves also function as sediment accretion zones and this may slow or even alter the effects of sea level rise. Overall the prognosis is a loss of land area in EVER, BISC, DRTO and eventually BICY. Florida Bay will likely get deeper as sea level rises, but the rate and the effects on this shallow system are unclear (see Figure J.2-C).

The Virgin Island parks will probably experience less impact due to sea level rise than the low-lying South Florida parks. The steeper islands of VIIS and BUIS may lose some low-lying areas, barrier reefs will become deeper, but overall most of the park areas will be unaffected. SARI with its low elevation may lose land area as the estuary expands further inland. Sea level rise may affect the deepest coral reefs if they fall below the light zone at a rate faster than their growth, but otherwise is expected to have little effect on marine resources.

J.2.2f Increasing human population and urbanization

Both South Florida and the U.S. Virgin Islands are experiencing rapid human population increases as well as increased numbers of tourists annually. Rising populations and rising tourism are associated with the stressors of habitat conversion, hydrological modifications, contaminant problems, increased recreation and visitation, urban edge effects, fire management issues, exotic species, and increased harvest of resources which are discussed further below.

2.2.2g Habitat conversion



Figure J.2-D. Construction occurring just outside SARI and right to the edge of the mangroves. Coral communities are just off-shore (2005).

The large size of the SFCN parks and adjacent managed natural areas does provide some good opportunities for preserving species and many ecosystem processes, although these parks remain highly vulnerable to many stressors in the region. EVER and BICY are both large parks which share borders with one another and with other conserved federal, state, and private conservation lands. To the west of BICY are the smaller preserves of the Florida Panther NWR, Fakahatchee Strand State Preserve, Picayune Strand State Forest, Thousand Islands NWR, Collier Seminole State Park, and Corkscrew Swamp Sanctuary. To the north and east of EVER and BICY are the state Water Conservation Areas. Thus, the south-western tip of Florida contains a large connected area of conserved land, with some inholdings, roads and smaller cities. However, rapid urbanization is taking place to the east in the large Miami/Fort Lauderdale metropolitan area which is expanding southward towards the urbanizing Florida Keys. Rapid development is also occurring to the north in the Orlando area and northwest in the Tampa Bay and Naples/Ft. Myers areas. The agricultural areas south of Lake Okeechobee could also become developed with impacts on the Everglades watershed. VIIS and SARI are also anticipated to have more urban development occur along park borders and inholding development (see Figure J.2-D). SARI is particularly vulnerable as it is a small estuary on the north shore of St. Croix with a large boundary-to-park-interior ratio making it more vulnerable to direct urban edge effects. The end result is a reduction in the total amount of natural habitat in areas outside SFCN parks, reducing the total amount of habitat available for maintaining species populations and restricting native species more and more to the parks.

Increasing road density and traffic is expected to increase roadkill throughout the area, effectively becoming semi-permeable barriers to wildlife movement and population sinks. Although currently Florida has a non-urban buffer around the parks, its possible future legislation may change this. Urban edge effects include increased introduction of exotic plants and animals, pet intrusion into parks, contaminants from urban runoff, mosquito control, wildlife control, fire control and unseasonal fires, and increased disturbance and trails around boundaries. The size of EVER and BICY coupled with the buffer will keep such effects to the outer boundaries. However, in BISC the urban edge is expected to extend right to the western park boundary. VIIS has over 100 inholdings within the park boundaries, most either developed or being developed causing a variety of impacts to park

resources. BICY also has a number of inholdings mostly in the form of fish and hunting camps.

Habitat conversion also affects the marine environment. BUIS, DRTO, BISC, and VIIS[1] protect all or nearly all the lands (submerged and otherwise) within their boundaries reducing impacts of some stressors and allowing consistent management of terrestrial and marine resources (e.g., coral reefs, seagrass, and open ocean) that fall within their jurisdiction. However, the "fluid" nature of marine managed areas means these parks are strongly influenced by stressors in nearby areas such as nutrient enrichment, sediment runoff, contaminants, heavy fishing pressure, reduction in the quality of marine habitat outside the parks, and release of exotic invasive species.

J.2.2h Freshwater & estuarine hydrology and human alterations

Summer rains historically caused Lake Okeechobee in southern Florida to overflow in a shallow, slow-moving sheet that moved south and southwest across EVER and the eastern half of BICY, exiting in Florida Bay and the 10,000 Islands. Water also moved eastward to Biscayne Bay through natural spillways that breeched the coastal ridge (i.e. Miami River, New River, and other southern transverse glades). The deeper part of the "river of grass" is found in slough habitats in the Water Conservation Areas to the north of Everglades National Park and the Shark Slough and Taylor Slough areas within the park. These deeper areas grade into shallower portions of the Everglades called wet prairies. The shallower parts of the "river of grass" are found in broad expanses bordering the deeper sloughs and as glades among the forested wetlands (see Figure J.2-E).

When the rains cease, water begins receding on the floodplain forming a "drying front." Presence of aquatic refugia in the form of alligator holes, solution holes within the marl, deeper "moats" around tree islands and sloughs provide areas for small fish, invertebrates, and amphibians to survive during dry season. These refugia, and also drying fronts in general, provide highly concentrated food sources for wading birds and other fauna as retreating waters concentrate aquatic fauna.

The historical water flow into the area of Everglades National Park was first altered in 1919 by the construction of the Tamiami Trail and then during the past 50 years by the Central and Southern Florida (C&SF) Project in order to provide a reliable water supply, flood protection, water management and other benefits to South Florida agricultural and urban areas (see Figure J.2-E). To accomplish this, approximately 1000 miles of canals, 720 miles of levees and hundreds of water control structures were built (CERP web page, http://www.evergladesplan.org/about/rest_plan.cfm). The result was a major modification in the Everglades watershed and a severe reduction in the amount of water flowing into the Everglades and ultimately a drying

[1] VIIS has numerous private inholdings (e.g., one ~450 acre hillside/watershed) that disrupt ecological processes.

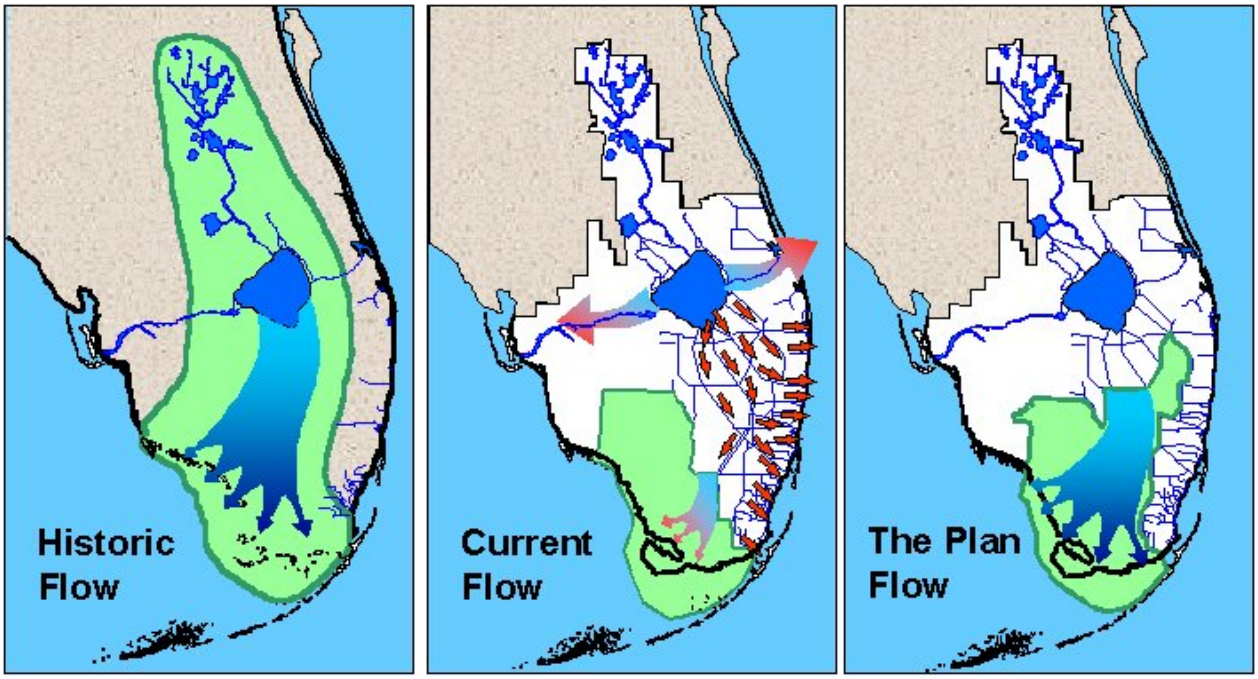


Figure J.2-E. Figures show the historic flow pattern of the greater Everglades system, the current flow patterns, and the projected flow patterns under the Comprehensive Everglades Restoration Plan. Please note that the diagrams do not show water historically going into Biscayne Bay which is incorrect. (From the Comprehensive Everglades Restoration Plan web site http://www.evergladesplan.org/facts_info/maps.cfm). Accessed 10 August 2005.

of the Everglades with unintended adverse impacts on the unique and diverse flora and fauna of the Everglades, Florida Bay, eastern BICY and Biscayne Bay. These alterations in the Everglades watershed and hydrology have disrupted natural patterns of sheet flow direction, extent, depth, and duration with altered timing of high water and low water events. Compartmentalization, coupled with wet season water level reversals and drying pattern reversals, also disrupt the system. Overall, these have led to gradual alterations in the mosaic of vegetation communities across the landscape with invasion of wet prairies by woody species, invasion of sloughs and longer hydroperiod marsh by sawgrass, and general alterations of vegetation composition in marsh communities (Davis 2004; Ogden 2004). The drier Everglades have also resulted in a reduced biomass of fishes, crayfish, grass shrimp, frogs, turtles, and many other foraging species with corresponding impacts on wading birds, alligators, etc. The large numbers of wading birds for which Everglades used to be known have experienced major reductions in size and changes in distribution of wading bird populations and nesting colonies.

The reduction in the water flowing into the Everglades is also thought to have impacted Florida Bay by greatly decreasing outflow from Taylor Slough and Shark River Slough, probably resulting in higher than historic salinity levels. In addition, several canals and levees were created during the 1930s (including East Cape Canal,

Homestead Canal, Slegel's Ditch, Houseman's Ditch, and Middle Cape Canal) to divert the water out from the Cape Sable area in a failed attempt at creating "prime" real estate. These canals have changed the flow of water and have altered sediment transport. These canals and levees are now degrading with potential further effects on the Bay.

In Biscayne Bay, large water diversions as part of the Everglades water works have greatly decreased outflow from transverse glades, rivers and wetlands into Biscayne Bay. Many of the rivers and transverse glades have been converted to hardened canals, reducing the amount of estuarine habitat on the western side of the Bay and creating pulsed changes in the amount of freshwater and corresponding salinity levels, sometimes with scouring effects on benthic communities. In addition, freshwater upwelling from groundwater has virtually disappeared since the massive water diversions occurred. With decreased freshwater influx, the brackish areas of the bay have become more saline and the brackish areas have moved back into the canals which lack the estuarine habitat that supported wildlife. Conversion of rivers and transverse glades to canals along the west shore of the bay has resulted in the historic elimination of freshwater and brackish habitat and conversion to mangroves, reduction of mangrove habitat to fringe mangrove areas along the shoreline, and elimination of tidal creeks and significant groundwater inputs to the Bay.

In the U.S. Virgin Islands, much of the rainfall (avg. 30-55 inches/year) rapidly runs off the steep slopes, leaving a xeric landscape with moister tropical forest in the ravines and ephemeral streams. During the dry season, little to no fresh water exists on these islands with the few exceptions of areas that may catch and hold rain water such as karst formations in BISC or "guts" in VIIS. Urbanization on St. John is linked with sedimentation filling in the "guts" and unseasonal water diversions *into* the parks from landscape irrigation. Unseasonal water contributes to vegetation change and invasive species incursion. Salt River Bay on St. Croix is being channelized upstream of the SARI park boundary to improve flood control; the impacts on the hydrology and water quality of the Salt River estuary in the park are unclear.



Figure J.2-F. Fire is a major driver in Everglades and Big Cypress.

J.2.2i Fire & altered fire regimes

Fire is an important natural driver of South Florida wet prairies, marshes and forests, and to a lesser degree of coastal wetlands and island forests (see Figure J.2-F). Historically, in South Florida most fires occurred during the summer months when lightning started fires that were usually small and didn't

destroy the submerged soil and roots. Dry season fires occurred less frequently in April or May. These fires were more destructive, destroying peat soils and roots. In the absence of fire, fire-sensitive hardwood hammock trees and shrubs expand into pinelands and cypress; shrubs and trees expand into herbaceous wet prairies and marshes, and mangroves expand inland. Deeper peat fires occur less often, setting back succession and perpetuating long-hydroperiod marshes. Lack of fire can indirectly affect system hydrology as dense sawgrass impedes water flow.

Humans have altered the timing of fires and altered the pattern of fire spread across the landscape. Human-initiated fires frequently occur during the dry season in winter and early spring rather than during the summer. These unseasonal fires are larger, hotter, vegetation-altering fires which can get into the exposed peat layer causing soil volume loss and destroying plant roots. Historical fire suppression and use of roads as fire breaks also impacted wetlands, altering the normal pattern of fire across the landscape. Canals serve as barriers to fire thereby limiting the spatial extent of individual ignitions. The invasive species Brazilian pepper (*Schinus terebinthifolius*) resists fires and once established, acts as a fire barrier, altering fire patterns. In addition, fire has been excluded from large areas of EVER and BICY. For example, protection of Cape Sable seaside sparrow populations has resulted in exclusion of large areas from fire treatment, although recent management has started to allow natural fires to burn in these areas. Current NPS fire management practices are working to better mimic the natural system while maintaining human safety.

Fire has never been part of the Virgin Islands ecosystem but with the spread of invasive non-native plants primarily the African tan-tan (*Leucaena leucocephala*) and guinea grasses (*Urochloa maximum)* seasonal brush fires are an issue in SARI.



Figure 2.2-G. Water quality instrument in BISC.

J.2.2j Water quality- Nutrient enrichment

Nutrient enrichment is a major concern in both South Florida and the Virgin Islands. The Everglades system is historically oligotrophic (low nutrient). However, increased phosphorus from the Everglades Agricultural Areas and urban areas has resulted in shifts in the periphyton algal community from green algae and diatoms to calcareous blue-green algae which is less beneficial to the food web; increases in the density of grasses which shade the periphyton mat; increases in cattail density (*Typha* spp.) in sawgrass habitat; eutrophication and low dissolved oxygen in water which stresses fish and invertebrates; and may be associated with increased disease outbreaks in wading birds

(eustrongyloidosis caused by a nematode (USFWS 1999)). Increased nitrogen is also a concern in the freshwater wetlands although phosphorous loading is considered a more important problem at present.

In estuaries and marine environments, elevated concentrations of nitrogen and phosphorus result in algal blooms, both in planktonic and benthic forms, and changes in the composition of algal and submerged aquatic vegetation (SAV) communities. This can result in changes to estuarine and marine productivity and food web structure. In addition, excessive algal and SAV growth followed by vegetation die-offs can result in periods of low dissolved oxygen that can negatively impact fish and benthic communities. Excess nutrients resulting from runoff from agriculture (EVER, SARI, VIIS, BISC), urban runoff (BISC, SARI, VIIS), sewage effluent (VIIS, SARI from leaking septic systems and neighboring British Virgin Islands; Florida Bay in EVER and coastal BISC from leaking septic systems in the Florida Keys; Biscayne Bay from treated waste water and waste water treatment overflows; BUIS, DRTO, SARI, and VIIS from boats and local discharges), sewage from charter boats and cruise ships, and golf courses. SARI is currently considered an "impaired body of water" by the territorial Division of Environmental Protection under EPA water quality standards due to 1% of septic systems being faulty in homes within the watershed. Fortunately, currents move waters from the heavily impacted Miami River northwards away from Biscayne Bay. Southern Biscayne Bay has been experiencing a prolonged algae bloom which began in 2005. Some localized impacts can occur due to high seabird guano that affect nearby vegetation.

J.2.2k Water quality - Sedimentation

Excessive sediment runoff is occurring due to local urban and inholding development in VIIS and SARI. This excessive runoff causes filling in of "guts", siltation of beaches and filling in of marshes and salt ponds. Mangroves and marshes can trap some of this sediment, but can be overwhelmed. Excessive sediment results in increases in water turbidity that impacts estuarine health and can smother nearby coral reefs.

J.2.2l Water quality - Contaminants

Sources of contaminants in the SFCN include mercury from aerial deposition and watershed contamination (EVER, BICY, BISC), pesticides in agricultural runoff and aerial deposition, gasoline and contaminants from marinas, bottom paint on container ships (tributyl tin and cuprous oxide), water treatment plant effluent (BISC), active and historic landfills (BISC), creosote spills, oil spills (BICY), industrial contaminants, ballast and bilge water from commercial ships, canal discharges, and various wastes such as tires and vehicles dumped in canals. Contaminated water injected into the Floridian aquifer may be able to impact the bays if injection systems were improperly constructed. Plans are underway to dredge the Miami River which could release contaminants into the area and although general water flow will carry contaminants away from the park, bioaccumulation by local fauna may carry the contaminant burden into the park waters. In addition, there continue to be new emerging pollutants of concern (EPOCs), including pharmaceuticals, personal care

products, detergents and industrial compounds which all may act as hormone mimics as well as acting as estrogen and estrogen mimics in treated sewage effluent. All these contaminants can have small but cumulative impacts on the system depending on the scale and spatial extent of the area affected.

Mercury is both a serious problem and probably one of the more widespread concerns in South Florida parks. Aerial mercury deposition in EVER and BICY is thought to come from waste incineration and electricity production from burning fossil fuels. Mercury becomes methylated (biologically active) in marshes and there is believed to be a link with sulfur that may exaggerate mercury methalization. Mercury becomes concentrated to toxic levels in fauna at higher trophic levels (bioamplification) in the food chain (e.g., bass, pig frogs, wading birds, and panthers).

With increased oil tankers and container ships traveling throughout the Caribbean and South Florida, there is an increased probability of a major contaminant disaster. The effects will depend on the contaminants involved. Oil spills have been found to have major long-term consequences on ecosystems and can take millions of dollars to restore ecosystem health (e.g., Tampa Bay spill in 1993). The danger is especially a concern for BUIS where oil tankers travel east of the park to and from one of the world's largest oil refineries located on the south side of St. Croix.

J.2.2m Air quality

Mercury deposition from the atmosphere, presumably from power plants and incinerators both local and distant, is a huge stressor for South Florida parks. In addition, rising urbanization (i.e., powerplants (sulfur dioxide, mercury, and nitrogen oxides), incinerators, cars and other vehicles) could diminish local air quality leading to increased deposition of sulfur dioxide, nitrogen oxides and particulates, although strong ocean breezes may partially mitigate these impacts. African dust storms from the Sahara and Sahel periodically diminish air quality in the Virgin Island parks and to a lesser degree in South Florida parks. The dust storm impacts on the environment are unclear. Volcanism in the Caribbean occasionally diminishes air quality for U. S. Virgin Island parks. British Virgin Island landfill burning affects air quality in VIIS.

J.2.2n Introduction and spread of invasive fauna, flora and disease

Invasive plants and fauna are one of the greatest threats to maintaining native biodiversity in the in SFCN parks, causing large-scale changes in vegetation community structure and function and consumer food web dynamics. Particularly problematic species are listed in Appendices M and N. Invasive plants include not only the more typical herbaceous community species (e.g., *Eichhornia crassipes*), but also include invasive trees (e.g., *Melaleuca quinquenervia, Casuarina spp.*), shrubs (e.g., *Schinus terebinthifolius*), and tree-smothering vines (e.g., *Lygodium spp.)*.

Invasive fauna are another major threat to native flora and fauna. Released pets and fishing bait are frequent sources of new invasive species. Burmese pythons and other



Figure J.2-H. Alligator with large non-native python in its jaws. Photo by Everglades National Park staff.

introduced constrictors are becoming established as a new top predator in EVER and BICY with unknown consequences to the food web (see Figure J.2-H). Feral cats (*Felis domesticus*) prey on native songbirds and small fauna at a level far higher than native bobcat predation, often creating severe "sink" habitat around residential areas. Feral hogs (*Sus scrofa*) disturb sites, plowing up and eating native vegetation. Exotic fish alter marsh, estuarine, bay, river, gut, and hydric forest fish communities and food web dynamics. Mongoose (*H. javanicus*) and black or tree rats (*R. rattus*) are devastating USVI food webs as new top predators. Some other non-native species of concern include the marine toad (*Bufo marinus*), Cuban tree frog (*Osteopilus septentrionalis*), fire ants (*Solenopsis invicta*), Mexican Red-bellied Squirrel (*Sciurus aureogaster*), Green Iguana (*Iguana iguana*), Lionfish (*Pterois volitans/miles*) and, in the USVI, white-tailed deer (*Odocoileus virginianus*), feral goats (*Capra hircus*) and donkeys (*Equus asinus*). Coyotes (*Canis latrans)* have been expanding their range southward into Florida and are already present in BICY and EVER (Wilson *et al.* 2007). While technically a species native to the eastern United States, they historically were not found in South Florida. Their presence will add a new medium-sized top predator to the system and the consequences are unclear.

Each new species takes time and money to develop and implement effective controls and many do not yet have controls. With increasing global travel coupled with people's desire for exotic pets and plants, new introductions of invasive species will be an ongoing problem. Diseases in coral, seagrass, sea urchins, spiny lobsters, sea turtles, etc., are also a great concern in the marine ecological zones although it is unclear whether these are a natural occurrence or are human-related. Early detection of new problem species is important for cost-effective control of this problem.

J.2.2o Harvest & harvest methods

Heavy fishing and damaging fishing methods in coral reefs and marine communities are causing severe changes to the food web that are impacting the coral reefs (see Figure J.2-I). Modern fishing methods such as gill nets and long lines allow fishermen to fish more efficiently and in deeper waters than was historically possible. Fishermen can now set nets along parrotfish daily migration pathways between the

coral reefs and seagrass beds allowing the capture of entire schools (Drayton *et al*. 2004). Seine nets allow harvesting of large numbers of fish while the weights dragging along the bottom disrupt reefs and seagrass beds. Lost fish traps or "pots" continue "ghost-fishing," capturing and killing non-target fish. Extensive fishing has reduced communities of the very large predators (apex piscivores, sharks, large groupers). Normally, a drop in top predators would be associated with increases in trophic levels directly below them. However, when one type of fish becomes rare, fishing continues "down the food web." This serial depletion, decreases stocks of mid-level predators and then stocks of herbivorous fish, taking smaller and smaller fish as the larger ones are depleted. Serial depletion has severely altered the food web in marine communities in the U.S. Virgin Islands and to a lesser degree in South Florida. Even spawning populations of grouper and snapper are illegally fished, helping reduce some stocks such as goliath groupers to historically low levels.



Figure J.2-I. Undersized lobsters illegally taken at BISC (Photo from BISC).

As a consequence, in areas where fishing continues, many of the larger fish species in the coral reefs and seagrass beds are now rare. Average fish size of remaining species has decreased. And many are harvested before becoming sexually mature. The consequences on the food web are not completely understood. However, reduction in herbivorous fish reduces the control on the growth of turf and macroalgae which when allowed to grow, inhibit coral growth and prevent larval settlement. Algal overgrowth was further encouraged by a late 1980s disease outbreak in the long-spined sea urchin (*Diadema antillarum*) that caused a Caribbean-wide die-off of approximately 90% of this other major reef herbivore. The overfishing at the top of the food web has probably had other effects such as impacting the abundance of coral bioeroders, but these changes are less clearly understood.

Historically, illegal collection of sea turtle eggs and poaching of adult and subadult sea turtles, rare plants such as orchids and ferns, rare snails, butterflies, and reptiles such as indigo snakes has been a serious problem. Although much reduced at present, due to strict enforcement by park personnel, this continues to be a problem in some cases (e.g., orchid poaching) and can seriously impact native populations, even jeopardizing population survival. Some rare snail collectors burned hammocks to prevent others from collecting the same pattern snails. Historic hunting of Florida panthers and bears may have contributed to their decreased numbers in the present. Hunting of typical game species such as deer, turkey and feral pigs continues in BICY.

J.2.2p Human disturbance

Human disturbance includes inappropriate visitation (e.g., too many people in sensitive areas or at sensitive times for some species), boat and anchor damage, speed boats and personal watercraft, ORV use, physical trash and abandoned fishing gear, and recreational hunting disturbance.

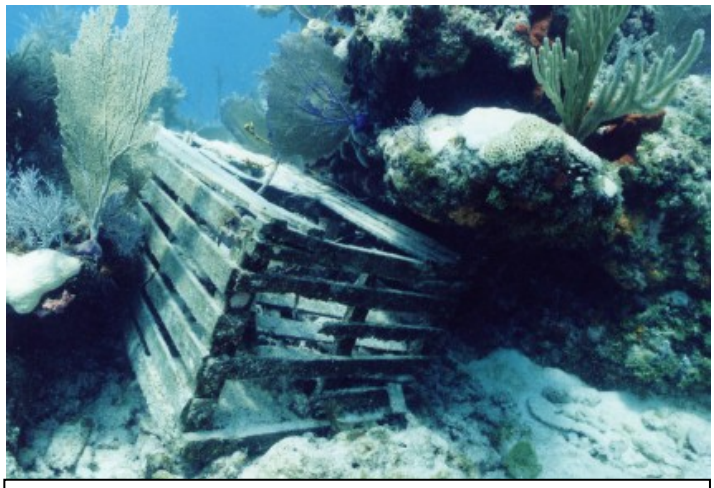


Figure J.2-J. Lost trap lodged in coral reef at Biscayne National Park.

Given the high amount of boat traffic through shallow areas, damage from boat groundings, anchors and propellers scar seagrass beds and coral reefs and are a major concern in SFCN marine park areas. Boat groundings and other damage in seagrass beds can create shallow to deep gouges, cutting through seagrass rhizomes, and stirring up sediments. Wave action can then act upon these cuts, increasing their size through time. Groundings and damage to coral reefs can rip apart and fragment coral that took hundreds of years to grow. Major groundings can "break the back" of the reef, breaking through the outer layer and exposing the interior limestone to erosion. The cumulative impact of this damage from many boats through time can severely impact and even destroy the resources. Often removing the grounded vessel causes additional damage to resources adjacent to the original grounding site. Anchor damage by a small cruise ship in VIIS showed no recovery a decade after the incident (Rogers and Garrison 2001). Boat groundings also stir up sediments and can alter local bathymetry, causing local contamination problems as gasoline and other contaminants leak into the area. Recovery of seagrass beds from propeller scars and groundings can take from 3-15 or more years (USFWS 1999). Recovery of coral reef damage from groundings can take centuries.

Snorkelers and scuba divers can damage the reef by standing on, kicking, collecting the corals, and suspending sediments. Given the large visitation pressure that focus on coral reefs, this chronic damage is cumulative, especially in popular viewing areas. In addition, illegal collection can be a problem with tourists collecting coral and organisms as souvenirs.

Lobster divers and spear fishermen can damage resources by moving or hurting coral colonies in an effort to reach their prey. Lost fishing traps or "pots" and lost nets cause physical damage as waves move them back and forth across reefs and seagrass areas, and continue to capture fish long after they are lost (see Figure J.2-J).

Physical trash, storm debris and abandoned fishing gear (nets, lost or abandoned crab and lobster traps, fishing line monofilament and hooks) litter beaches and underwater environments in SFCN parks. The source of this trash and debris is from commercial and recreational boats, oceanic dumping, abandoned boats, storm debris, and park visitation. Trash, fishing lines and hooks, crab pot lines, and other debris entangles and kills wildlife such as pelicans, wading birds, sea turtles, terns, dolphins and manatees (see Figure J.2-K). Debris also entangles, abrades and damages reefs and underwater habitats. Larger debris such as abandoned boats can damage vegetation. Debris on beaches may also deter or inhibit sea turtle nesting efforts. In addition, trash and debris reduces visual quality for park visitors and can create health hazards for visitors when extreme.



Figure J.2-K. Entangled dead frigate bird on Buck Island, BUIS.

Recreational hunting disturbance and oil drilling occur in Big Cypress. Hunting camps are often associated with invasive plant problems, sewage, ORV trails, trash, noise, and general disturbance. Oil drilling is associated with invasive plant problems, noise, creation and maintenance of roads, and the potential for contaminant problems.

J.2.3 Anticipated Effects of Drivers and Stressors on Biological System Attributes

Although some changes can be anticipated due to physical drivers and stressors, the nature and outcomes of those changes are not always easy to predict, especially as several drivers will be changing simultaneously. However, some of the larger expected changes on the biotic part of terrestrial and marine systems are described below.

J.2.3a Terrestrial and freshwater primary producer and consumer dynamics

Several changes in vegetation composition, structure, and function can be anticipated due to changes in hydrology, fire management, invasive species, frost frequency, and plant succession processes. As hydrology is rehabilitated by the Comprehensive Everglades Restoration Program, vegetation is expected to respond: marsh and slough vegetation may expand into wet prairies, shrubs and trees expanding into wet prairies and marshes may recede, tree islands may recover, and groundwater levels in Long Pine Key may rebound. Fire management is likewise expected to impact the

extent and distribution of hardwood communities and the extent and structure of slash pine and cypress communities. Sea level rise is expected to move mangroves and tidal wetlands further inland – although this may be slowed if freshwater inputs to Everglades are restored (Whelan *et al.* 2005). The periphyton mat, which plays a critical role in the Everglades marsh food web, shows shifts in composition due to hydrology and nutrient level changes.



Figure J.2-L. Numbers of white ibis and wood storks at EVER are depressed below historic levels.

Invasive plant species are sources of future change and, if unchecked, have the possibility of altering much of South Florida's native vegetation and the effects of fire and hydrology on the landscape. Disturbed and stressed areas are especially vulnerable to invasion. If climate change results in decreased frost frequency, tropical hardwood hammocks may expand further northwards. Previously, many areas of BICY and EVER were logged, and now these areas are expected to gradually mature.

In South Florida, top predators such as Florida panthers have been declining due to loss and fragmentation of large expanses of land. This resulted in panther genetic isolation and inbreeding which necessitated bringing in panthers from Texas to reinvigorate the gene pool. Florida bear populations have also declined. Alligators are a keystone species in the Everglades - as top predators, as habitat change agents that maintain and deepen holes in prairies and marshes, and whose nest mounds provide brooding habitat for other marsh reptiles such as red-bellied turtles. However, decreased water levels and shortened hydroperiods have caused alligators to move out of the prairies into the deeper marshes (Davis 2004a). In addition, alligators may also still be recovering from historic hunting levels that temporarily reduced them to be listed as an Endangered Species. Other new top predators are establishing, such as released boa constrictors, pythons and other constrictors combined with the southward range expansion of coyotes. The combined effects of these changes on the food web are difficult to predict but could be considerable.

Species dependent on old mature forests have declined or disappeared. The red-cockaded woodpecker has declined due to the loss of old stands of slash pines with an open understory maintained by frequent fires. Logging of the old bald cypress stands likely contributed to the local extirpation of the Ivory-billed woodpecker. Hopefully the elimination of logging, coupled with more natural fire patterns will allow some species to recover.

Historically the Everglades was noted for its large wading bird communities and diversity of wildlife (see Figure J.2-L). Unfortunately, this is no longer the case. The system is naturally oligotrophic with low densities of fish and invertebrates produced over a wide area, then concentrated in drying fronts into dense food resources for wading birds and other predators. The reductions in the extent of wet prairies and marshes and the alterations in the hydrology have greatly reduced the fish and invertebrate productivity and consequently impacted upper trophic levels such as the wading birds. Wading bird colonies have been reduced in size, nesting timing has changed, reproductive success has declined, and colony locations have moved. Species such as wood stork, roseate spoonbill and white ibis have especially been impacted.

Proposals to alter the hydrology of the Greater Everglades Ecosystem should positively impact fish communities by mimicking historical depth, duration, and timing of flooding. However, non-native fish are also altering those fish communities, especially within strands, deeper sloughs, and canals.

Mercury toxicity is a continuing stress on the system, contributing to the deaths of at least three panthers since the 1990s (USFWS 1999), and is impacting other upper trophic level species such as alligators, wading birds, pig frogs, and bass. Mercury toxicity can lead not only to death but behavioral changes in affected animals which can affect reproductive success and ultimately population survival with consequences for the rest of the food web.

SFCN parks are important migratory bird stopovers in their annual migrations. With global climate change occurring, the timing of these migrations and species involved could change through time. Pollination, seed dispersal, and consequently food webs could also be affected.

The fauna on islands such as the BUIS, SARI, VIIS, DRTO, and keys of BISC are characterized by limited numbers of species when compared with the same guilds on larger islands and mainland areas, coupled with simplified food webs where the top predators are typically raptors and raccoons (BISC). The absence of predators has made some smaller islands important locations for seabird and shorebird colonies and wading bird rookeries. Island food webs can be very dependent on additional food from the sea (seabird fishing, dead fish carcasses, intertidal invertebrates, etc). Probably the biggest impact on island food webs is the introduction of invasive animals and plants by humans (e.g., cats, mongoose, rats, goats, hogs) which both compete with and prey upon native species.

As urban encroachment continues, SFCN parks could experience a temporary "concentrating" effect as species outside the parks are forced to retreat to within the park boundaries. As encroachment continues, the "edge effect" could increase, although the large size of BICY and EVER reduces the seriousness of these impacts.

However, roadkill along the major roads and highways continues to be a population sink and cause of fragmentation within the parks and neighboring conservation areas. Some proposed changes by the Comprehensive Everglades Restoration Program such as building underpasses along Tamiami Trail could help reduce this impact. Urban adapted species such as raccoons can be augmented around campsites, docks, and urban areas causing problems for other species such as sea turtles.

Rare plant and animal species can be negatively impacted by recreational disturbance, genetic bottleneck effects, illegal collecting, and catastrophic weather events such as hurricanes, introduction of exotic species, and loss of pollinators due to other disturbances in the system. Unfortunately, illegal collection of rare species such as indigo snakes, tree snails, rare orchids and bromeliads continues to be a problem. Poaching/illegal fishing at BUIS can be eliminated with effective enforcement but is still a problem currently. How this will affect the recovery of the fisheries remains to be seen, but will have to be considered as a factor for meeting effective management and recovery goals. Ultimately, strong and effective enforcement of park laws and regulations coupled with species-specific mitigation measures has reduced problems and benefited some species and in some cases the entire ecosystem (e.g., exotic plant control).

J.2.3b Estuarine and marine systems primary producer & consumer dynamics

The marine ecosystem is interconnected. Healthy reefs are dependent upon healthy seagrass and mangrove communities which buffer reefs from land-based nutrient enrichment and sedimentation problems. Healthy reefs are also strongly dependent upon balanced fish and invertebrate food webs with sufficient levels of herbivores to keep algal overgrowth in check. In turn, healthy fish and invertebrate communities are dependent upon healthy seagrass beds, coral reefs, and mangroves. Thus, although anticipated changes in coral reef communities, seagrass communities and the marine consumer food web are described separately, they should be seen as inter-related.

Coral reef communities are under stress Caribbean-wide. Outbreaks of coral disease, increased coral bleaching, nutrient enrichment and sedimentation problems, vessel groundings, contaminant problems, and altered food webs are all taking their toll on the coral reefs. Losses of live coral cover are rarely, if ever, "recovered," with that lost substrate being colonized by algae for decades. There is growing concern over apparent declines in live coral cover (NOAA 2001), declines in the main reef-building corals, and over the apparent lack of successful re-growth or recruitment of the main reef-building corals. In fact, staghorn coral (*Acropora cervicornis*) and elkhorn coral (*A. palmata*) cover have been reduced to such a degree that, coupled with the lack of evidence of successful reproduction, these species have been the first marine invertebrates to be listed as threatened under the Endangered Species Act (May 2006). With increasing urban development and tourism coupled with global climate change and intense fishing pressures, these problems are expected only to get worse and careful park management will be required to mitigate these pressures.

Seagrass and algal communities are very susceptible to nutrient enrichment, sedimentation problems, and changes in salinity. Disease outbreaks and new invasive species are also a concern. A large-scale seagrass die-off occurred in Florida Bay in 1987 from which the Bay has not yet recovered and the causes of which are still debated. With hydrological changes expected due to increasing human population in South Florida and the U. S. Virgin Islands coupled with the Comprehensive Everglades Restoration Program, seagrass community extent, distribution, and composition is expected to change in response. Algal blooms are sometimes a problem in South Florida with red tide events along the west coast and "black water" events in the Florida Keys. Plankton blooms due to nutrient enrichment also occur in Florida Bay, diminishing light and oxygen for other SAV and aquatic fauna. Benthic and planktonic algal overgrowth are a problem for reefs, probably exacerbated as all the primary herbivore species were either overfished (especially in USVI) and because sea urchins experienced a Caribbean-wide die-off.



Figure J.2-M. Blue tangs at U.S. Virgin Islands.

The mangroves and seagrass beds are important nurseries for many juvenile fish and invertebrates. The Dry Tortugas pink shrimp fishery is supported by larval and juvenile shrimps emigrating from Florida Bay. Coral reefs are also highly productive habitat, supporting many fish and invertebrates. Thus, the health of the mangroves, seagrass beds, bays and reefs directly affect the abundance and composition of fish and invertebrate communities and the fisheries that utilize them. Functional mangrove bays have become extremely limited and/or damaged in the Virgin Islands. Coral Bay in VIIS and Salt River Bay in SARI are some of the few mangrove areas which may still be functioning. Loss of these mangrove areas is directly impacting the fisheries through loss of juvenile developmental habitat for many of the reef fishes.

Most large marine mammals and reptiles in the region have become threatened or endangered, including crocodiles, manatees, sea turtles, and whales. Goliath grouper and the small-toothed sawfish have also received protection status in Florida. Numbers are vastly reduced over historical numbers due to hunting pressures, collisions with boats, entanglement in nets, and altered habitats. It is unclear what

impact larger numbers of herbivores such as green sea turtles and manatees historically had on marine systems. Their loss and the loss of top predators such as goliath grouper is a great concern, however.

Marine fish and invertebrate communities (see Figure J.2-M) are under considerable pressure due to overfishing, damaging fishing methods, contaminants and changes in mangroves, seagrass, and coral reefs (including habitat loss). The largest changes in parks that allow commercial and recreational fishing have been losses or severe reductions in the large top predators in the system and reductions in the numbers and size of mid-level predators, herbivores and some crustaceans such as lobsters. Careful park management will be needed to prevent and/or recover from such problems within the park boundaries. BISC is developing a new Fisheries Management Plan to guide how fisheries and fishing activity will be managed over the next 20 years in the face of declining fish stocks and increasing fishing pressure in the park. Buck Island Reef National Monument was established as a marine protected area in 2001 and a section of Dry Tortugas National Park has a Resource Natural Area (RNA) zoned in the current General Management Plan. While controversial, the creation of no-take marine reserves is expected to allow coral reef and seagrass beds to recover along with a balanced marine food web. Healthy fish communities in no-take areas are expected to increase to the point that there will be emigration into the surrounding areas, increasing the size, and number of fish and crustaceans caught by commercial and recreational fisheries outside the no-take areas. However, at present, NPS marine protected areas are still in early phases, need careful evaluation and may not be large enough to effectively replenish surrounding areas.

J.2.4 Potential and ongoing management actions

Knowing what management strategies are potentially available helps with prioritizing among indicators, clearly stating objectives, selecting protocols, and determining sampling designs.

The following regional management programs are underway.

- The Comprehensive Everglades Restoration Program is rehabilitating the hydrology of the Everglades watershed, impacting EVER, BICY, and BISC.
- NPS Fire Management operates on a South Florida regional level, conducting controlled burns during the wet season and controlling unseasonal fires during the dry season to try and mimic natural historical fire patterns across the landscape while maintaining human safety.
- NPS Exotic Plant Management Program operates on a regional level across SFCN parks, controlling invasive plant species and recently initiating some actions on invasive fauna.
- The South Florida Multispecies Recovery Plan (USFWS 1999) and the Comprehensive Wildlife Conservation Strategy for the U. S. Virgin Islands

(Platenberg et al. 2005) were prepared to guide efforts to recover federal listed species and restore and maintain biodiversity of natural communities.

More localized management actions include:

- Develop and implement best management practices for urban, agricultural, and construction areas that affect nutrients, pesticides, water runoff, and sedimentation in park waters
- Minimize contaminant impacts on the system including mercury, pesticides, pharmaceuticals, etc. This may involve seeking additional regulations for the sources of contaminants
- Acquire land to expand parks or work out agreements to maintain buffer area around parks
- Public education, signage, and communication of park regulations
- Enforcement of scientifically based regulations regarding fishing and hunting such as minimum fish and shellfish take size, bag limits, and restrictions on fishing gear
- Minimize new introductions of invasive species through public education, work with local nurseries and bait shops, and early detection at likely establishment sites
- Rapid response to vessel groundings and effective notification of authorities and cleanup experts, charge fees to grounded boat owners who damage resources
- Develop and implement best management practices regarding visitor use such as off-road vehicle activity, slowing boats in manatee zones, etc.
- Regular trash pickups, park cleanup days, use animal proof trash receptacles.
- Location and removal of abandoned fish gear
- Conduct restoration of mangroves, wetlands, beaches, seagrass beds, coral reefs
- Maintenance or alterations of structures such as canals around Cape Sable in Everglades
- Strong enforcement of fishing, water quality, illegal dumping, poaching and other regulations
- Establish mooring buoys and/or mooring zones to reduce anchor damage
- Maintain accurate park maps and install navigational aids to prevent vessel groundings
- Implement and evaluate effectiveness of no-take zones in allowing reef, seagrass, fish, and crustacean communities to recover and successfully reproduce, and the degree that they improve harvests in nearby waters outside of the parks; modify zones as necessary
- Seasonally or temporarily close areas to keep visitors away from sensitive areas, rare plants, seabird nesting, etc.
- Provide additional protection and assistance to listed species as needed, such as increasing connectivity among populations, reintroducing populations, rehabilitating habitat quality, research into causes of declines

- Limit boat speeds (with enforcement) in areas with manatees
- Protect fauna road-crossing points (corridors) by slowing speeds and/or creating underpasses and barrier fences

APPENDIX J.3

FRESHWATER PRAIRIES AND MARSHES ECOLOGICAL ZONES

Appendix J.3 Freshwater Prairies and Marshes Ecological Zone

The following conceptual model draws strongly throughout from the following references: Ogden (2004), Davis (2004a), Lodge (2005), USFWS (1999), Thornberry-Ehrlich (2005d), and Rutchey *et al.* (2005). The reader is strongly referred to these references for more detailed information.

J.3.1 Summary

The Freshwater Prairies and Marshes Ecological Zone is a vast, shallow, clear-water, oligotrophic (low nutrients) system that includes the deeper regions of Shark River Slough, Taylor Slough, Lostmans Slough, and Mullet Slough plus large expanses of wet prairies. This zone expands northwards outside the parks into the state-managed Water Conservation Areas and the hydrology of the Everglades is highly dependent on water management in these areas (see Figure J.3-A; see also Figure J.4-A in the Forest Uplands and Wetlands Ecological Zone model).

Freshwater Marsh (includes slough)

Freshwater marshes are graminoid/herbaceous wetlands with long-hydroperiods of historically around 10-12 months, although post-Everglades drainage hydroperiods range from 7-12 months (see Figure J.3-C). The faster-flowing center of the broad marshy river is called a "slough." However, the topography is more complex than a single flat river. Slightly elevated sawgrass "ridges" are interspersed with deeper "sloughs" with tree islands called hammocks or heads dotting the landscape. Vegetation in these long-hydroperiod marshes is typically dominated by sawgrass (*Cladium jamaicense*), spikerush (*Eleocharis spp.),* and panicgrass *(Panicum hemitomon*, *P. rigidulum*) (Rutchey *et al*. 2005). (Please note: Tree islands are covered in greater detail in the Forested Uplands and Wetlands zone). Everglades National Park contains two distinct sloughs: Shark River Slough, the main slough, and Taylor Slough, a narrow, eastern slough that flows into northeast Florida Bay. Lostmans Slough and a series of other sloughs through Big Cypress National Preserve supply freshwater to northwest Everglades and the Ten Thousand Islands.

Some deeper areas of sloughs, plus canals and borrow pits, have water all year round and typically contain open water with a myriad of sparse graminoid and emergent vegetation such as spikerush (*Eleocharis* spp.), panicgrasses (*Panicum* spp.), low stature sawgrass (*Cladium jamaicense*) , cattail (*Typha* spp.), arrowhead (*Sagittaria* spp.), pickerelweed (*Pontederia cordata*), waterlily (*Nymphaea* spp.), green arum (*Peltandra virginica*), swamp-lily (*Crinum americanum*), spider-lilies (*Hymenocallis* spp.), etc. (Rutchey *et al*., 2005). These areas concentrate larger aquatic species during dry-down

periods, becoming popular wildlife viewing areas (e.g., Anhinga Trail) (see Figures J.3-D and J.3-E).

Freshwater wet prairies
Wet prairies border the deeper marshes; they have short-hydroperiods (historically 5-9 months, but post-drainage around 2-8 months) and they are dominated by graminoid/ herbaceous plants (see Figure J.3-B). Wet prairies include marl prairies, short-sawgrass prairie, muhly prairie, mixed grass/sedge prairies and rocky glades prairies and typically include vegetation dominated by *Muhlenbergia filipes*, *Schizachyrium rhizomatum, Paspalum monostachyum, Schoenus nigricans,* sparse *Cladium* species (< 1.5 m tall), *Panicum tenerum*, sparse *Rhynchospora*, and/or *Spartina bakeri* (freshwater only) (Rutchey *et al*. 2005). These large wet prairies have marl sediments (marl is a calcareous material produced by periphyton that settles on the limestone). These prairies extend on either side of the deeper Shark River and Taylor Sloughs and also occur as glades among forest areas (see Figure J.3-A).

The freshwater wet prairies and marshes of EVER and BICY are valued for their unique ecosystems with world-wide preservation value; the rich abundance and diversity of wading birds, fish, and vegetation including unique and rare listed species; recreational fishing, canoeing, and wildlife viewing opportunities; their cultural heritage; ORV use in BICY; and as a watershed for Florida Bay and the Ten Thousand Islands.

The main physical driver in this system is the hydrology and geomorphology. Seasonal rains historically caused Lake Okeechobee to overflow in a shallow, wide sheet that moves at a leisurely rate that averages around 100 feet (30 meters) per day. This process channeled life-giving waters through the Water Conservation Areas into Everglades National Park and out into Florida Bay (see Figure J.3-A). When the fish and invertebrates of this vast "river of grass" are concentrated along drying fronts, they have historically supported large numbers of wading birds, alligators, and other wildlife. Other key drivers are major weather events, water quality (nutrients and pH), and fire frequency and severity. Additional important biological drivers include alligators which maintain and enhance alligator holes and the periphyton mat. The major anthropogenic stressors are the water diversions, canals, levees, and water level reversals that have severely altered the system hydrology, (i.e., flood duration, depth, seasonality, and effects of droughts). Other stressors include the reduction in habitat outside parks, fire suppression and altered fire seasonality, invasive plants and animals, contaminants including mercury and pesticides, and phosphorous enrichment. Roadkill along Tamiami Trail and, to a lesser extent, along park roads is a further stressor. ORV use in BICY is a stressor in the dry season. Airboats used to be a stressor but are now restricted within Everglades National Park.

Anticipated changes in zone extent and biological attributes of particular note include a reduction in the freshwater and marshes zone due to sea level rise and as

trees and shrubs invade due to altered hydrology and fire regimes; changes in extent and distribution of wet prairie, marsh and slough communities and alterations in community structure due to altered hydrology, altered fire regimes, increased phosphorous inputs and invasive species; changes in the periphyton mat species composition; reductions in the biomass of fish and invertebrates produced in the vast wetland; declines in wading bird communities and shifts in locations of supercolonies; impacts of mercury bioaccumulation on top predators; introduction of new top predators; movement of alligators out of the drying wet prairies; and the cumulative impact of these changes and stressors on the abundance and community composition of fish, invertebrates, herpetofauna, passerine birds, raptors, wading birds, mammals, etc. including rare and listed species.

The key management issues in the Freshwater Prairies and Marshes Ecological Zone include rehabilitation of system hydrology, fire management, controlling and preventing the introduction of invasive plants and animals, reductions in phosphorous loading from outside the park, determining methods to reduce or mitigate mercury bioaccumulation, managing recreational impacts, and protection and management of rare plants and animals.

Figure J.3-F shows the interrelationships among natural system drivers, anthropogenic stressors, and biological system attributes (e.g., primary producer dynamics and consumer interaction dynamics). A simplified Freshwater Wet Prairies and Marshes food web is shown in Figure J.3-G. The remainder of this conceptual model consists of describing the drivers and stressors in greater detail. The section headings discussed include:

- Driver: Hydrology and geomorphology
- Stressor: Freshwater diversions, canals, levees, flood control and water level reversals
- Driver: Major weather events - hurricanes and tropical storms
- Driver: Alligators create/ deepen holes and depressions
- Driver: Fire frequency and severity
- Stressor: Fire suppression and altered seasonality
- Driver/stressor: Water quality – nutrients (especially excess phosphorus)
- Stressor: Water quality – contaminants (mercury, pesticides)
- Stressor: Reduction in habitat outside parks.
- Stressor: Introduction and spread of invasive plant species
- Stressor: Introduction and spread of invasive fauna
- Stressor: Roadkill

In the subsequent section the effects of these physical drivers, key background attributes, and anthropogenic stressors on the following key system attributes are discussed:

- Change in extent and distribution of Freshwater Prairies and Marshes Zone

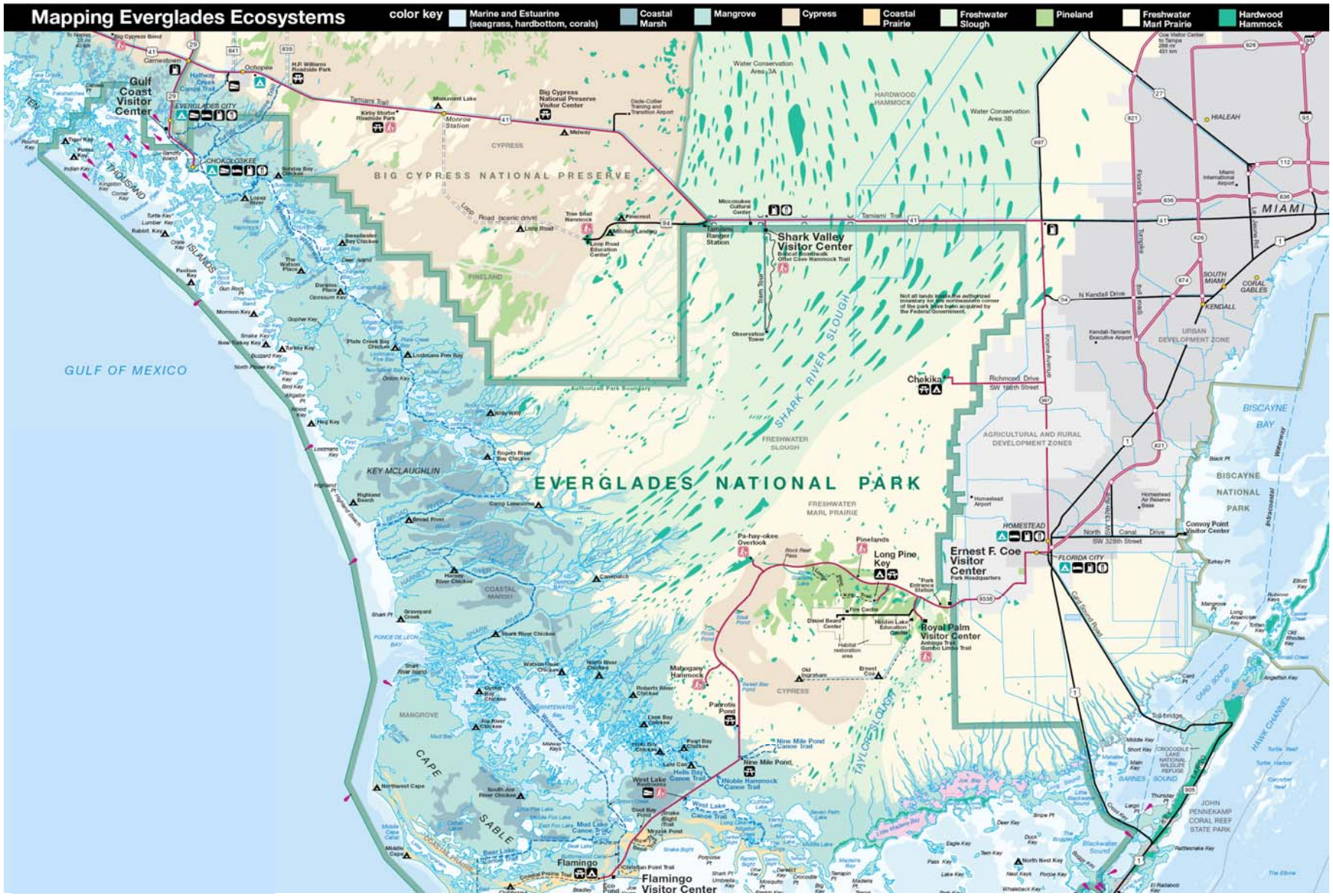


Figure J.3-A. Park Map of Everglades National Park. "□eshwater marl prairie" in the map corresponds to "freshwater wet prairie" and "□ freshwater slough" to "freshwater marsh" in the Freshwater Prairies and Marshes Ecological Zone Conceptual Model.



Figure J.3-B. Muhly grass wet prairie in glade near Long Pine Key in EVER during dry season.



Figure J.3-C. Sawgrass marsh at Taylor Slough in EVER during dry season



Figure J.3-D. Deeper permanent slough (borrow pit?) at Shark River Valley Trail in EVER during dry season.



Figure J.3-E. The permanently flooded borrow pits at Anhinga Trail in EVER have become a popular wildlife viewing area.

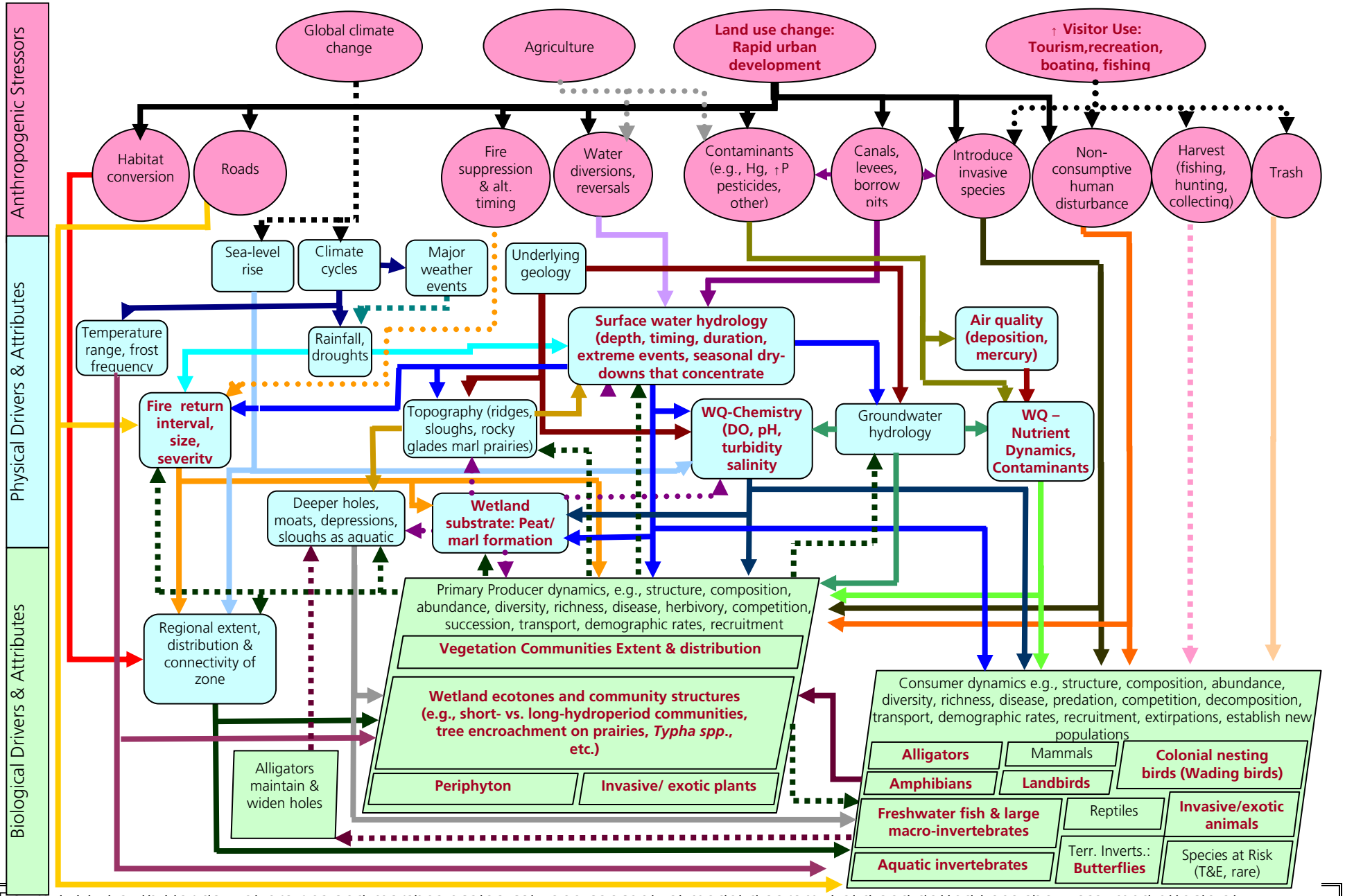


Figure J.3-F. South Florida wet prairies and marshes ecological zone conceptual model diagram. Solid and dotted lines show assumed effects of anthropogenic stressors, physical and biological drivers and attributes. Boxes with **red print** directly relate to a proposed Vital Sign. (Use of dotted lines is used to clarify and does not indicate lesser importance).

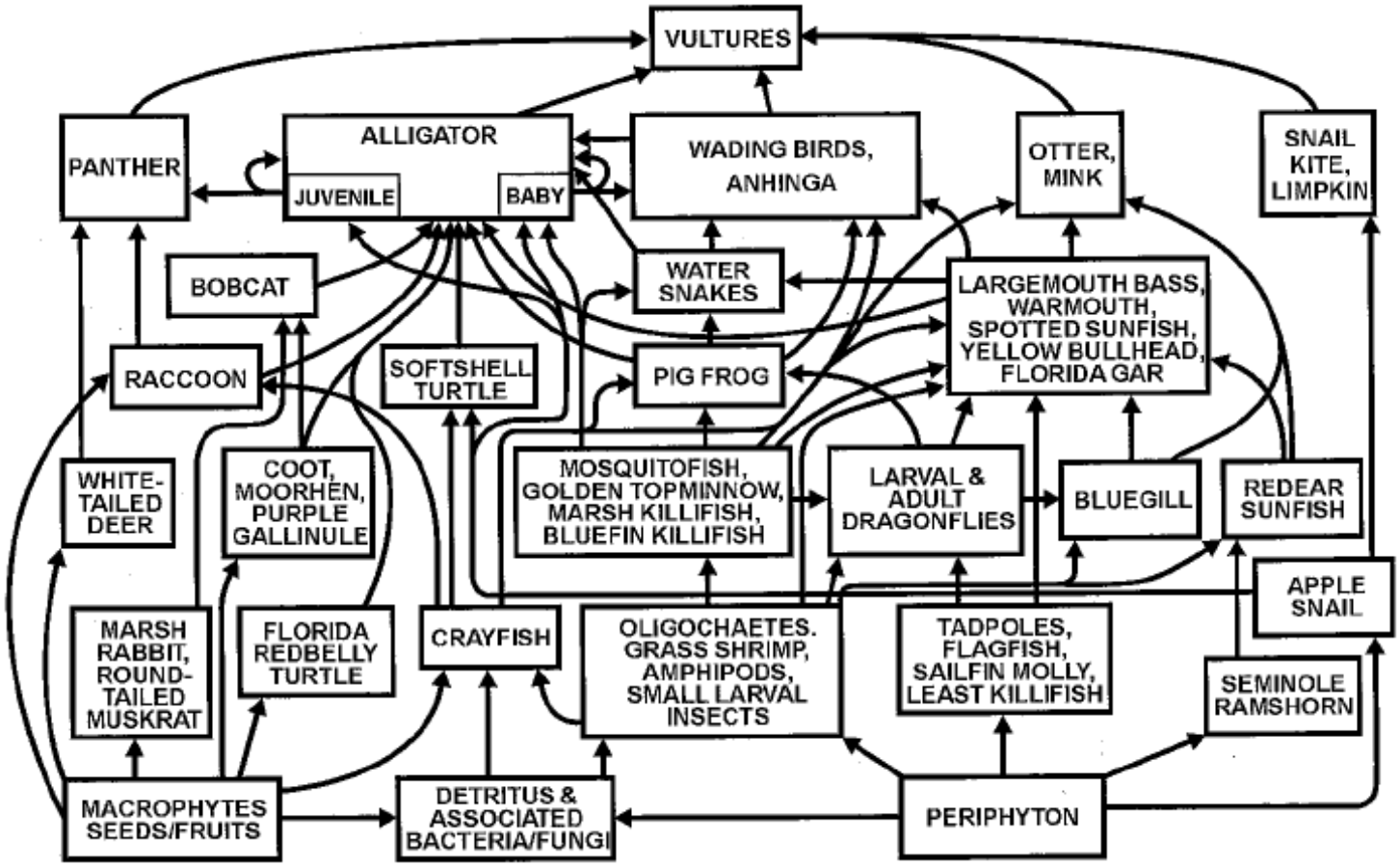


Figure J.3-G. Wet prairies and marshes food web [Figure from Lodge 2005].

- Change in primary producer dynamics, (e.g., vegetation composition, structure, and function);
- Change in consumer dynamics, (e.g., fauna food web structure, guild composition and abundance, and distribution and abundance of keystone species, top-down predators, and rare species)

J.3.2 Physical Drivers, Key Background Attributes, and Anthropogenic Stressors

J.3.2a Drivers: Geology, topography and surface hydrology (depth, seasonality, duration, extreme events); salinity intrusion; groundwater hydrology, concentrated drying fronts, alligator holes and depressions provide aquatic refugia

Summer rains historically caused Lake Okeechobee to overflow in a shallow, slow-moving sheet that has historically moved south and southwest across EVER and the eastern half of BICY, existing in Florida Bay and the Ten Thousand Islands. The deeper part of the "river of grass" is found in the Water Conservation Areas and the Shark Slough and Taylor Slough areas of the Everglades. These deeper areas grade into shallower portions of the Everglades called wet prairies. The shallower parts of the "river of grass" are found in broad expanses bordering the deeper sloughs and as glades among the forested wetlands.

Water depth, duration, and timing strongly affect vegetation and soil composition, structure, and function creating a mosaic of vegetation communities along a hydrology gradient. The deeper portions are graminoid/herbaceous marsh with historically longer hydroperiods of typically 10-12 months, with the deepest sloughs, canals, and borrow pits remaining flooded all 12 months (current hydroperiods due to altered Everglades hydrology are approximately 7-12 months). The longer hydroperiod areas remain submerged long enough that dead plant material does not have enough time to decompose and instead accumulates as peat, creating histisols (Loxahatchee and Everglades peats) underlain by limestone. The peat acidifies the water, which in turn prevents the formation of the marl deposits seen in short-hydroperiod prairies.

Wet prairies are graminoid/herbaceous short-hydroperiod prairies that border the deeper marshes. Wet prairies were historically flooded for 5-9 months with some as short as 2-4 months (current hydroperiods range from 2-8 months). The increased exposure to air prevents peat from accumulating. Instead the soils are entisols with a build up of marl, a calcareous layer deposited by blue-green algae.

The Water Conservation Areas and the Shark River Slough area are deeper areas of the "river of grass" that form a ridge and slough system with higher sawgrass ridges running next to deeper sloughs (see Figure J.3-H). Slough depths typically range from 1 to 3+ feet and were probably greater historically. The dynamics of this topography are not completely understood, but appear related to water movement.

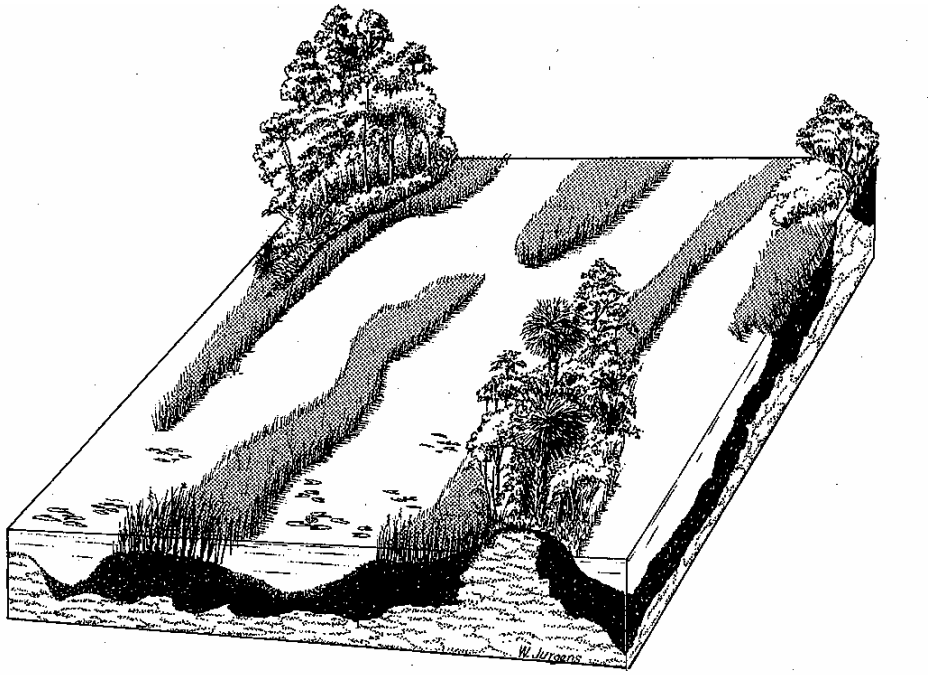


Figure J.3-H. Ridge and slough complex found in Shark River Slough and Water Conservation Areas. Tree islands will sometimes form on the ridges, especially where the underlying limestone substrate protrudes upwards [Figure from Lodge 2005].

Tree islands are an important feature of the landscape in the ridge and slough system. Most of the drivers and stressors regarding tree islands are dealt with in the Forested Uplands and Wetlands Ecological Zone Conceptual Model. However, the presence of tree islands as well as the ecotone between marsh and tree island increases overall faunal species diversity. Tree islands also provide food for deer, perches for predatory hawks and kites, and some upland refugia for terrestrial species during deeper floods. Tree islands appear to form on high points in the underlying limestone, on higher sawgrass "ridges," and on peat "pop-ups;" but the processes are not completely understood.

When the rains cease, water begins receding on the floodplain forming a "drying front." Presence of aquatic refugia in the form of alligator holes, solution holes within the marl, deeper "moats" around tree islands and sloughs provide areas for small fish, invertebrates, and amphibians to survive during dry seasons. These refugia, and also drying fronts in general, provide highly concentrated food sources for wading birds and other fauna as retreating waters concentrate aquatic fauna. The small fish, invertebrates, and amphibians that are able to survive in these refugia are then able to quickly disperse and re-colonize flooded areas allowing faster reproduction and increases in population densities. Some are able to survive in only small amounts of damp mud under the periphyton mat. These deeper areas provide habitat for species requiring longer hydroperiods such as *Sagittaria lancifolia* and apple snails. In addition, alligator holes and solution holes often have higher levels of

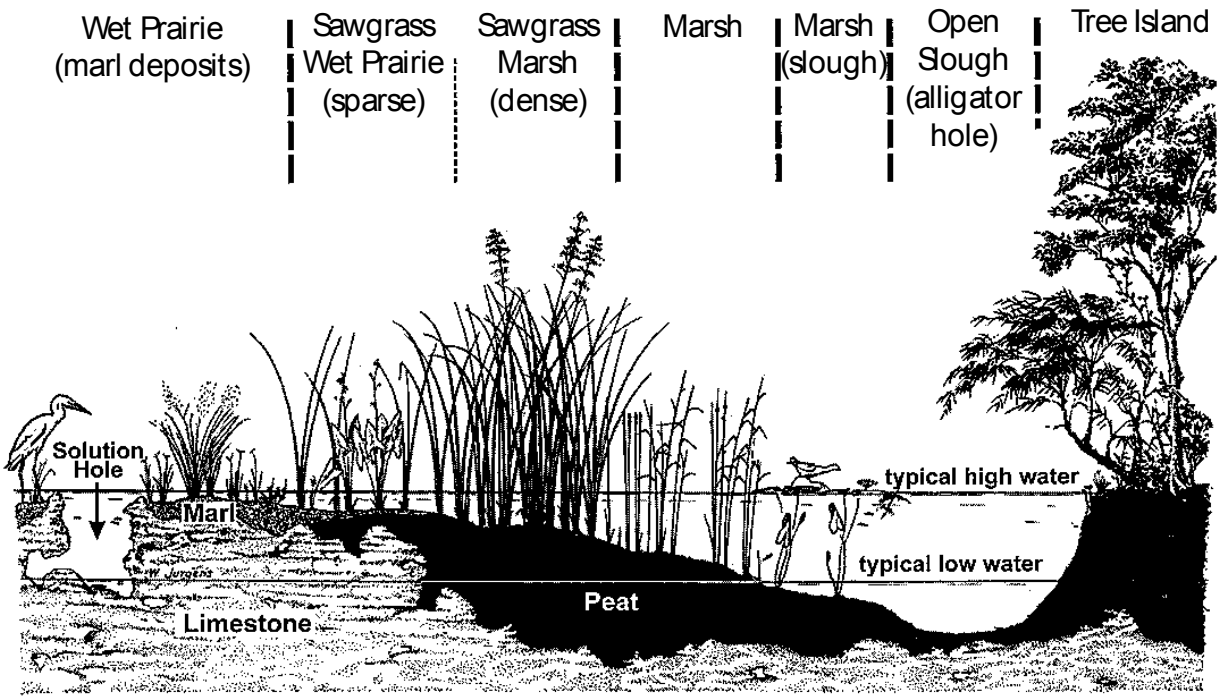


Figure J.3-I. Simplified gradient from wet prairie to marsh to open slough and the changing hydrology involved. Note that in the wet prairies, marl deposits dominate while in the longer hydroperiod marshes peat accumulation occurs. Solution holes occur in the "rocky glades" area of Everglades [Figure modified from Lodge 2005].

nutrients. This is due to alligator and wading bird excrement which affects the vegetation communities surrounding the holes.

Deeper sloughs, borrow pits and canals with hydroperiods of 10-12 months function as aquatic refugia during the driest months for wetland species, as thermal refugia for tropical species during cold temperature events, and provide habitat for larger predaceous fish, turtles and other wildlife requiring permanent water.

J.3.2b Stressor - Freshwater diversions, canals, levees, flood control and water level reversals

The historical water flow in the Everglades was altered during the past 50 years by the Central and Southern Florida (C&SF) Project in order to provide a reliable water supply, flood protection, water management, and other benefits to south Florida agricultural and urban areas. To accomplish this, 1000 miles of canals, 720 miles of levees and hundreds of water control structures were built (CERP web page, http://www.evergladesplan.org/about/rest_plan.cfm). The result was a major modification in the Everglades watershed and a severe reduction in the amount of water flowing into the Everglades with unintended adverse impacts on the unique and diverse flora and fauna of the Everglades, Florida Bay, eastern BICY and Biscayne Bay (See Figure J.3-J).

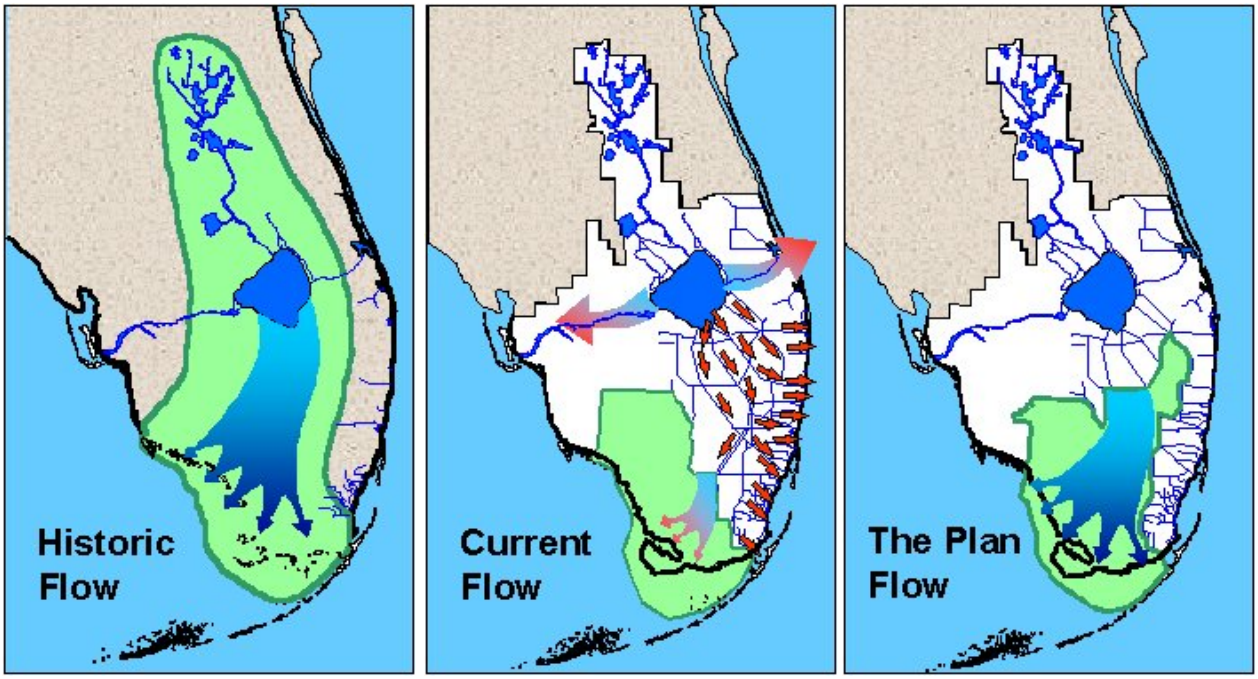


Figure J.3-J. Figures show the historic flow pattern of the greater Everglades system, the current flow patterns, and the projected flow patterns under the Comprehensive Everglades Restoration Plan. (From the Comprehensive Everglades Restoration Plan web site http://www.evergladesplan.org/facts_info/maps.cfm) (downloaded 8/10/2005).

These alterations in the Everglades watershed and hydrology have disrupted natural patterns of sheet flow direction, extent, depth, and duration with altered timing of high water and low water events. Compartmentalization, coupled with wet season water level reversals and drying pattern reversals, also disrupt the system. Overall these have led to gradual alterations in the mosaic of vegetation communities across the landscape, severe impacts on fish and invertebrate communities, and major alterations in wading bird populations and nesting colonies.

Reductions in the amount of sheet flow into the Everglades have resulted in shortened hydroperiods allowing invasion of wet prairies by woody species, invasion of sloughs and longer hydroperiod marsh by sawgrass, and general alterations of vegetation composition in marsh communities (Davis 2004a; Ogden 2004). This in turn, has reduced abundance (number and biomass) of fishes, crayfish, grass shrimp, frogs, turtles, and many other forage species with corresponding impacts on wading birds, alligators, etc. The spread of invasive plants such as *Melaleuca quinquenervia* and *Casuarina spp.* is enhanced as they can opportunistically invade the drier "wet prairies."

The increased amount of woody vegetation provides roosts for raptors, making formerly favorable wet prairie and marsh habitat unfavorable for species such as the

federally endangered Cape Sable Seaside Sparrow. Water level reversals, shortened hydroperiods and drought have negatively impacted Cape Sable Seaside Sparrow communities.

Greater frequencies and durations of marsh dryouts also cause a lowering of the water table, exposing peat soils to oxidation by air and to fires, causing soil loss and subsidence which further alters local hydrology. The drier vegetation further increases frequency and impact of fires which alter vegetation and peat. The drying of the wet prairies has also caused alligators, a keystone species, to move from wet prairies into deeper slough areas (Davis 2004a). The shortened hydroperiods also tend to cause a shift in the periphyton from green algae and diatoms to less nutritious calcareous blue-green algae (Ogden 2004).

The deeper part of the Everglades system now occurs in the Water Conservation Areas (WCAs) whereas historically the deepest area was located in northeast Shark River Slough. Compartmentalization of the WCAs due to canals and levees has resulted in unusually deep and shallow areas of water that are causing flooding and loss of some tree islands in the WCAs. In addition the deeper flooding in some parts of the WCAs has resulted in a loss of shallow water habitat for wading birds and stress on fish communities, vegetation communities, and periphyton communities. Other areas have experienced shallower water depths and are also showing vegetation community changes.

Pulsed discharges with rapid reversals of flow can severely impact the reproductive and foraging success of many species. For example, rapid flooding and water level changes can flood and kill alligator nests, turtle nests, Cape Sable Seaside Sparrow nests, and apple snail egg masses. In addition, raising of water levels above the tops of sawgrass shoots immediately after a burn can cause sawgrass death, resulting in replacement by a different vegetation community, such as maidencane or muhly grass.

The canals have also enhanced the influx of nutrient enrichment deeper into the Everglades and provided conduits for invasive species.

J.3.2c Driver: Major weather events – (e.g., hurricanes, tropical storms, droughts – and effect of sea level rise)

Major weather events such as periodic hurricanes and tropical storms bring high winds and heavy flooding, which can cause rapid increases in water levels and flooding. This can drown plants recently damaged by fire if water completely submerges the plant shoots. Storm surges can carry salt water into freshwater areas causing impacts to marshes, especially if salt water becomes trapped behind coastal berms. This could result in changes in vegetation composition as non-salt tolerant species are killed. The rapid decomposition in freshwater marshes in the Cape Sable area appears to be accelerated by storms. Storm surges can also carry propagules such as red mangroves far inland where they can establish in prairies and marshes.

Sea level rise, which will probably be in the range of 1-3 feet over the next century, is expected to cause an inland movement of mangroves and tidal marsh and a retreat of freshwater marshes. The changes are difficult to predict and some changes could occur suddenly as large storm surges alter older berms and levees and create new berms, causing rapid inundation of formerly freshwater marshes. See Section J.5 for more discussion on this issue.

J.3.2d Driver: Alligators create/ deepen holes and depressions

Alligator holes in marshes and wet prairies provide important refugia for fish, amphibians, and invertebrates during dry-downs, allowing them to escape larger predaceous fish in the deeper sloughs and to disperse and re-establish across the floodplain when the wet season resumes. These holes also become critically important feeding sites for wading birds as fish and invertebrates become concentrated in them.

J.3.2e Driver: Fire frequency and severity

Fire is a natural driver of this zone. Fire eliminates encroachment of shrubs and trees into wet prairies and marshes and releases nutrients in vegetation and peat, making them accessible for plant uptake. Deeper peat fires occur typically about once a decade, setting back succession and opening up and perpetuating long-hydroperiod marshes. Figure J.3-K shows plant succession processes in presence and absence of fire. In addition, fires indirectly affect system hydrology (e.g., large, dense, unburned areas of sawgrass south of highway US 41 slow the southern-bound sheet flow).

Historically, most fires occurred during summer months when lightning started fires that were usually small and didn't destroy the submerged soil and roots. Dry season fires occurred less frequently in April or May. These fires were more destructive, destroying peat soils and roots.

J.3.2f Stressor: Fire suppression and altered seasonality

Human-initiated fires frequently occur during the dry season in winter and early spring. These unseasonal fires are larger, hotter, vegetation-altering fires which can get into the exposed peat layer causing soil volume loss and destroying plant roots.

Historical fire suppression and use of roads as fire breaks also impacted wetlands, altering the normal pattern of fire across the landscape and allowing increased shrub encroachment into wet prairies and marshes. Current fire management practices are trying to better mimic the natural system while maintaining human safety.

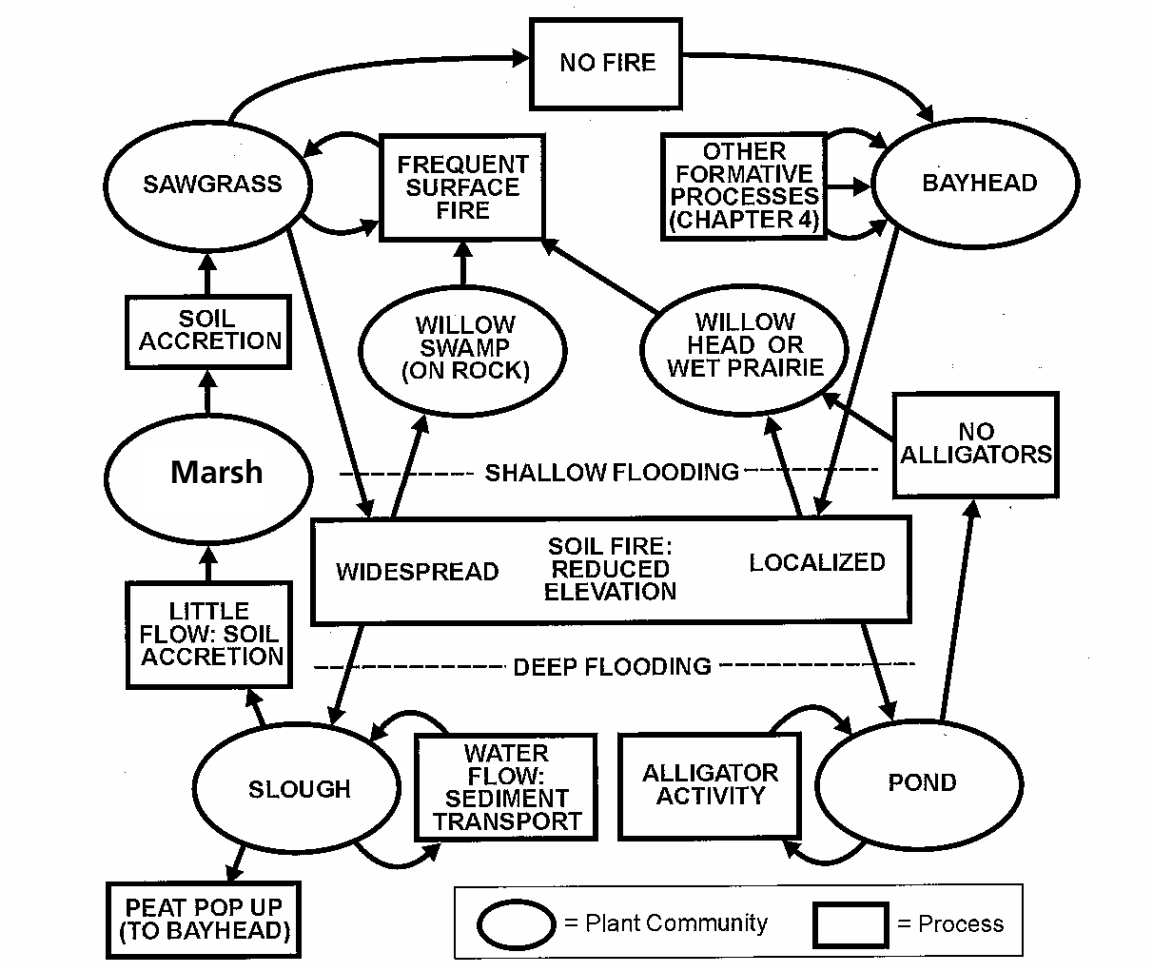


Figure J.3-K. Plant community succession and relationship to fire, flooding, and soil accretion processes in the deeper ridge and slough system of Everglades marshes. [Modified from Lodge 2005]

J.3.2g Driver/stressor: Water quality – nutrients (especially excess phosphorus)

The Everglades system is historically oligotrophic (low nutrient). However, increased phosphorus from the Everglades Agricultural Areas and urban areas has resulted in shifts in periphyton algal community from green algae and diatoms to less nutritious calcareous blue-green algae; increases in the density of grasses which shade the periphyton mat; increases in cattail density (*Typha* spp.) in sawgrass habitat; eutrophication and low dissolved oxygen in water which stresses fish and invertebrates; and may be associated with increased disease outbreaks in wading birds (eustrongyloidosis caused by a nematode (USFWS 1999)). Increased nitrogen is also a concern although phosphorous loading is considered a more important problem at present.

J.3.2h Stressor: Water quality – contaminants (mercury, pesticides, etc.)

Mercury is probably the biggest contaminant problem in south Florida parks. Aerial mercury deposition in EVER and BICY is thought to come from waste incineration

and electricity production from burning of fossil fuels at both local and distant sources. Mercury becomes methylated in marshes (biologically active) and bioaccumulates to toxic levels in fauna at higher trophic levels in the food chain (e.g., bass, pig frogs, wading birds, panthers, and alligators). Mercury is thought to have contributed to the deaths of at least three Florida panthers (USFWS 1999). Pesticides, herbicides, and fungicides from agricultural areas south of Lake Okeechobee, the eastern edge of EVER and north of BICY are also a concern. Organochlorine pesticides are also bioaccumulated and are suspected in causing lowered testosterone and small penises in alligators in Lake Okeechobee. The effects in the Everglades are unclear, but are a concern.

With a rapidly changing urban region and constant changes in technology, new contaminant problems are expected to be an ongoing challenge.

J.3.2i Stressor: Reduction in habitat outside parks.

Former marshes to the south of Lake Okeechobee have been converted to agriculture and former wet prairies have been drained and converted to agriculture along the eastern side of Everglades National Park. This reduced the total amount of freshwater inflow that enters the Everglades and affects the dynamics that create the diversity of ridge, slough, and tree island habitats. The reduction in total acreage also reduces the total biomass of fish and invertebrates produced in this oligotrophic system, affecting upper trophic levels that rely on these food sources during critical dry-down periods.

J.3.2j Stressor: Introduction and spread of invasive plant species

Invasive plants are a major threat to south Florida wet prairies and marshes. They compete with and replace native vegetation, create habitat that is less favorable or completely excludes native species, and frequently create habitat that may be more favorable to invasive species. Especially problematic species include: Brazilian pepper (*Schinus terebinthifolius*), melaleuca (*Melaleuca quinquenervia*), Australian pine (*Casuarina equisetifolia*), old world and Japanese climbing ferns (*Lygodium* spp.), water hyacinth (*Eichornia crassipes*), hydrilla (*Hydrilla verticilata*), water lettuce (*Pistia stratiotes*), torpedo grass (*Panicum repens)*, air potato (*Dioscorea bulbifera*), tropical soda apple (*Solanum viarum*), and water spinach (*Ipomoea aquatica*). Other species are listed in Appendix G. Invasive plant species are frequently introduced as ornamentals which then escape into nearby natural areas or are released from aquariums. Canals provide conduits for some invasive plants, whereas others appear to be distributed via wind and birds as well as by water. Alterations in the timing and severity of fires, alterations in hydrology, and nutrient enrichment can allow non-native vegetation to invade stressed communities. Once established some species simply spread further following fires. Urban edges and park inholdings can provide seed sources for invasive species to establish within park boundaries.

J.3.2k Stressor: Introduction and spread of invasive fauna



Figure N.2-L. Alligator with large non-native python in its jaws. Photo by Everglades National Park staff.

Invasive fauna are another major threat to native flora and fauna. Released pets, escapes from aquaculture and ornamental fish culture industries, and fishing bait are frequent sources of new invasive species. In addition, local people sometimes deliberately introduce fish into canals that they plan to harvest later. Exotic fish alter wet prairie, slough and canal fish communities and food web dynamics. In general, canals, borrow pits, and detention ponds contain more invasive species than the marshes, sloughs, and ephemeral wet prairies. Short- and long- hydroperiod wetlands near source habitats such as canals and headwater tidal creeks show higher numbers of introduced fishes than wetlands further away (Trexler *et al.* 2001; and recent park-wide monitoring work within EVER (Jeff Kline, personal communication)).

Problematic, introduced fish include cichlids (*Astronotus* spp., *Cichlasoma* spp., *Hemichromis* spp), live bearing pike killifish (*Belonesox belizanus*), *Tilapia* spp., walking catfish (*Clarias batrachus*), and Asian swamp eel (*Monopterus albus*). Several species of introduced fishes such as African jewelfish (*Hemichromis letourneuxi*) and black acara (*Cichlasoma bimaculatum*) use solution hole habitats and prey upon the smaller native species. Canals increase the spread of invasive fauna into water conservation areas and areas neighboring EVER, increasing their consequent spread into the park. In addition when canals are over-topped to contribute to sheet flow, this increases the spread of introduced fishes directly into EVER. The short-hydroperiod wetlands along the eastern boundary have the most introduced species within EVER (Jeff Kline, personal communication).

Burmese pythons and other introduced constrictors are becoming established as a new top predator in EVER and BICY with unknown consequences to the food web. Feral and domestic cats (*Felis domesticus*) prey on native songbirds and small fauna at a level far higher than native bobcat predation, often creating severe "sink" habitat around residential areas. However, flooding restricts their intrusion into the park. The Cuban tree frog (*Osteopilus septentrionalis*) readily eats smaller native frogs. The purple swamp hen (*Porphyrio porphyrio*) has been established just outside the WCAs and may eventually impact the park. Invasive apple snails (*Pomacea "canaliculata group*") have recently been collected within EVER and are a large concern because of their potential impacts on Everglades wetlands and native apple snails.

J.3.2l Stressor: Roadkill

High-speed highways such as the Tamiami Trail (US Hwy 41) and Interstate 75 have become mortality sinks for fauna such as alligators, panthers, deer, Everglades mink, snakes, turtles, lizards, amphibians etc. Speed limits on roads within the park are reduced and strongly enforced, but roadkill still occurs.

J.3.3 Anticipated Effects of Drivers and Stressors on Ecological Zone Extent and Biological System Attributes

J.3.3a Change in extent and distribution of freshwater wet prairies and marshes zone

Unless system hydrology is restored and without appropriate fire management, the overall extent of the wet prairies and marshes zone is expected to decrease over time as trees and shrubs are expected to invade the wet prairies. With restored hydrology and fire management, the extent of the wet prairies and marshes zone may expand again, eliminating woody encroachment.

Rising sea levels are expected to convert some coastal freshwater marshes to tidal marshes. This may already be occurring as some noticeable freshwater marsh collapse is occurring in the Cape Sable areas. The extent and location of these changes are difficult to predict, but will cause a net loss of freshwater marsh in the parks.

J.3.3b Change in primary producer dynamics, (e.g., vegetation composition, structure, and function)

Vegetation communities in freshwater wet prairies and marshes are a function of water depth, hydroperiod, flow velocity, timing of flooding and soil type. Unless system hydrology is restored, there is concern that vegetation and soils are changing to reflect the altered hydrological gradient, (i.e., that woody vegetation will invade wet prairies, that wet prairie vegetation will extend further into what was formerly marsh and slough areas, and that deeper slough areas will be reduced). The conversion of marsh to wet prairie and the drying out of the wet prairies is a major concern. As water levels continue to drop, peat is exposed to oxidation and fires. The subsequent loss of peat then alters local topography and hydrology. The role of fire will also be critical, as this will affect the rate of woody encroachment, wetland vegetation community change, and burning of the peat layer.

The periphyton mat is a key biological driver at the base of the food web in this low nutrient, oligotrophic system. The periphyton mat provides an important primary production base for the aquatic food web, influencing the total biomass of fish and invertebrates. The periphyton mat also creates a moist environment that allows some small fish, amphibians, etc. to survive during dry-downs. Periphyton also produces marl, which leads to marl sediment accretion in wet prairies. Under short-hydroperiod conditions and/or increased phosphorous conditions, periphyton communities change from green algae and diatom dominated communities to

calcareous blue-green algae dominated communities, which are less digestible to consumers.

Invasive vegetation is an extreme and ongoing concern. Some species such as *Melaleuca quinquenervia* and *Casuarina* species which invade wetlands have well-established control methods. Others such as *Lygodium* have had less successful control. Such species have the capability of radically altering the native vegetation community and rendering the environment virtually inhospitable to all but a few native fauna. This is also a big source of unknown problems in the future as new invasive species are introduced and become problematic.

Phosphorous enrichment is another major concern. The main source is hypothesized to be from the agricultural areas south of Lake Okeechobee. Phosphorous enrichment has been associated with expansion of cattails (*Typha* sp.); with favoring invasive plant species; with overall changes in the structure and composition of wetland communities; and with changes in periphyton communities. Excess nutrients also cause denser stands of graminoids which shade out the periphyton mat. Continued phosphorous enrichment is expected to cause the system to further deviate from historical conditions with consequences for the upper food web. Reductions in phosphorous inputs are hoped to facilitate the return to more historical vegetation communities and periphyton mat composition and structure.

J.3.3c Change in consumer dynamics, (e.g., fauna community structure and function, guild composition, distribution and abundance of keystone species, top-down predators, and rare species)

Historically, the Everglades was noted for its large wading bird communities and diversity of wildlife. Unfortunately this is no longer the case. The system is oligotrophic with low densities of fish and invertebrates present over a wide area. These populations are concentrated in drying fronts and serve as dense food resources for wading birds and other predators. The reductions in the extent of wet prairies and marshes and the alterations in the hydrology have greatly reduced the fish productivity and invertebrate productivity and consequently impacted upper trophic levels such as the wading birds. Wading bird colonies have been reduced and their locations have moved and species such as wood stork, roseate spoonbill, and white ibis have been especially impacted.

The wet prairie and marsh food web is complex and depends greatly on the health of the periphyton mat which plays a critical role in this system, providing a food base that supports the food web (see figure J.3-G). Shifts to calcareous blue-green algae due to altered hydrology and increased phosphorus levels produce less palatable food for grazers which, in turn, impacts upper trophic levels.

Apple snails are important prey for a diverse range of species including Everglade snail kites, limpkins, young alligators, many turtles, raccoons, and otters. However, large mats of the invasive water hyacinth (*Eichornia crassipes*) shade out the

submerged aquatic vegetation upon which the apple snails feed. These snails prefer the marsh and slough areas which are being reduced under the restricted Everglades hydrology at present.

The native fish community structure in the sawgrass marshes strongly reflects recent flooding and dry-down events. In the long-hydroperiod marshes, the strongest determinant of fish assemblage structure appears to be dry-down events and the length of time the marsh is flooded after the marsh has completely dried (Chick *et al*. 2004, Ruetz *et al*. 2005, and Trexler *et al*. 2005). Large fish abundance declines (Chick *et al*. 2004), and small fish assemblages shift from species common after lengthy hydroperiods to a species assemblage composed of early colonizers after dry-down events (Ruetz *et al*. 2005, Trexler *et al*. 2005). The longer the marsh remains flooded after a dry-down event, the more common the species that are sensitive to dry-downs become and less common the early re-colonizing species become. In the shorter hydroperiod marshes, it is thought that native species are more common in the shallow solution holes that dry annually because of low minimum water levels. Deeper solution holes tend to be dominated by introduced species and native species that are more tolerant of poor water quality conditions (Kobza *et al*. 2004).

Crayfish and other invertebrates are also important both as predator and prey. Invertebrates can burrow in the mud, waiting for water to return. However, the shortened hydroperiods and increased drying of the wet prairies eliminates aquatic refugia as the water levels drop below the bottom of the holes.

Few species of passerine birds inhabit the wet prairies and marsh habitats year-round. However, species such as the Cape Sable Seaside Sparrow (CSSS) and eastern meadowlark have been negatively impacted by the altered seasonality of fires (i.e., fires occurring in the spring during nesting season). Sudden dry season water level reversals impact species by swamping nests. In addition, the invasion of wetlands by woody species creates roosts for raptors which then directly impact CSSS populations and cause them to abandon former nesting territories.

The tree islands that dot the landscape in the ridge and slough area of the Everglades marsh greatly increase faunal diversity in the area. Their loss due to altered hydrology is likewise expected to impact bird, herpetofauna, and mammal diversity. Deer wade out to the islands to feed. Wading birds roost in the trees. Herpetofauna and mammals use the range of upland to wetland zones.

Alligators are an important keystone species in this ecological zone. In addition to their critical role in maintaining and deepening holes in prairies and marshes, alligators are an important top predator in this system and their nest mounds provide brooding habitat for other marsh reptiles such as red-bellied turtles. However, decreased water levels and shortened hydroperiods have caused alligators to move out of the prairies into the deeper marshes (Davis 2004a). In addition, alligators may

also still be recovering from historic hunting levels that temporarily reduced them to the level of a federally listed species.

Mercury bioaccumulation is also thought to be strongly impacting the wet prairies and marshes food web. Three panther deaths are thought to be related. Other species at the top of the food web that could be impacted include wading birds, raptors, alligators, mink and otters. Thus, mercury bioaccumulation could be contributing to the declines in wading birds, panthers, and other larger species in the area. In addition, organochlorine pesticides remain a concern.

Unknown future problems such as new contaminant problems, new invasive species, and diseases could impact the system in unforeseeable ways.

J.3.4 Potential and ongoing local management actions:

Following, is a list of potential and ongoing local management actions to manage stressors and, if necessary, system drivers in the Freshwater Prairies and Marshes Ecological Zone:

- Rehabilitation of south Florida hydrology north and within the Everglades through alterations in canals, levees, water control structures, and water operations to more closely resemble historical hydrographs through Comprehensive Everglades Restoration Plan (CERP), (e.g., increasing sheet flow, higher flow volumes, maintaining longer hydroperiods marshes and wet prairies of appropriate timing, depth and seasonality; avoidance of wet season water level reversals and drying pattern reversals; reducing compartmentalization and effects of levees, canals and water management structures; and creating underpasses for structures such as Tamiami trail) (see Figure J.3-M).
- Manage fire regimes that mimic natural historical patterns to prevent shrub and tree encroachment into prairies and maintain mosaic of vegetation types
- Control invasive plant species and animal species as needed and, if determined necessary, conduct habitat restoration
- Seek to minimize new introductions of invasive species through public education, work with local nurseries and bait shops, and early detection at likely establishment sites
- Minimize anthropogenic nutrient enrichment of park waters outside of historical range, especially phosphorus, from the Everglades Agricultural Areas.
- Minimize mercury impacts on system, through research and reducing inputs from incinerator and coal-burning emissions
- Minimize organic pesticide input into park waters
- Protect fauna road-crossing points (corridors) by slowing speeds and/or creating underpasses and barrier fences

- Provide additional protection and assistance to listed species as needed, such as increasing connectivity among fauna populations; rehabilitating habitat quality; research into listed species habitat use and needs and further causes of declines
- Perform interagency consultation on proposed projects to minimize impacts

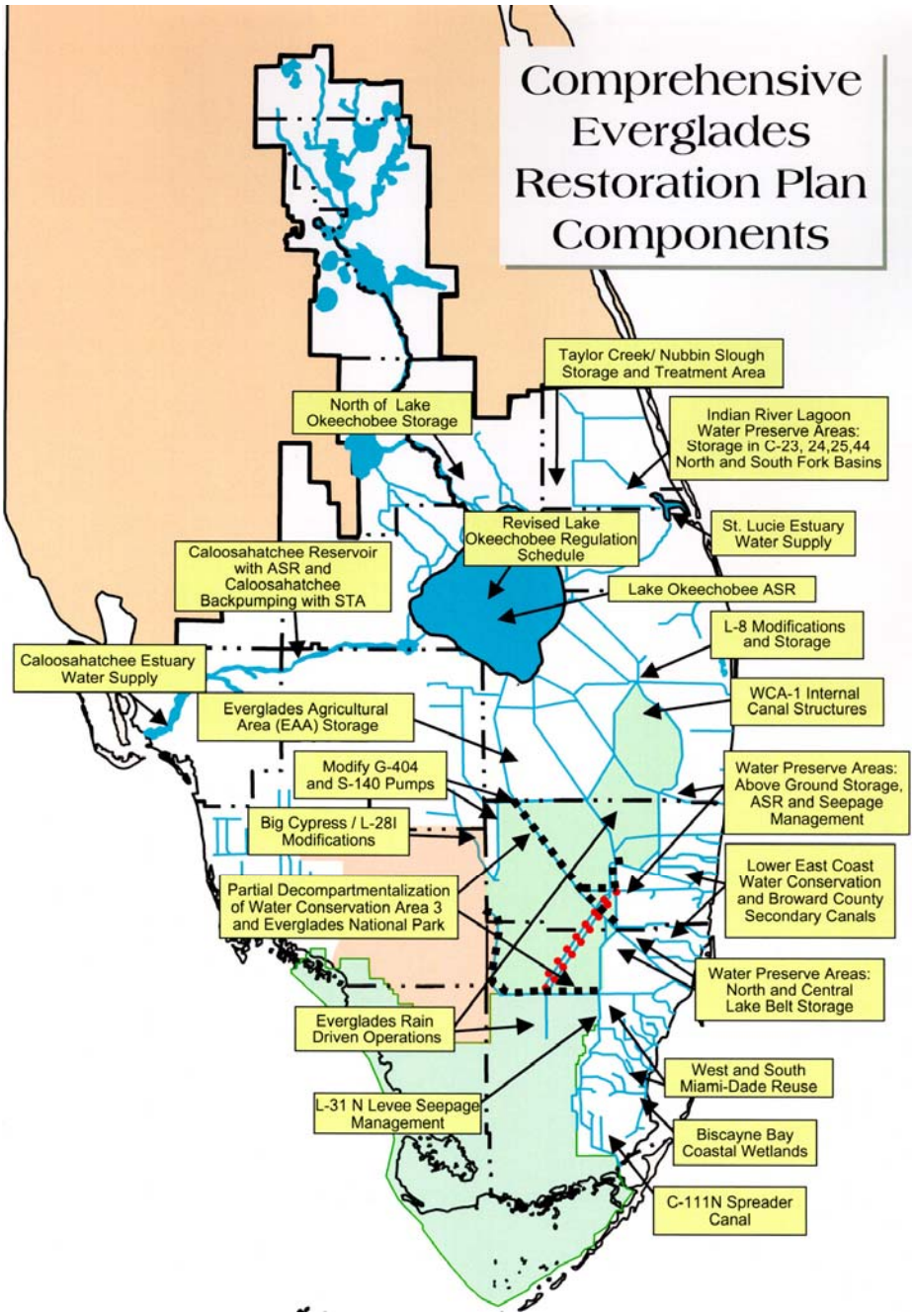


Figure J.3-M. Comprehensive Everglades Restoration Plan map of program components. From Comprehensive Everglades Restoration Plan web page http://www.evergladesplan.org/about/rest_plan_cerpmap.cfm. (downloaded 8/10/2005

APPENDIX J.4

FOREST UPLANDS AND WETLANDS ECOLOGICAL ZONES

J.4 Forest Uplands and Wetlands Zone

The following conceptual model draws strongly from the following references: Deuver (2004); Deuver *et al.* (1979); Lodge (2005); USFWS (1999); Thornberr-Ehrlich (2005a); and Rutchey *et al.* (2005). The reader is strongly referred to these references for more detailed information.

J.4.1 Summary

The Forest Uplands and Wetlands Zone is located in EVER and BICY and consists of pine rocklands and flatwoods, temperate and sub-tropical hardwood hammocks, tree islands, cypress swamps, strands and domes, and dwarf cypress scrub (see Figure J.4-A; see also Figure J.3-A in the Freshwater Prairies and Marshes model). Considerable overlap exists between this zone and the wet prairies, marshes, and sloughs zone as fire and hydrology allow trees to either invade or be eliminated from marshlands. A few of the larger vegetation communities are described below. Other forest and woodland communities are described in Rutchey *et al.* (2005).

Slash Pine Woodland

Slash pine (*Pinus elliottii* var. *densa*) is the dominant overstory species typically occurring in a matrix of diverse herbaceous/graminoid or shrub understory, often including bluestem (*Andropogon* spp.), wax myrtle (*Myrica cerifera*), saw palmetto (*Serenoa repens*), among others (see Figure J.4-B) (Rutchey *et al.* 2005). Fire is an essential process for survival of the pine community, clearing out the shade-tolerant hardwoods. Slash pine is fire-tolerant due to its multi-layered bark of which only the outer bark is scorched during fires and due to the long-pine needles protecting meristems. The underlying substrate strongly impacts the understory composition creating two distinctive communities:

- *Slash pine rocklands* grow on top of rocky limestone ridges and are found at Long Pine Key in EVER and in southeast BICY, (e.g., near Pinecrest). In southeast BICY, a thin layer of sandy soil may be present overlaying limestone rock and these pine woodlands can be considered a bridge between the pine rocklands and flatwoods (Snyder *et al*. 1990).
- *Slash pine flatwoods* grow on poorly drained, acidic, sandy substrate, (e.g., Bear Island in BICY).

Slash pine rocklands are particularly rare worldwide and contain many rare understory and epiphytic species. Slash pine flatwoods are more common throughout central Florida and occur more typically in BICY. Although the overstory is similar in these two communities, the understory communities differ, causing fire to move differently through these woodlands.

Sub-tropical and Temperate Hardwood Hammocks

Hammocks are dense stands of sub-tropical and temperate hardwood trees whose composition depends on flooding, frost frequency, and fire frequency and severity (see Figure J.4-C). Typical communities include "Sub-tropical hardwood forest," "Temperate hardwood forest," "Hardwood swamp forest" and "Bayhead Forest" (for others see Rutchey *et al.* 2005). Hammocks appear as teardrop-shaped tree islands in the middle of the ridge-and-slough marshes (see Figures J.4-D and J.4-E) or as hardwood areas within pine or cypress forests. Some typical sub-tropical species include mahogany (*Swietenia mahogoni*), gumbo limbo (*Bursera simaruba*), and cocoplum (*Chrysobalanus icaco*) whereas familiar temperate species include live oak (*Quercus virginiana*), laural oak (*Quercus laurifolia*), and hackberry (*Celtis laevigata*) (Rutchey *et al.* 2005). Shaded from the sun by the tall trees, ferns and bromeliads thrive in the moisture-laden air inside the hammock.

Cypress Forest

Pond Cypress (*Taxodium ascendens*) and Bald Cypress (*T. distichum*) are deciduous conifers that thrive in ponded water and slow seepage swamps (See Figure J.4-F). Vast forests cover BICY and extend into EVER. These trees form dense clusters called cypress "domes" in natural water-filled depressions. Trees in the deeper water at the center grow taller than those further away from the center. Cypress "strands" occur along sloughs and running water. In EVER and BICY, stunted cypress trees, called dwarf cypress, grow in sparse stands in wet prairies (see Figure J.4-G).

The Forest Uplands and Wetlands Ecological Zone is valued for its rare vegetation communities, rare and endangered species, recreational fishing and hunting of deer and pigs (BICY), hiking, wildlife viewing, canoeing, ORV use, and oil and mineral extraction. The pine rockland community on Long Pine Key in EVER and in some areas of the Florida Keys is unique and contains many plants endemic to south Florida. EVER and BICY contain the largest dwarf cypress strands worldwide. The term "Big Cypress" refers to the vast stands of cypress rather than the size. The larger "bald cypress" trees were logged in the past two centuries. The few remaining giants are extremely old; some with trunks over 6 feet wide and several hundred years old. Sub-tropical hardwood "hammocks" contain tropical vegetation that has successfully dispersed to south Florida from the Caribbean, including rare orchids and bromeliads. Tree islands of varying size dot the wet prairies and marshes. This zone also contains many cultural sites used by the Miccosukee Indian Tribe.

Important system drivers include climate (temperature range, frost frequency, rainfall, and drought frequency), hydrology, fire, major weather events, water quality, dispersal agents, and the underlying geology, topography, and soils. The major anthropogenic stressor on the system is the alterations in regional hydrology due to water diversions and canals south of Lake Okeechobee plus additional diversions to the north and west of BICY. Other important stressors include

alterations in fire regime, contaminants, invasive plants and animals, reduction and fragmentation of habitat, roadkill, disturbance from recreation and extractive uses such as hunting, fishing and illegal collection. In addition much of the system is in recovery from historic logging and agriculture.

Anticipated changes in zone extent and biological attributes include a reduction in the extent and connectivity of the forest uplands and wetlands zone outside the parks which will restrict species to the parks; increases in forest wetlands within BICY as historical agricultural areas are invaded by shrubs and trees and exotics are controlled; changes in extent and distribution of hardwood hammock, pine, and cypress communities and alterations in community structure due to altered surface hydrology, altered groundwater levels, altered fire regimes, reduced frost frequency, increased phosphorous inputs, invasive species and plant succession effects as communities recover from historical logging and clearing; changes in the size and distribution of tree islands; declines in wading bird communities and shifts in locations of supercolonies; impacts of mercury bioaccumulation and other contaminants on top predators; introduction of new top predators; and the cumulative impact of these changes and stressors on the abundance, community composition and percent native species of fish, invertebrates, herpetofauna, passerine birds, raptors, wading birds, mammals, top predators, etc. including rare and listed species.

The key management issues in the Forest Uplands and Wetlands Ecological Zone include rehabilitation of system hydrology, fire management, control and prevention of introduction of invasive plants and animals, reductions in phosphorous loading from outside the park, determining methods to reduce or mitigate mercury bioaccumulation, managing recreational and extractive use impacts, managing hunting and fishing, and protection and management of rare plants and animals.

Figure J.4-H shows the interrelationships among system drivers, anthropogenic stressors and zone extent and biological attributes (e.g., primary producer dynamics and consumer interaction dynamics). The remainder of this conceptual model consists of describing the drivers and stressors in greater detail, followed by a description of anticipated effects on system attributes coupled with potential local management actions. The section headings discussed include:

- Driver: Geology, topography, and soils
- Driver: Climate - temperature range, frost frequency, rainfall, drought frequency
- Driver: Major weather events - hurricanes and tropical storms
- Driver: Hydrology – average depth, timing, duration of flows, and frequency of extreme floods and droughts
- Stressor: Freshwater diversions, canals, levees and flood control
- Driver: Fire interaction with plant competition and succession
- Stressor: Fire suppression and altered fire seasonality, frequency, and extent

- Driver: Seed dispersal by birds, wind and water
- Driver/Stressor: Water Quality - Nutrient enrichment
- Stressor: Water quality – Contaminants (mercury, pesticides, oil impacts)
- Stressor: Reduction and fragmentation of habitat outside park and increased roadkill
- Stressor: Introduction and spread of invasive plant species
- Stressor: Introduction and spread of invasive fauna
- Stressor: Historic and current overfishing, overhunting and illegal collection of rare species
- Stressor: Disturbance and damage from visitation, recreation and extractive use
- Stressor: Historical logging of pinelands, cypress and mahogany coupled with agricultural clearing

In the subsequent section the effects of these Physical Drivers, Key Background Attributes, and Anthropogenic Stressors on the following key system attributes are discussed:

- Change in extent and distribution of the Forest Uplands and Wetlands Zone
- Change in primary productivity dynamics, (e.g., vegetation composition, structure, and function)
- Change in consumer dynamics, (e.g., fauna community structure and function, guild composition and abundance, and distribution and abundance of keystone species, top-down predators, and rare species)



Figure J.4-A. Park map of BICY. ash pine woodland. ardwood hammock press Forest. Freshwater Marsh Wet Prairie



Figure J.4-B. Slash pine rocklands at Long Pine Key in EVER.



Figure J.4-C. Hardwood hammock at "Mahogany Hammock Trail" in EVER.



Figure J.4-D. Multiple tree islands in sawgrass near Shark Valley Visitor Center in EVER during dry season.



Figure J.4-E. Tree island near Shark Valley Visitor Center in EVER during dry season.



Figure J.4-F. Cypress stand along Loop Road in BICY during dry season.



Figure J.4-G. Dwarf cypress stand along EVER main park road during dry season.

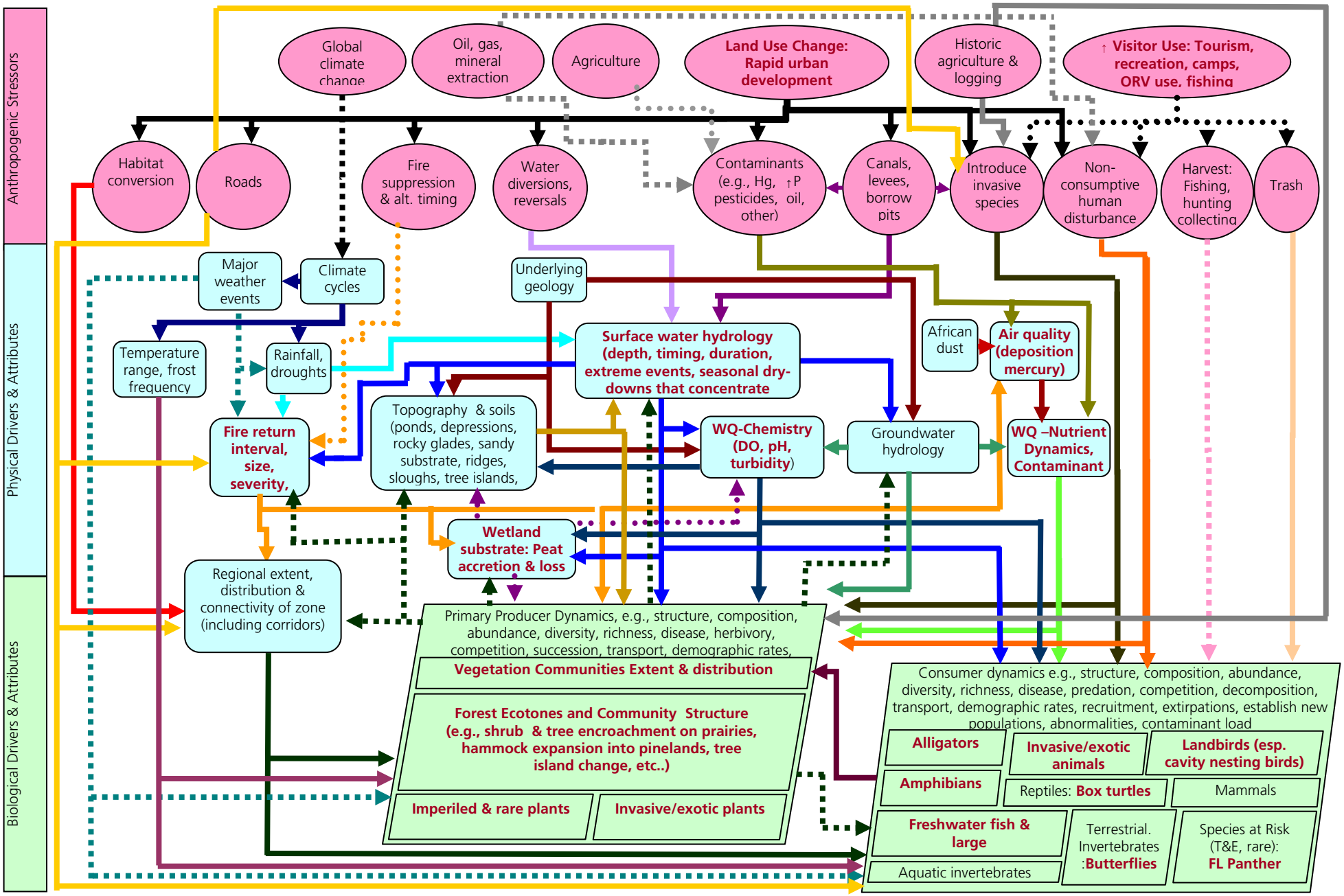


Figure J.4-H. S. Florida Forested uplands and wetlands ecological zone conceptual model diagram. Solid and dotted lines show assumed effects of anthropogenic stressors, physical and biological drivers and attributes. Boxes with **red print** directly relate to a proposed Vital Sign. (Use of dotted lines is to clarify and does not indicate lesser importance).

J.4.2 Physical Drivers, Key Background Attributes, and Anthropogenic Stressors

J.4.2a Driver: Geology, topography, and soils

South Florida is typified by low elevation with much of the forested areas inundated by water during the summer wet season. Hardwood hammocks and pine rocklands tend to occur at slightly higher elevations than nearby marshes and sloughs with vegetation varying depending on the hydroperiod. In general the Big Cypress area is slightly higher in elevation than EVER and is dominated by cypress forest, strands and domes. Organic acids from decaying vegetation can further eat away at the underlying limestone causing deeper moats around tree islands and deeper ponds in Cypress domes.

J.4.2b Driver: Climate— temperature range, frost frequency, rainfall, drought frequency

Hot, wet summers and warm, drier winters has resulted in a mixture of tropical and temperate vegetation in south Florida parks. Frost frequency limits the northward expansion of some tropical hardwood species to areas south of U.S. Highway 41. Once established, the interior of hardwood hammocks maintain a high humidity which buffers the interiors against frost damage and fire incursions and also provides habitat for many rare endemic plants.

J.4.2c Driver: Major weather events - hurricanes and tropical storms

Periodic hurricanes and tropical storms bring high winds and heavy flooding that can cause patchy to widespread disturbance of park forests and dispersal of flora and fauna, including non-native species. Some effects can be delayed: Hurricane Andrew damaged pine trees on Long Pine Key which then suffered subsequent beetle and weevil outbreaks (Lodge 2005) although the outbreak may have been exacerbated by high stand density (Rick Anderson, personal communication).

J.4.2d Driver: Hydrology – average depth, timing, duration of flows, and frequency of extreme floods and droughts

When the rains begin in the summer, most areas of Big Cypress and the Everglades are inundated in a large shallow sheet of water that moves slowly southward from Lake Okeechobee to Florida Bay. The average depth, timing, speed, and duration of flows strongly influences vegetation composition of both overstory and understory in cypress woodlands, temperate tree island communities and hardwood hammocks (See Figures J.4-I, J.4-J). Cypress domes form where deeper water is ponded with taller trees growing in the deeper water. Hardwood hammocks form in higher areas and on tree islands. Cypress strands form along sloughs, canals and areas of faster flowing water. Pines can be found in both wetland and upland areas. Vegetation density can in turn affect water flow. Large, dense, unburned areas of sawgrass south of highway US 41 slow the southern bound sheet flow.

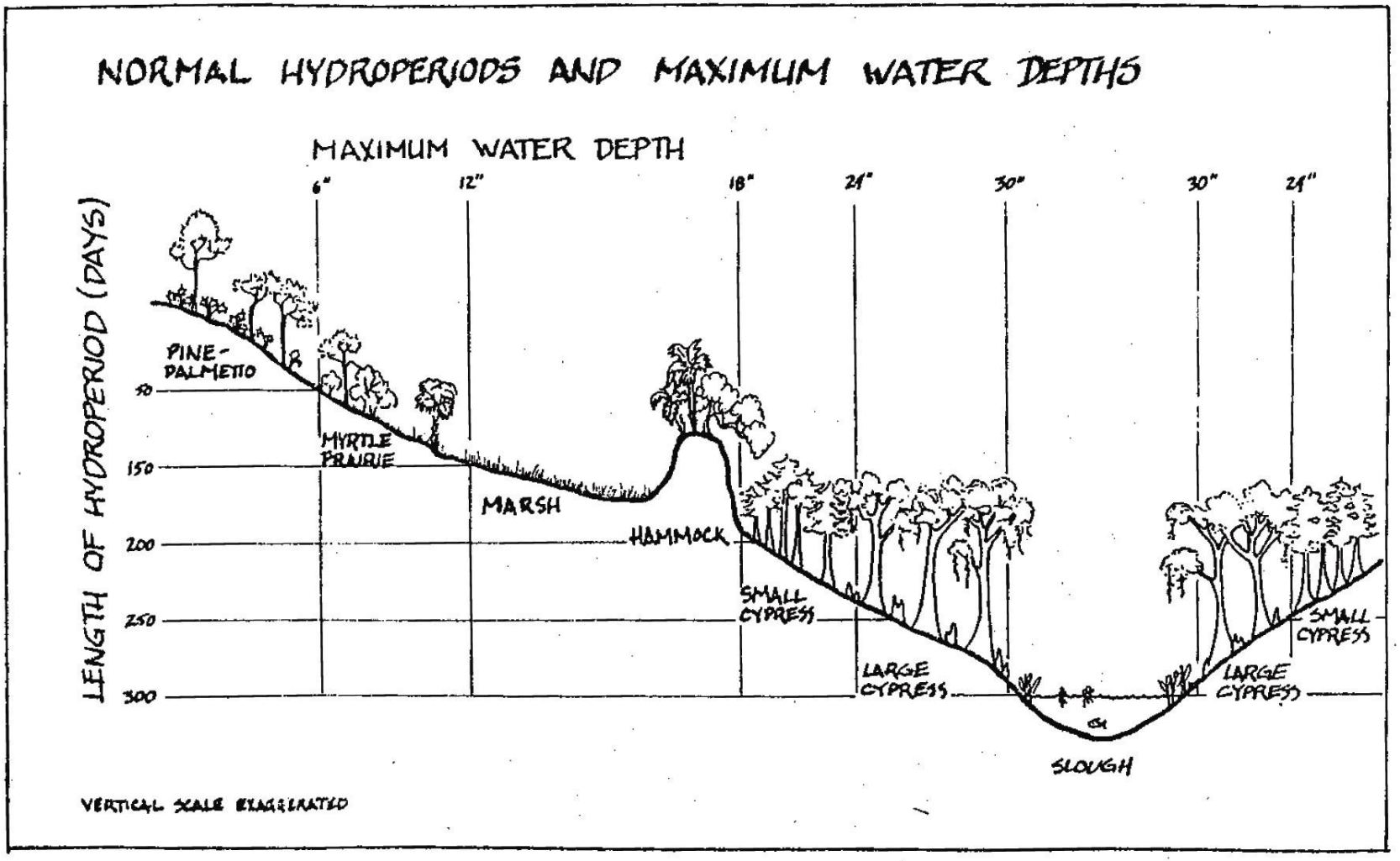


Figure J.4-I. Relationship between different types of vegetation and normal hydroperiods and water depths. The vertical scale in this figure is exaggerated. Only a few meters separate the lowest and highest points. Figure from Deuver *et al*. (1979)

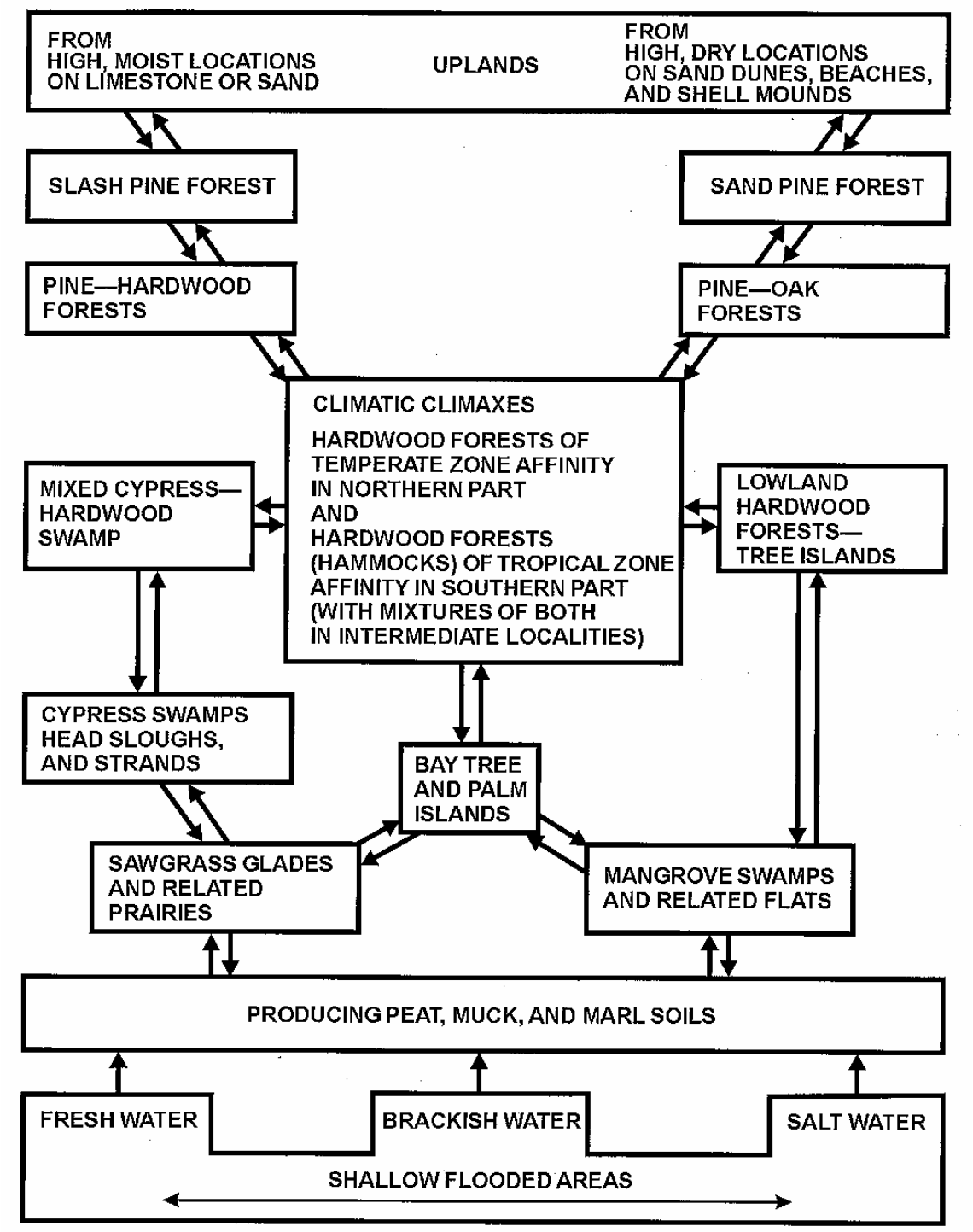


Figure J.4-J. Relationship between plant succession and climax communities and system hydrology. Figure from Lodge (2005).

Extreme floods and droughts can influence vegetation by restricting the range of flood-intolerant vegetation or drought-intolerant species and shifting competitive relationships.

J.4.2e Stressor: Freshwater diversions, canals, levees and flood control

Major changes were made to south Florida hydrology in the form of freshwater diversions, canals, levees, and flood control structures. These alterations reduced the amount of water flowing into the Everglades, the seasonality, the duration and depth of flows which in turn affect vegetation. Alterations in Big Cypress hydrology have also occurred due to drainage and residential development mostly west of Fakahatchee Strand and agricultural development mostly in the northern Big Cypress area. The canals and levees cause increased water depth in some areas of the Water Conservation Areas and decreased depth in others, resulting in flooding and gradual loss in the number and area of tree islands over the past 50 years (Rutchey 2005). Areas in pine rocklands have experienced a reduction in water table, impacting species composition and potentially fire impacts. Other areas throughout Everglades and Big Cypress have experienced alterations which are resulting in general changes in vegetation. The altered hydrology and lowered water table has resulted in the loss of dry season refugia for fish, invertebrates and amphibians in some areas (Duever 2004).

J.4.2f Driver: Fire interaction with plant competition and succession

In the absence of fire, fire-sensitive hardwood hammock species, both hydric and mesic, expand into pineland areas. Herbaceous wet prairie communities are diminished by the shade of encroaching shrubs. Herbaceous wetlands and cypress forests are encroached upon by shrubs and hardwood dominated forests (See Figures J.4-K, J.4-L). Light to moderate fires, approximately every 1-7 years, maintain fire-tolerant pineland communities while reducing and top-killing fire-sensitive hardwood species and also maintain a diverse herbaceous/graminoid understory layer in pinelands that is considered to provide better habitat for fauna such as the red-cockaded woodpecker and eastern bluebird. These less-intense fires are important for pineland community seedling establishment and growth. Cypress trees are likewise fire-tolerant and the humid interior of cypress domes makes them even more so. The lack of connectivity between the peat in different cypress domes helps prevent the spread of fire between domes. Fire around cypress dome edges also suppresses hardwood encroachment.

Hardwoods are less resilient to frequent fires than pines or cypress. Low-intensity fires can partially impact hardwood hammocks by top-killing edge and tall individuals. Severe fires can reach the interiors, strongly impacting the entire hammock. These severe fires affect both understory and overstory composition and can reinitiate succession processes. The wet, humid hammock interiors have some resistance to light to moderate fires but not to the more severe fires. The “moats” or areas of deeper water around tree islands may also help prevent the spread of fire into their hardwood interiors.

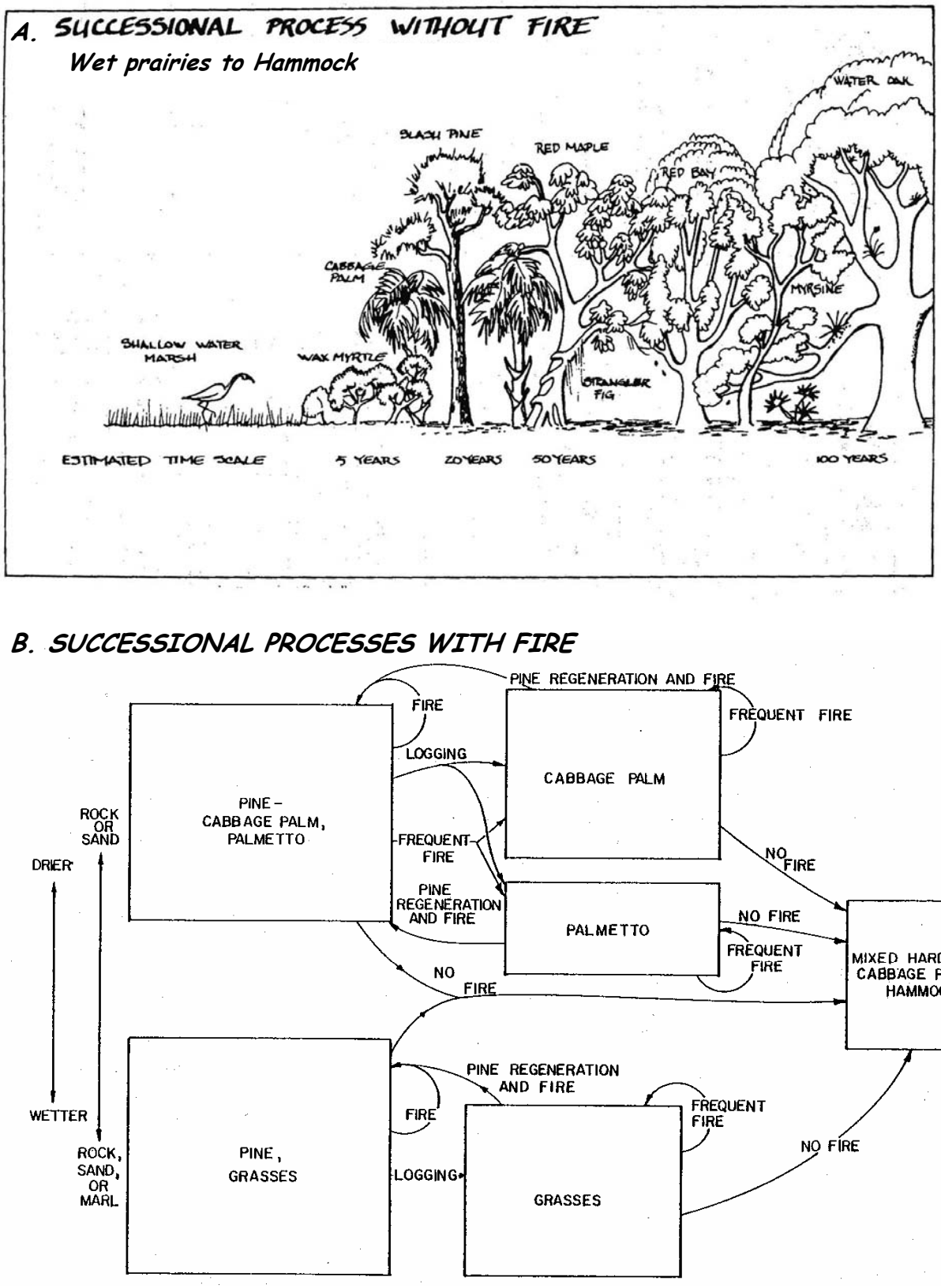
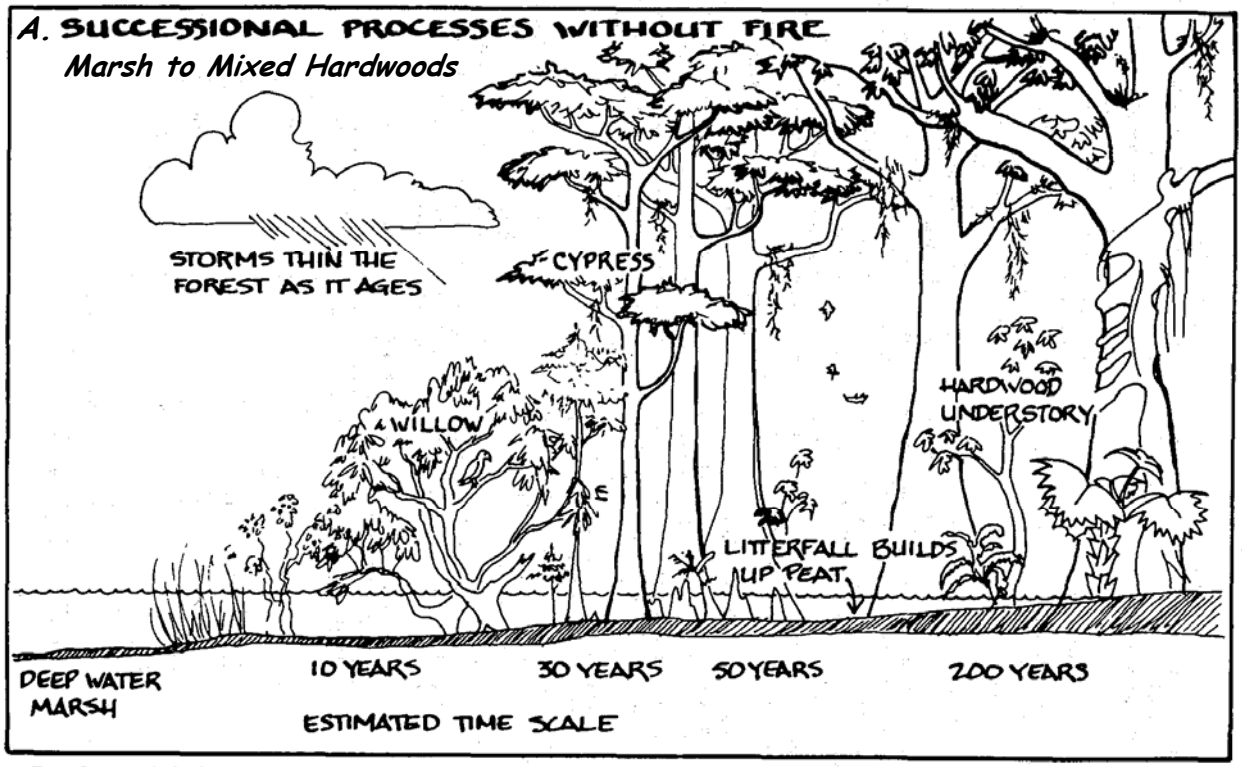


Figure J.4-K A and B. Forest successional processes in absence of fire in wet prairies (upper figure) and in presence of fire (lower figure). [Figures from Duever *et al*. 1979]



B. SUCCESSIONAL PROCESSES WITH FIRE

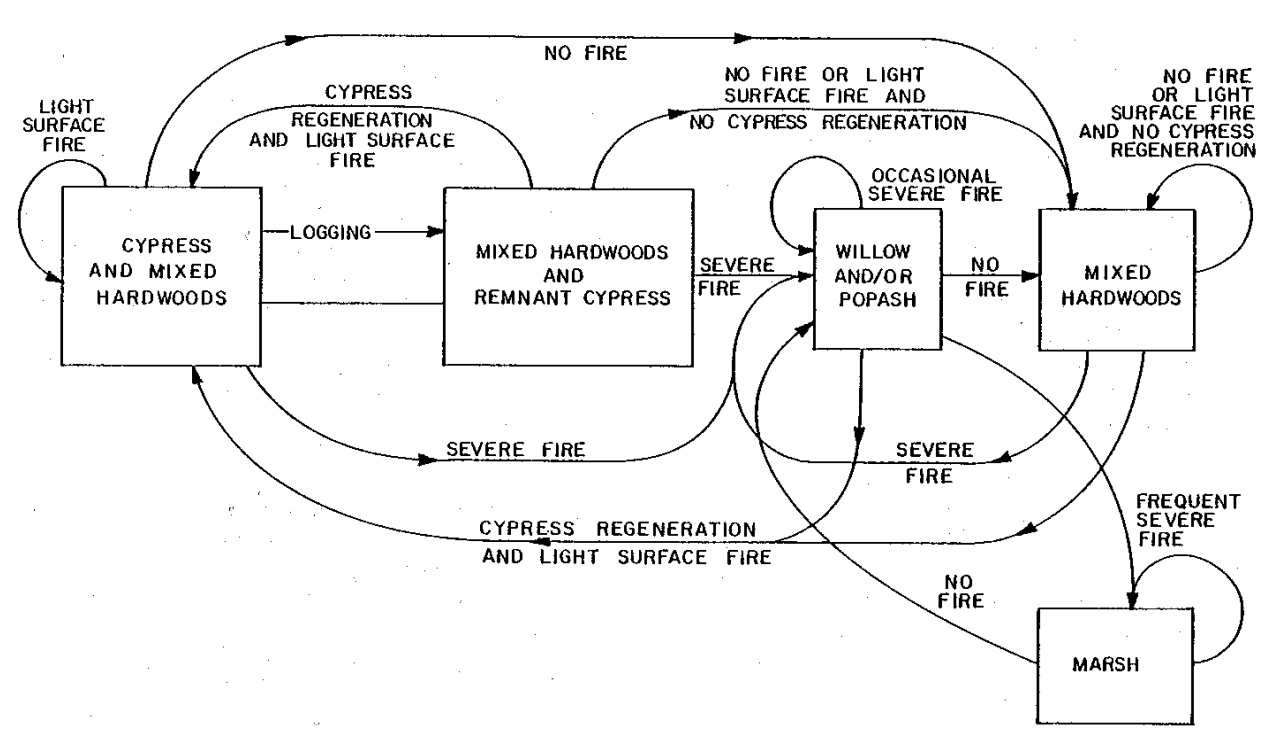


Figure J.4-L. Forest successional processes in absence of fire in marshes (upper figure) and in presence of fire (lower figure). [Figures from Duever *et al*. 1979]

High severity fires kill the roots and trunks of pine and cypress trees preventing re-growth and effectively killing them. This reinitiates tree establishment and succession processes, allowing invasion by non-native trees. Such severe fires can strongly damage hardwood hammocks and their associated fire-sensitive endemic species. The probability of severe fires is increased by drought and fire exclusion.

J.4.2g Stressor: Fire suppression and altered fire seasonality

Fire exclusion in wildland areas allows hardwoods to invade pines and cypress stands and overgrowth of understory species. Dense shrubby understories can increase the fuel-load depending on the species composition, which can in turn, increase the probability of a hot, catastrophic fire when a fire finally occurs. Such dense habitats are also less favored by sensitive species such as the red-cockaded woodpecker and eastern bluebird. Fires are initiated by lightning strikes during the wet summer months. Unfortunately human-started fires frequently occur during the dry winter months, tend to be more severe, more widespread, and have greater effect on vegetation and peat soils.

Fire has been excluded from large areas of EVER and BICY. For example, protection of Cape Sable seaside sparrow populations has resulted in exclusion of large areas from fire treatment. Canals serve as barriers to fire thereby limiting the spatial extent of individual ignitions. Brazilian pepper (*Schinus terebinthifolius*) resists fires and acts as a fire barrier, altering fire patterns.

J.4.2h Driver: Seed dispersal, especially by birds, wind and water

Birds appear to play a strong role in the initial dispersal of tropical hardwood species in south Florida. Locally birds are responsible for the spread of tropical hardwood hammock species (Lodge 2005). Water dispersal along strands, canals and sloughs, plus wind dispersal, are also important dispersal agents for many non-native as well as native plants.

J.4.2i Driver/Stressor: Water Quality - Nutrient enrichment

Historically Everglades and Big Cypress have been oligotrophic systems. Agriculture south of Lake Okeechobee has resulted in nutrient enrichment of park waters which has impacted wet prairies and marshes and also had some impacts on forested areas. Hunting and fishing camps as well as inholdings can also result in local nutrient enrichment problems. As a natural factor, rookeries and favored bird roosts can increase local nutrients around tree islands sometimes resulting in downstream "tails" of denser vegetation. Wetzel *et al.* (2005) also suggest additional processes that cause tree islands to act as local nutrient hotspots with total soil phosphorus concentrations up to 6 to 100 times greater than phosphorus levels in the surrounding marshes and sloughs and that help perpetuate the development of tree islands once initiated (see Figure J.4-M).

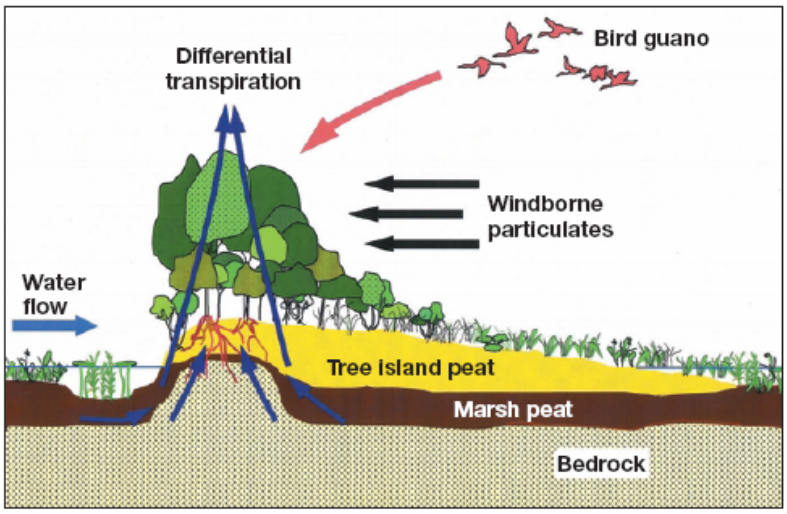


Figure J.4-M. *"Major mechanisms that redistribute nutrients from marshes and sloughs to tree islands in the Everglades.* Tree islands capture more windborne particulates than surrounding marshes because of their taller plant canopies. Subsurface water flows towards them because of higher evapotranspiration rates, and they attract birds and other animals to nest or rest, resulting in guano deposits on the island." [From Wetzel *et al*. 2005]

J.4.2j Stressor: Water Quality – Contaminants (e.g., mercury, pesticides, and oil impacts)

Mercury, as mentioned in the system-wide model, has become a serious problem in Everglades and Big Cypress wetlands. Mercury is made more biologically available by mercury methylation processes in wetlands. Mercury then bioaccumulates in the food chain resulting in decreased fitness and increased mortality rates, especially for species at high trophic levels such as predatory fish, wading birds, alligators, and panthers.

J.4.2k Stressor: Reduction and fragmentation of habitat outside park and increased roadkill

Increased urbanization is reducing and fragmenting habitat outside the south Florida parks resulting in increased isolation of Everglades and Big Cypress fauna communities. Roads, especially U.S. Highway 41 and I-75, increase fragmentation, acting as barriers and as population sinks. Urban encroachment on parks can cause "edge effects" where pets, mosquito control efforts, fire suppression, contaminants, and other factors impact the outer boundaries of the parks. The sum of these impacts can result in genetic isolation and inbreeding problems, especially for larger species needing large home ranges.

J.4.2l Stressor: Introduction and spread of invasive plant species

Invasive plants are a major threat to south Florida forests. They compete with and replace native vegetation, create habitat that is less favorable or completely excludes native species, and frequently create habitat that may be more favorable to invasive animal species. Brazilian pepper (*Schinus terebinthifolius*) in particular has rapidly

invaded old agricultural fields, preventing natural fire occurrence and altering the natural fuel complexes. Other problematic species include: melaleuca (*Melaleuca quinquenervia*), Australian pine (*Casuarina equisetifolia*), downy rose myrtle (*Rhodomyrtus tomentosa*), old world climbing fern (*Lygodium microphyllum*), java plum *(Syzygium cumini)*, air potato (*Dioscorea bulbifera*), coral ardisia (*Ardisia crenata*), rosary pea (*Abrus precatorius*), guava (*Psidium guajava*), Japanese climbing fern (*Lygodium japonicum*), tropical soda apple (*Solanum viarum*), Gold Coast jasmine (*Jasminum dichotomum*), nephthytis (*Syngonium podophyllum*), latherleaf (*Colubrina asiatica*), Burma reed (*Neyraudia reynaudiana*), earleaf acacia (*Acacia auriculiformis*), natal grass (*Rhynchelytrum repens*), shrub verbena (*Lantana camara*), tongue tree (*Albizia lebbeck*), skunk vine (*Paederia foetida*) and aquatic soda apple (*Solanum tampicense*).

Invasive plant species are frequently introduced as ornamentals which then escape into nearby natural areas. Human activities provide transport for invasive species along roads and trails as well as creating disturbed environments for them to establish. Alterations to the timing and severity of fires, alterations in hydrology, and nutrient enrichment, can allow non-native vegetation to invade stressed communities. Urban edges and park inholdings can provide seed sources for invasive species to establish within park boundaries. Sometimes non-native plants that initially do not act as invasive species can adapt to local conditions over time (decades) and suddenly become problematic.

J.4.2m Stressor: Introduction and spread of invasive fauna

Invasive fauna are another major threat to native flora and fauna. Released pets, ornamental plant nurseries, and fishing bait are frequent sources of new invasive species. Burmese pythons and other introduced constrictors are becoming established as a new top predator in EVER and BICY with unknown consequences to the food web. Feral cats (*Felis domesticus*) prey on native songbirds and small fauna at a level far higher than native bobcat predation, often creating severe "sink" habitat around residential areas. Feral hogs (*Sus scrofa*) disturb sites, plowing up and eating native vegetation, providing opportunities for invasive plants to establish. Exotic fish alter pond and hydric forest fish communities and food web dynamics. Other non-native species of concern include the bromeliad weevil(*Metamasius callizona*), lobate lac scale (*Paratachardina lobata*), marine toad (*Bufo marinus*), Cuban tree frog (*Osteopilus septentrionalis*), greenhouse frog (*Eleutherodactylus planirostris*), brown anole (*Anolis sagrei*), armadillo (*Dasypus novemcinctus)*, black rat (*Rattus rattus*), fire ants (*Solenopsis invicta*), parrots and parakeets, and walking catfish (*Clarias batrachus*).

Coyotes (*Canis latrans)* have been expanding their range southward into Florida and are already present in BICY. While technically a species native to the eastern United States, they historically were not found in south Florida. Their presence will add a new medium-sized top predator to the system and the consequences are unclear.

J.4.2n Stressor: Historic and current overfishing, overhunting and illegal collection of rare species

Hunting of Florida panthers and bears in the past may have contributed to their decreased numbers in the present. Past collection and current illegal collection is impacting indigenous plants such as bromeliads and orchids as well as rare snails, butterflies, indigo snakes, and others. Some collectors even set fire to tree islands or hammocks to reveal rare snails and make collection easier.

J.4.2o Stressor: Disturbance and damage from visitation, recreation and extractive use

Tourism and park visitation if unmanaged can impact flora and fauna through roadkill, excessive noise, trash, and introduction of new exotic species carried on cars or in camping gear. These are mostly limited to the upland areas in easily accessed locations. Fishing and hunting camps, if improperly maintained, can greatly increase disturbance to surrounding areas. Oil and gas drilling is also thought to have limited localized impact although contamination is always a concern. Off-highway vehicles must be carefully managed to avoid excessive damage to vegetation and soil and disturbance of park wildlife.

J.4.2p Stressor: Historical logging of pinelands, cypress and mahogany coupled with agricultural clearing

Logging of the pinelands, cypress and mahogany, occurred before the establishment BICY and EVER (especially during the 1940-1950s). Many forests in these parks are still recovering along with fauna dependent on old mature forests. This logging reduced old growth pines which provided prime red-cockaded woodpecker nesting trees. Many former inholdings were cleared of forests for agriculture. These areas are currently grasslands and wet prairies in various stages of succession back to forest. Unfortunately the species that usually establish are invasives and many of these old sites are now dominated by Brazilian pepper.

J.4.3 Anticipated Effects of Drivers and Stressors on Ecological Zone Extent and Biological System Attributes

J.4.3a Change in extent and distribution of forest wetlands and uplands zone, including loss of large contiguous areas, dispersal corridors

The anticipated trend is a continued decrease in the amount of forest wetlands and uplands zone outside the parks and increased fragmentation due to roads. The extent and distribution of this zone in south Florida has already been reduced by agricultural development, urban development, and hydrological alterations. Further reduction in the extent of these habitats is expected outside the parks. Increasing numbers of roads are fragmenting the habitat outside the park and several major roads and highways fragment habitat within the parks. Although habitat within the parks is protected, eventually sea level rise may also impact the edges of forested wetlands.

J.4.3b Change in primary producer dynamics, (e.g., vegetation composition, structure, and function)

Several changes in vegetation composition, structure, and function can be anticipated due to changes in hydrology, fire management, invasive species, frost frequency, and plant succession processes. As hydrology is rehabilitated by the Comprehensive Everglades Restoration Program, vegetation is expected to respond: shrubs and trees expanding into wet prairies and marshes may recede, tree islands may recover, and groundwater levels in Long Pine Key may rebound. Fire management is likewise expected to impact the extent and distribution of hardwood communities and the extent and structure of slash pine and cypress communities. Invasive plant species are source of future change and have the possibility of completely altering much of south Florida's native vegetation if unchecked. Disturbed and stressed areas are especially vulnerable to invasion. If climate change results in decreased frost frequency, tropical hardwood hammocks may expand further northwards. Previously logged areas are expected to gradually mature. Some future changes are unclear. For example, the Carolina parakeet, now extinct, is hypothesized to have helped cypress seed dispersal and the consequences of losing such dispersal agents are unclear.

Although changes can be anticipated due to alterations in system drivers, the nature and outcomes of those changes are not always easy to predict, especially because several drivers will be changing simultaneously.

J.4.3c Change in consumer dynamics, (i.e., fauna community structure and function, reduction in native top predators, keystone species, introduction of invasive species; guild composition and abundance and distribution and abundance of rare species)

Anticipated changes in the faunal food web structure and position are difficult to predict. However, the following points can be made:

- Top predators such as panthers have been declining due to loss and fragmentation of large expanses of land which have resulted in genetic isolation and inbreeding including separation of the east Everglades and Big Cypress populations. Florida bear populations have also declined. Other new top predators are establishing, such as released boa constrictors, pythons and other constrictors combined with the southward range expansion of coyotes. The combined effects of these changes on the food web are difficult to predict but could be considerable.

- Species dependent on old mature forests have declined or disappeared. The red-cockaded woodpecker has declined due to the loss of old stands of slash pines with an open understory maintained by frequent fires. Logging of the old bald cypress stands likely contributed to the local extirpation of the Ivory-billed woodpecker. Hopefully the elimination of logging will allow recovery of these and similar species (sightings of the presumed extinct Ivory-billed Woodpecker have occurred in Arkansas).

- Historical hunting stressors have extirpated some species such as the Carolina parakeet and severely reduced other species such as panthers, bears, and even tree snails. Recovery from these historic stressors is ongoing. Unfortunately illegal collection of rare species such as indigo snakes, tree snails, rare orchids and bromeliads continues to be a problem.

- Proposals to alter the hydrology of the Everglades and eastern Big Cypress should positively impact fish communities by mimicking historical depth, duration, and timing of flooding. However, non-native fish are altering fish communities, especially within strands and canals.

- As urban encroachment continues, parks in south Florida could experience a temporary "concentrating" effect as species outside the parks are forced to retreat to within the park boundaries. As encroachment continues, the "edge effect" could increase, particularly around Big Cypress although the large size of BICY and EVER reduces the seriousness of these impacts. However, roadkill along the major roads and highways continues to be a population sink and case of fragmentation within the parks and neighboring conservation areas. Some proposed changes by the Comprehensive Everglades Restoration Program such as building underpasses along Tamiami Trail could help reduce this impact.

- Mercury toxicity is a continuing stress on the system, contributing to the deaths of at least three panthers since the 1990s (USFWS 1999) and is impacting other upper trophic level species such as alligators, wading birds, pig frogs, bass and mosquito fish. Mercury toxicity can lead not only to death but behavioral changes in affected animals which can affect reproductive success and ultimately population survival with consequences for the rest of the food web.

- Unknown future problems such as new contaminant problems, new invasive species, and diseases could impact the system in unforeseeable ways.

J.4.4 Potential and ongoing local management actions

Following is a list of potential and ongoing local management actions to manage stressors and, if necessary, system drivers in SFCN parks:

- Purchase land to expand parks where habitat is suitable or work out cooperative agreements to maintain buffer area around parks
- Rehabilitate south Florida hydrology north of and within the Everglades and eastern Big Cypress through alterations in canals, levees, water control structures, and water operations to reestablish sheet flow and flow volumes to

more closely resemble historical hydrographs through the Comprehensive Everglades Restoration Plan (CERP)

- Rehabilitate south Florida hydrology as part of the Comprehensive Everglades Restoration Plan may involve increased underpasses below major highway which may also facilitate wildlife movement.
- Rehabilitate Big Cypress hydrology to reduce impacts due to nearby agriculture and urban development
- Manage fire regimes that mimic natural historical patterns of fire frequency and size in pinelands (every 1-7 years) and cypress swamps
- Control invasive plant and animal species and, as needed, conduct habitat restoration
- Seek to minimize new introductions of invasive species through public education, work with local nurseries, and early detection at likely establishment sites
- Minimize anthropogenic nutrient enrichment of park waters outside of historical range
- Minimize mercury impacts on system, through research and reducing inputs from incinerator and coal-burning emissions
- Minimize organic pesticide input into park waters
- Develop and implement best management practices regarding off-road vehicle activity in BICY as necessary, close trails if determined necessary
- If necessary, create "off limits" areas that keep visitors away from sensitive areas
- Enforce scientifically based regulations (review and revision if necessary) regarding hunting and fishing within BICY
- Enforce regulations regarding illegal collection of plants and fauna within parks
- Protect fauna road-crossing points (corridors) by slowing speeds and/or creating underpasses and barrier fences
- Public education and signage
- Provide additional protection and assistance to listed species as needed, such as increasing connectivity among fauna populations; rehabilitating habitat quality; research into listed species habitat use and needs and further causes of declines
- Regular trash pickup and establishing park cleanup days with volunteers; use animal proof trash receptacles
- Perform interagency consultation on proposed projects to minimize impacts

APPENDIX J.5

ISLAND INTERIOR ECOLOGICAL ZONE

J.5 Island Interior Ecological Zone

The following conceptual model draws strongly from the following references: Kendall *et al.* (draft), Ross *et al.* (1992), U.S. Virgin Islands Division of Fish and Wildlife (2005), and Thornberry-Ehrlich (2005b,c).

J.5.1 Summary

The Island Interior Ecological Zone includes the terrestrial areas of islands in national parks that are inland of the mangroves and beaches. Beaches, mangroves, and tidal marshes are covered in another conceptual model (Section J.5). The Island Interior Ecological Zone is found in VIIS on St. John (Fig.J.5-A), BUIS on Buck Island (Fig.J.5-B), inland areas of SARI (Fig.J.5-C), the keys in BISC (Fig.J.7-A) and DRTO (Fig.J.5-D), and in EVER in the Ten Thousand Islands and Florida Bay (Fig.J.6-A). Similar habitat is found in the Florida Keys.

Vegetation primarily consists of tropical dry shrublands (see Figs. J.5-E to J.5-G), tropical dry forests (see Fig. J.5-H), a limited amount of tropical moist forest, sub-tropical coastal shrublands (coastal hardwood shrublands, nicker bean shrublands, coastal hardwood scrub), and sub-tropical coastal hammocks (see Figs. J.5-I to J.5-J). Grasslands in the US Virgin Islands are typically an early successional stage from other land uses. These vegetation communities are described more completely in USVI Division of Fish and Wildlife (2005) and Rutchey *et al.* (2005). Although this zone encompasses a number of different vegetation communities, the drivers, stressors and management issues tend to be similar.

This community assemblage is valued for its unique and rare plants and fauna (see Appendix I), its dry tropical and sub-tropical vegetation, as stopover habitat for migrating and over-wintering songbirds and raptors, and its hiking and recreational communities.

The main natural system drivers for the Island Interior Zone include climate, xeric island hydrology, orographic effects in VIIS parks, underlying island geology, island topography, soils, earthquakes, landslides, and island size and isolation. Additional natural drivers that may be increased due to global climate change include sea level rise and major weather events such as hurricanes and tropical storms. Water quality and air quality may have localized impacts.

The larger islands of St. John and St. Croix are experiencing the greatest degree of anthropogenic stressors due to the urbanization directly occurring on these islands. St. Croix and St. John are experiencing reduction and fragmentation of habitat outside VIIS and SARI and due to inholdings within VIIS, construction impacts, increased roadkill, increased hydraulic loading on septic system, increased solid waste, increased contaminants in the ephemeral streams on the islands, and possibly increased freshwater runoff from lawns into natural areas which alter plant

communities. Additionally St. Croix and St. John have had greater opportunities for introduction of non-indigenous species. Historic agriculture and logging occurred within these parks.

Elliott Key, other Keys in BISC, and Garden Key and Loggerhead Key at DRTO have had historic residential homes, lighthouses, agriculture, logging, and, of course, Fort Jefferson on DRTO. Some facilities remain to support park staff housing, picnic areas and camping areas. Challenging stressors on these more isolated islands are the introduction of non-native plants and fauna into parks and recreation impacts.

The smaller islands often provide predator-free habitat for seabird, shorebird, and wading bird colonies. Consequently, these smaller islands are strongly impacted by any introduction of non-native species (especially predators) or even arrival of native predators such as raccoons when they historically were not present on the islands.

Anticipated changes in zone extent and biological attributes include a reduction in the extent of the Island Interior Zone due to sea level rise; additional reduction in the extent of the zone on St. John and St. Croix due to urbanization; changes in vegetation community structure due to invasive plant and animal species and, on the larger islands, due to urban edge impacts and plant succession from earlier land uses; introduction of new top predators; and the cumulative impact of these changes and stressors on the abundance, community composition and percent native species of plants, herpetofauna, birds and mammals, including rare and listed species.

The key management issues in the Island Interior Zone include reduction of urbanization and inholding development impacts (VIIS and SARI only), control of and preventing the introduction of invasive plants and animals, management of recreation impacts, and protection and management of rare plants and animals.

Figure J.5-K shows the interrelationships among natural system drivers, anthropogenic stressors and zone extent and biological attributes (e.g., primary producer dynamics and consumer interaction dynamics).

The remainder of this conceptual model consists of describing the drivers and stressors in greater detail followed by a description of anticipated effects on zone extent and biological attributes coupled with potential local management actions. The section headings discussed include:

- Driver: Climate and xeric island hydrology
- Driver: Major weather events such as hurricanes, tropical storms, and large wind events
- Driver: Geology, topography, soils, earthquakes and landslides
- Driver/Stressor: Sea level rise
- Driver: Isolation from mainland, small island size, and dispersal
- Driver/Stress: Water quality and air quality
- Stressor: Reduction, fragmentation of habitat and urban edge impacts

- Stressor: Historical land use
- Stressor: Introduction and spread of invasive plant species
- Stressor: Introduction and spread of invasive animal species
- Stressor: Roads (VIIS, SARI, BISC only)
- Stressor: Recreational impacts, physical trash and refuse

In the subsequent section the effects of these Physical Drivers, Key Background Attributes, and Anthropogenic Stressors on the following key system attributes are discussed:

- Change in extent of Island Interior Zone
- Change in primary producer dynamics, (i.e., vegetation composition, structure, and function; distribution and abundance of rare flora; percent native vegetation)
- Change in consumer dynamics, (i.e., fauna community structure and function, guild composition and abundance, and distribution and abundance of rare species)

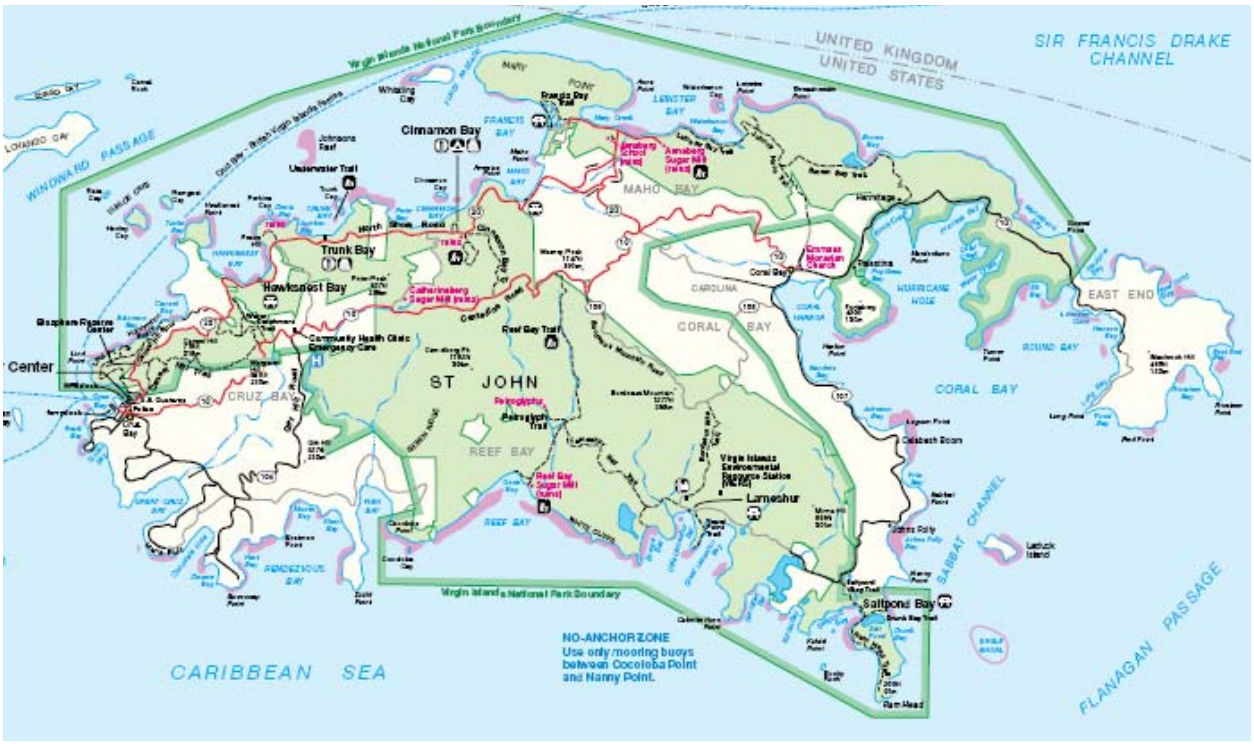


Figure J.5-A. Portion of VIIS park map. Green areas show the park and park boundary. Pink areas show the coral reefs. Gross acreage for the park in 2004 was 14,689 acres including marine areas.

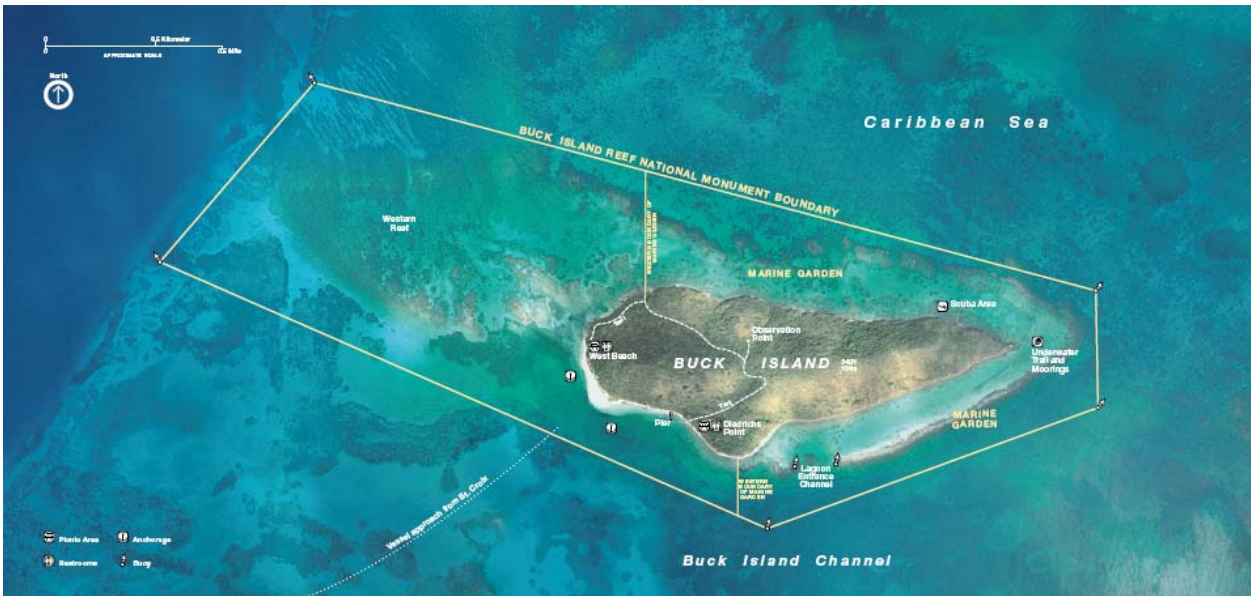


Figure J.5-B. Old BUIS park map showing Buck Island which is approximately 176 acres. Yellow line is the old boundary before the 2001 expansion.

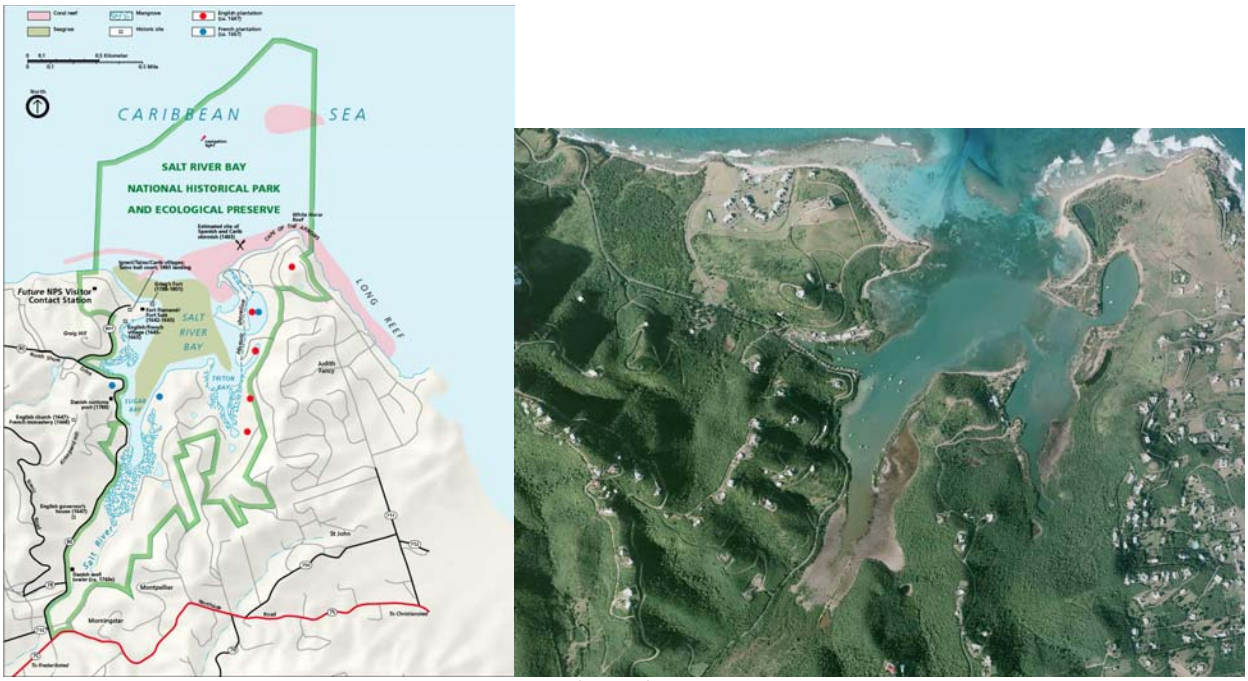


Figure J.5-C. SARI park map and aerial photo (2000). The Island Interior zone includes the areas upland of the mangroves and comprises about 358 acres. (Kendall *et al*. DRAFT)

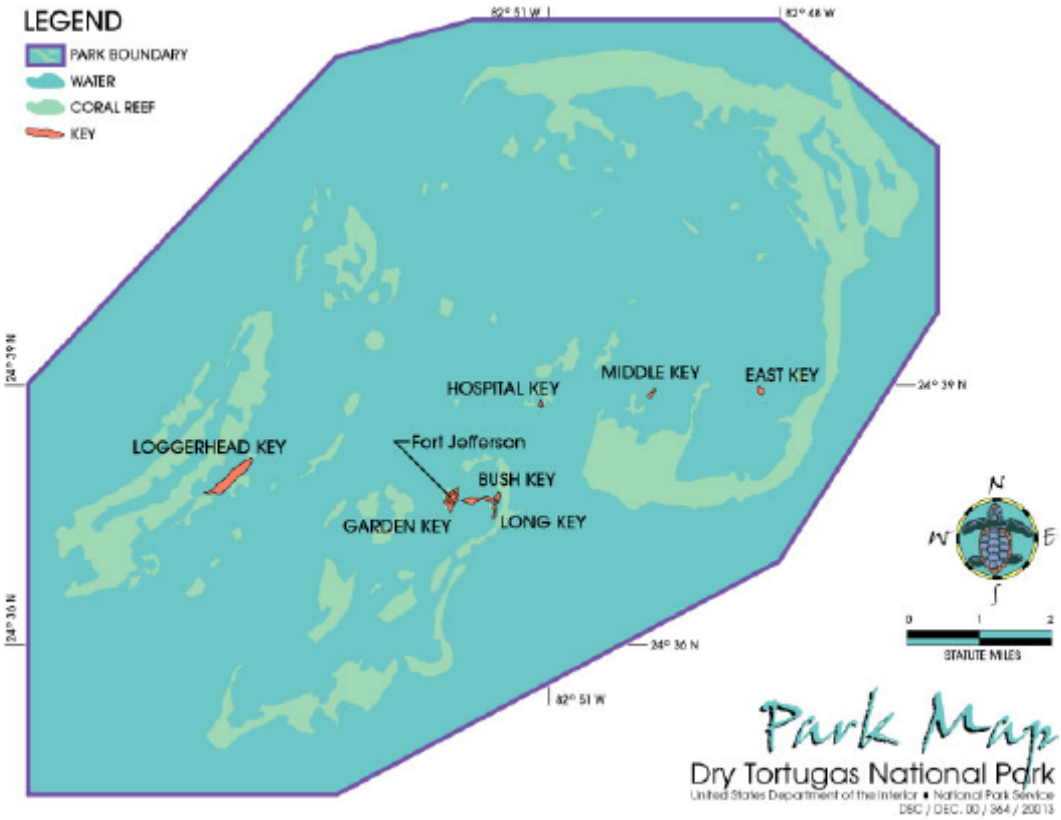


Figure J.5-D. DRTO Park Map. Islands total about 104 acres.



Figure J.5-E. Dry shrubland vegetation in Island Interior zone at Buck Island, BUIS.



Figure J.5-F. Dry shrubland in Island Interior Zone at St. John, U.S. Virgin Islands.



Figure J.5-G. Rocky slope on Buck Island, BUIS.



Figure J.5-H. Tropical dry forest vegetation on Buck Island in BUIS.



Figure J.5-I. Sub-tropical coastal forest hammock on Elliot Key, BISC.



Figure J.5-J. Spite Highway on Elliott Key, BISC.

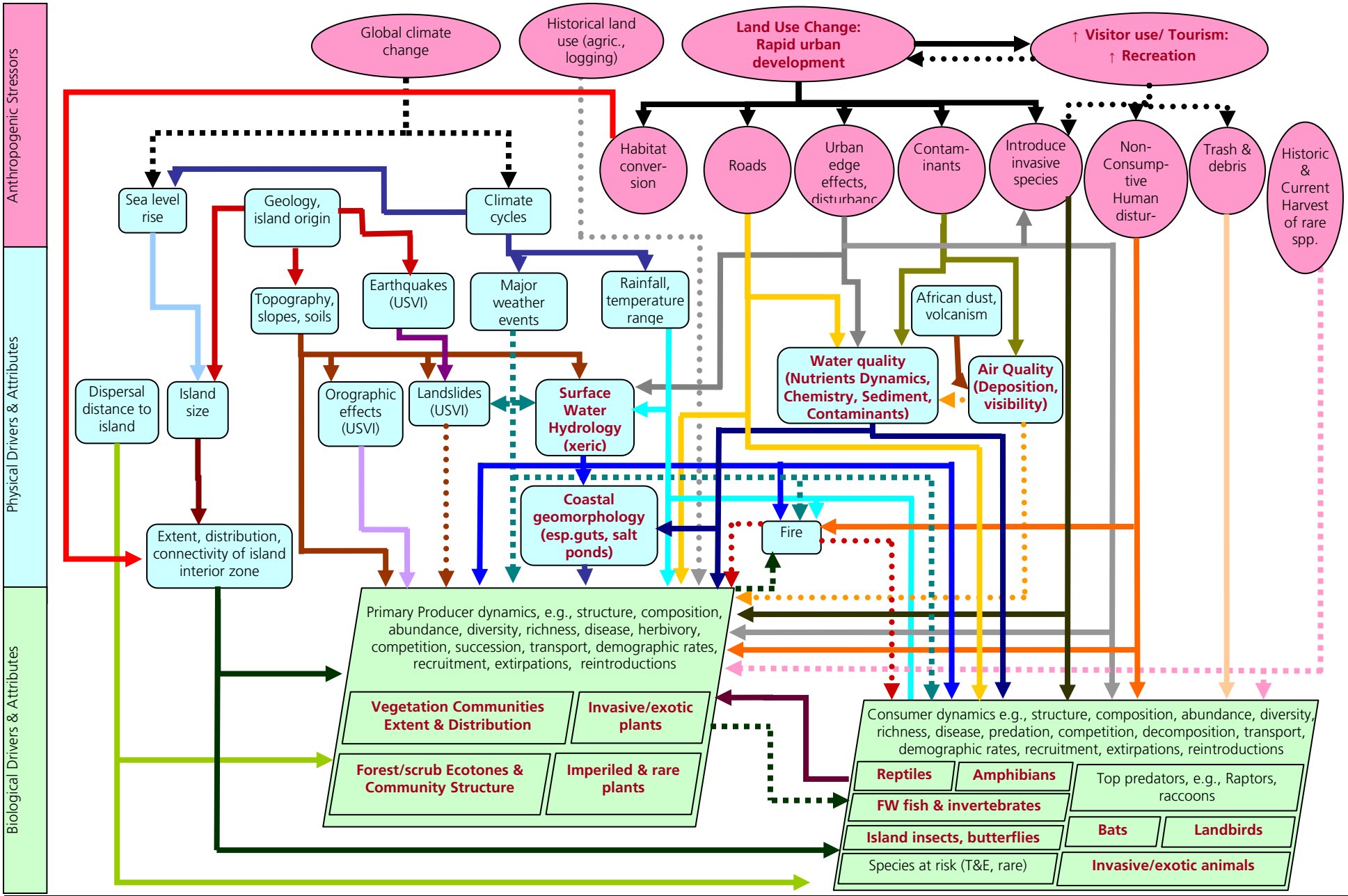


Figure J.5-K. Island interior ecological zone conceptual model diagram. Solid and dotted lines show assumed effects of anthropogenic stressors, physical and biological drivers and attributes. Boxes with **red print** directly relate to a proposed Vital Sign. (Use of dotted lines is to clarify and does not indicate lesser importance.)

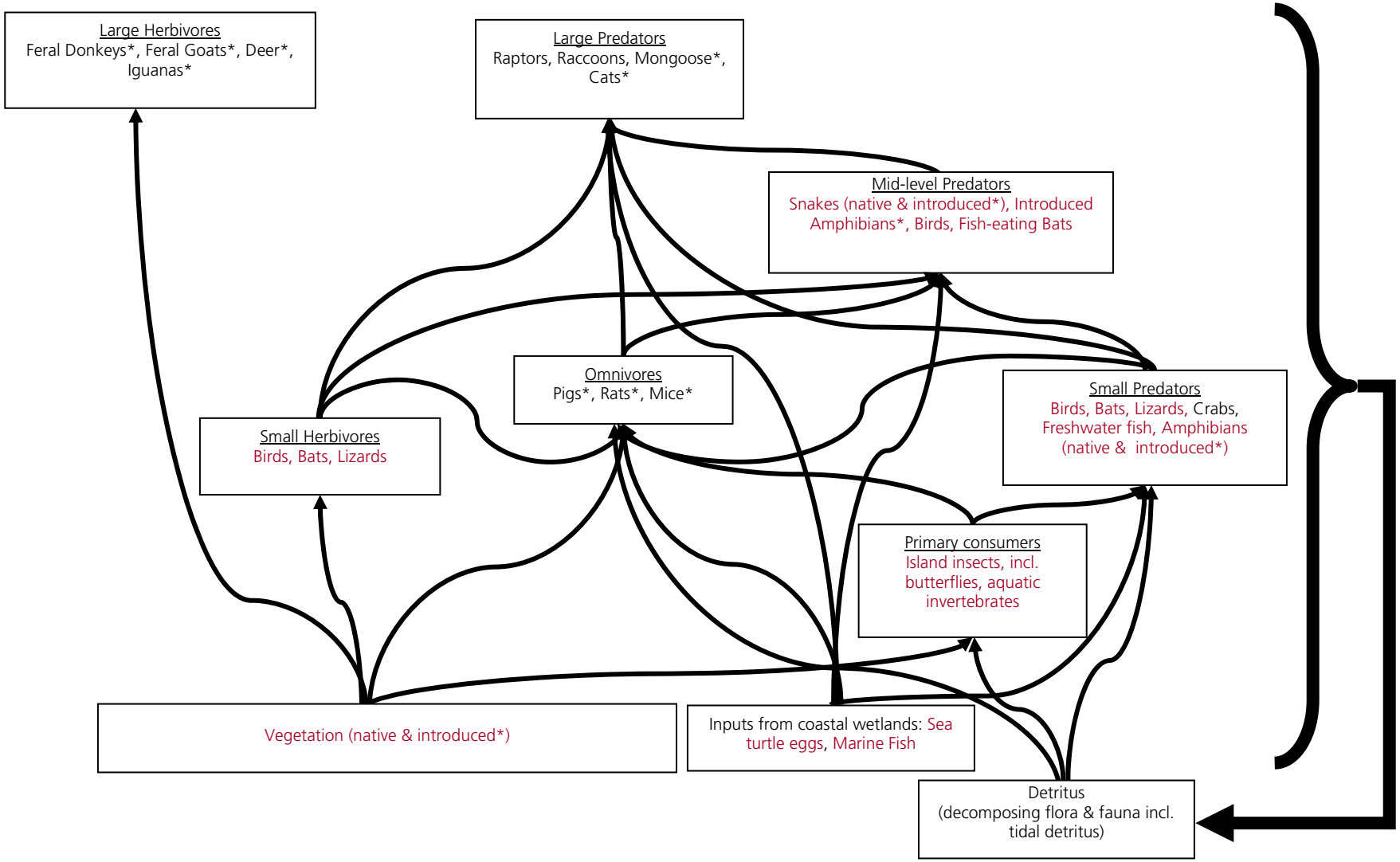


Figure J.5-L. Island interior food web. Introduced species have had a major impact and are indicated by a "*". Red items are directly related to a selected Vital Sign

J.5.2 Drivers and Anthropogenic Stressors

J.5.2a Driver: Climate, xeric island hydrology and orographic effects

The climate on these islands is primarily tropical, characterized by dry winters with wetter summers. Vegetation on the keys in BISC contains some temperate species such as oaks. During the dry season little to no fresh water exists on these islands with the few exceptions of areas that may catch and hold rain water such as karst formations in BISC or "guts" in VIIS. The steep topography of St. John, Buck, and St. Croix Islands creates orographic effects with drier, east-facing slopes and moister west-facing slopes. Vegetation and fauna are adapted to hot, xeric, high wind environments that are frequently inundated with salt spray.

J.5.2b Driver: Major weather events such as hurricanes, tropical storms, and large wind events

Weather events such as hurricanes, tropical storms, and large wind events cause periodic destruction to terrestrial vegetation, localized flooding, and landslides, resulting in a re-initiation of plant succession processes. The amount of impact depends on the strength of the storm and frequency. Some scientists suggest that global climate change may increase the strength and frequency of storms.

J.5.2c Driver: Geology, topography, soils, earthquakes and landslides

The underlying geology, topography and soils have strongly influenced the resulting vegetation communities that established and their stability. The U.S. Virgin Islands parks consist of steep rocky islands of uplifted metamorphic rock. VIIS on St. John is on a different tectonic plate from Buck Island (BUIS) and SARI on St. Croix and low-magnitude earthquakes are common. In contrast, the islands in South Florida parks are low and flat. The small amount of terrestrial habitat in DRTO and BISC is found on the keys, (i.e., flat sandy islands are built on top of historical reefs (Pleistocene Key Largo Limestone)). Only Garden Key, Long Key, Loggerhead Key, and Bush Key in DRTO are large enough to qualify as having an inland terrestrial community assemblage.

Earthquake effects on Virgin Island parks range from minor to major, depending on size of the event. During 2003, 947 earthquakes occurred in the Puerto Rico Seismic Network which includes the U.S. Virgin Islands. 26 of these earthquakes were large enough to be felt (7 on the Virgin Islands Platform) with the largest measuring 6.5 in the Richter Scale (Puerto Rico Seismic Network 2003). Effects can include bluff sloughing, landslides, and in extreme cases tsunami destruction.

Landslides are a natural occurrence on steep slopes, especially after storms or long periods of heavy rainfall such as November 2004. However, at VIIS and SARI, excessive grazing by feral goats and donkeys can increase slope failure.

J.5.2d Driver/Stressor: Sea level rise

The sea level has risen over the past several thousand years. However, the rate is expected to sharply increase due to global climate change and in fact has sharply increased during the past century to at least 12 inches/100 years (see Lodge 2005). Sea level rise will have a greater impact on low-lying BISC, EVER and DRTO keys than on the steeper Virgin Island parks, causing a gradual loss of low-elevation land area and reduction in the extent of island interior habitat. Sea level rise is also expected to further exacerbate deterioration of Fort Jefferson (DRTO) and thwart efforts to stabilize that structure.

J.5.2e Driver: Isolation from mainland, small island size, and dispersal

Island isolation and small island size, coupled with limited water resources, have resulted in fewer native land-based species than nearby mainland areas. Initial colonization and re-colonization events are very important. The lack of water resources creates stressful "founder effects" that make establishment of breeding populations difficult for all except island dispersal adapted species. In general the smaller the size of the island and the greater the distance from other dispersal areas decreases the number of native species present. The only native mammal in the Virgin Island Parks are bats. The top predators (rats, mongoose, raccoons, raptors) of St. Croix, St. John, DRTO and larger islands of BISC differ substantially from mainland areas. The smaller islands of Buck Island and some of VIIS keys have even fewer top predators, making them predator-free habitat for seabird colonies and migrating waterfowl.

Visitation by migratory birds distributes seeds among islands (e.g., white-crowned pigeon) and can transport avian viruses, (e.g., influenza A in least terns). Other natural dispersal of plants (seeds, propagules and pollen), insects, herpetofauna and small mammals occurs through wind and ocean currents via driftwood. Hurricanes and tropical storms can be a significant factor in dispersal of species. Exotic ungulates can distribute exotic plant seeds throughout St. John and St. Croix islands.

J.5.2g Driver / Stressor: Water quality and air quality

Diminishing water quality may impact riparian habitats along ephemeral streams on St. John and the Salt Rivers on St. Croix. In SARI and VIIS, excessive fertilizer and sedimentation in streams from urban and agricultural areas can alter stream ecology which in turn affects invasive plants and terrestrial fauna such as amphibians and birds.

African dust storms from the Sahara and Sahel periodically diminish air quality in the U.S. Virgin Islands parks and to a lesser degree in South Florida parks. In addition, rising urbanization diminishes local air quality.

J.5.2h Stressor: Reduction, fragmentation of habitat and urban edge impacts

On St. John (VIIS) and St. Croix (SARI) much of the non-park area is expected to eventually become developed, although the density of development is unclear. However, the amount of habitat available for fauna outside the park boundaries as

well as within inholdings is expected to be reduced and fragmented. As development increases, effects of urbanization at the park boundary are expected to increase the following: construction effects, introduction of non-native plants and fauna into parks, hydraulic loading on the septic system, solid waste, contaminants in the ephemeral streams on the islands, need for recreational opportunities, and possibly freshwater runoff into natural areas which can alter plant communities. Increasing numbers of roads and traffic may increase road-kill of land hermit-crabs during annual reproductive migrations and roadkill of snakes and amphibians. However, the mammals killed on roads are all exotic species.

J.5.2i Stressor: Historical land use

Historically, land was cleared on these islands for sugar, cotton (VIIS), lime and pineapple (BISC) plantations, grazing (VIIS, BISC), building Fort Jefferson (DRTO), and logging (BISC). Vegetation today is often in various successional stages of recovery from these earlier land uses.

J.5.2j Stressor: Introduction and spread of invasive plant species

Invasive plant species are a major problem in island interiors (see Appendix G). They compete with and replace native vegetation including rare plants, create habitat that is less favorable or completely excludes native fauna species, and create habitat that may be more favorable to invasive fauna species. Two species of particular concern in south Florida parks are Australian pine (*Casuarina* spp.) and Brazilian pepper (*Schinus terebinthifolius*). Brazilian pepper was recently treated and eliminated from the Caribbean parks by the Exotic Plant Management Team.

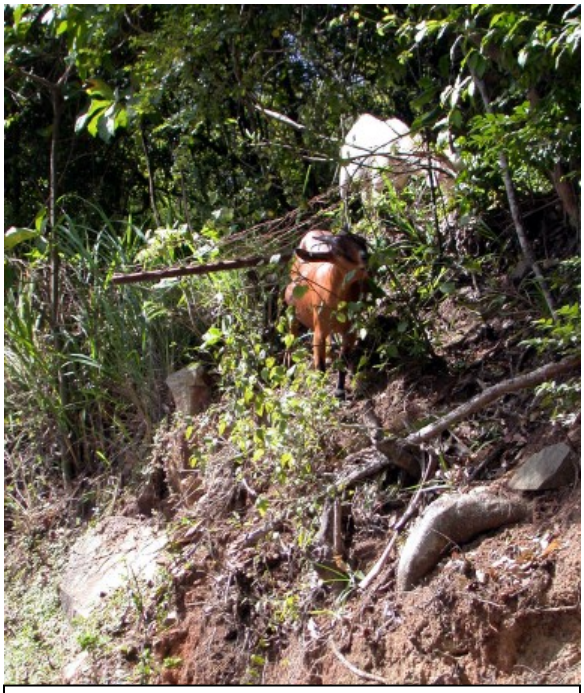


Figure N.4-L. Introduced goats in vegetation at St. John, U.S. Virgin Islands.

The main sources for new introduced species are dispersal from adjacent mainland areas, imported ornamentals (VIIS, SARI, historic BISC), agriculture and grazing (VIIS, SARI, historic BISC), and as seeds in camping/recreational gear.

J.5.2k Stressor: Introduction and spread of invasive animal species

The introduction of new animal species can have a strong impact on native plant and animal communities on islands. Although some introduced species do not establish as reproducing populations or only establish in urban areas, others have become major problems as invasive species that compete with native species, alter vegetation, or alter island food webs as new top predators. For example, introduction of Cuban tree

frogs, mongooses, red-eared slider turtles, corn snakes, and cats add new types of predators to the islands to which existing species are not adapted. Introduction of feral goats, Mexican red-bellied squirrels, and mice adds new herbivores to the islands. Roof rats and Norway rats are omnivorous, eating everything from eggs to vegetation to seeds. Domestic and feral cats prey on native birds and small mammals. Feral goats and donkeys also trample seabird nests and cause increased erosion and slope failure due to excessive grazing. Feral pigs and descendants of European Boars cause erosion and impacts to endangered plant species through rooting activities. Some of the more problematic invasive species in island interiors include rats, mice, Cuban tree frogs (VIIS, SARI), mongoose, goats, pigs, donkeys (VIIS), Mexican red-bellied squirrels (BISC), uncontrolled pets and illegally released pets in parks (all parks). Additional species are listed in Appendix H.

Some species such as the red-footed tortoise and green iguana were apparently introduced to the U.S. Virgin Islands in pre-Columbian times, although probably by humans. We decided to list them for completeness, but they are not recent introductions and their impact is assumed to be small (USVI Division of Fish and Wildlife 2005).

The main sources for new introduced species are dispersal from nearby mainland areas, released pets, released livestock, plant nurseries, ships, cargo, and bait shops.

J.5.2l Stressor: Roads (VIIS, SARI)

VIIS and SARI have roads through and around the parks. These roads can create roadkill and cause habitat fragmentation depending on use. Native species affected by roads are land hermit crabs during migration, native snakes and amphibians. Roads can also provide avenues for raptors to fly under the tree canopy providing access to prey not otherwise accessible. Additionally, in VIIS new dirt roads built for home construction on private inholdings have become major conduits for runoff and erosion affecting both island interior habitats and coastal marine resources.

BISC has a dirt road called “Spite Highway” that runs the length of Elliot Key which is used occasionally by park personnel. Raptors may use it, but it probably has minimal other impacts.

J.5.2m Stressor: Recreational impacts, physical trash and refuse

Hiking and camping are the main recreational impacts to island terrestrial interiors. When unmanaged, these uses can increase physical trash and refuse, increase disturbance around camp areas including noise pollution, increase disturbance to bird and turtle nesting areas, and increase emissions from visitor vehicles which can degrade air quality. Physical trash and refuse can strangle animals that are caught in it and can artificially subsidize predators such as raccoons and mongoose, allowing them to occur in higher populations than normal with increased impacts to native fauna (e.g., sea turtles and native birds).

J.5.3 Anticipated Effects of Drivers and Stressors on Ecological Zone Extent and Biological System Attributes

J.5.3a Change in extent of Island Interior Zone

Urban development outside park boundaries coupled with privately owned inholdings will reduce the total amount of habitat available to native species possibly all the way to park boundaries (VIIS, SARI). The density of expected development is unclear which may affect the utility of habitat outside the park for species. DRTO, BISC, BUIS and EVER islands are not expected to be affected by this stressor.

Sea level rise is expected to reduce the total amount of island interior zone in all parks with the greatest reductions to the low-lying islands of DRTO, EVER and BISC.

J.5.3b Change in primary producer dynamics: (i.e., vegetation composition, structure, and function; distribution and abundance of rare flora; percent native vegetation)

Vegetation communities in island interior environments are typically in various stages of succession from different types of disturbance, such as hurricanes, landslides or historical land uses. Slope, aspect, soil, local moisture gradients, presence of seed banks, and time since disturbance all influence the vegetation community structure and composition that emerges. The periodic, devastating impact of hurricanes is the largest natural disturbance factor in these communities.

Introduction of non-native plants is currently the strongest stressor on island interior vegetation communities and on rare plants. As much as 21% of the flora of VIIS is estimated to be non-native plants (Clark 2003). Non-native animals such as goats, hogs, donkeys, and rats also strongly impact the vegetation and rare plants.

Other impacts on vegetation are expected to be more localized. In VIIS and SARI, excessive nutrients from run-off and malfunctioning septic systems may impact plant community structure and composition in riparian areas. In areas around the park boundary (VIIS, SARI), water runoff into the park may alter island interior vegetation communities which are adapted to drier conditions. Recreational disturbance to vegetation can be a minor to major factor depending on management.

Rare plant species can be negatively impacted by illegal collecting, recreational disturbance, genetic bottleneck effects, catastrophic weather events such as hurricanes, presence of feral mammals, and loss of pollinators due to other disturbance in the system.

J.5.3c Change in consumer dynamics, (i.e., fauna community structure and function, guild composition and abundance, and distribution and abundance of rare species)

The fauna on these islands is characterized by limited numbers of species when compared with the same guilds on larger islands and mainland areas, coupled with simplified food webs where the top predators are typically raptors and raccoons (BISC). Founder effects and limited freshwater availability are the primary causes of

these differences. The absence of predators has made some smaller islands important locations for seabird colonies, shorebird colonies, and wading bird rookeries. Island food webs can be very dependent on additional food from the sea (seabird fishing, dead fish carcasses, intertidal invertebrates, etc.). Probably the biggest impact on island food webs is the introduction of invasive animals and plants by humans (e.g., cats, mongoose, rats, goats, hogs) which both compete with and prey upon native species. Island food webs are also sensitive to additional freshwater inputs and food inputs to the system due to urbanization and trash refuse which can artificially subsidize predators such as raccoons, mongoose, or rats, allowing them to reach higher than normal abundances by feeding on trash. These subsidized predators can then have higher impacts on sea turtles and bird nests. On St. John and SARI, road mortality and fragmentation could negatively impact land-bound species such as lizards, snakes, turtles, land crabs, and frogs to a greater degree than other fauna, but the population level impacts are unclear. The impacts of trash entanglement on bird, bat, and reptile populations is unclear, but a concern, as is the impact of illegal collection of rare species either as pets or for private collections.

J.5.4 Potential and ongoing management actions

Following is a list of potential and ongoing local management actions to manage stressors and, if necessary, system drivers in SFCN parks:

- Land acquisition, esp. through land trusts, government grants, or other donations in VIIS and SARI.
- Public education, signage, communication with park interpretive staff
- Research and establish best management practices in areas adjacent to park lands to minimize effects on park (VIIS, SARI), (e.g., recommended landscaping vegetation, preventing water runoff going into park during dry season)
- Pave dirt roads, especially on steep slopes to prevent runoff and sedimentation.
- Enforce water quality regulations and revise as necessary
- Control invasive plant and animal species
- Seek to minimize new introductions of invasive plants and animals through public education, work with local nurseries, work with neighboring and inholding land managers and land owners, and early detection at likely establishment sites.
- Seasonally or temporarily close areas that keep visitors away from sensitive areas, rare plants, seabird nesting, etc.
- Conduct additional actions to safeguard very rare plants such as establishing additional populations, implementing protective measures, etc.
- Conduct habitat restoration

- Alter frequency and locations of regular trash pickup and frequency of park cleanup days with volunteers. Use animal proof trash receptacles to avoid artificially subsidizing animals such as raccoons, mongoose, donkeys, and rats.
- Enforce speed limits on roads and revise as necessary
- Perform interagency consultation on proposed projects to minimize impacts
- Reintroduce extirpated species

APPENDIX J.6

COASTAL WETLANDS ECOLOGICAL ZONE

J.6 Coastal Wetlands Zone

The following conceptual model draws strongly throughout from the following references: Davis (2004b); Lodge (2005); Kendall *et al.* (2005), USVI Division of Fish and Wildlife (2005), and USFWS (1999). The reader is strongly referred to these references for more detailed information.

J.6.1 Summary

The Coastal Wetlands Model includes mangrove estuaries, mudflats, beaches, halophytic prairies and marshes, coastal lakes and lagoons, some of which are described in greater detail below. This is a highly dynamic zone in which each of these communities transition into each other and back due to the drivers and stressors acting upon them. This ecological zone is found in all seven parks in the south Florida/Caribbean Network (see maps in chapters J.3, J.4, and J.7).

Mangroves

Mangrove forests are found along shorelines and in the coastal channels and winding rivers in south and central Florida and the Caribbean (see Figure J.6-A through J.6-C). Red mangroves (*Rhizophora mangle*), identified by their stilt-like roots, black mangroves (*Avicennia germinans*) and white mangroves (*Laguncularia racemosa*) thrive in tidal waters, where freshwater mixes with saltwater. Buttonwood (*Conocarpus erectus*) is found at slightly higher elevations that are inundated during storms. Mangroves are only a narrow band in VIIS and SARI but can extend up to 12 miles inland in the Everglades (Smith, 1994).

Six mangrove community types are found within SFCN parks. These include overwash mangroves, fringe mangroves, riverine mangroves, basin mangroves, hammock/berm forest mangroves, and dwarf or scrub mangroves (USFWS 1999). Overwash mangroves include island areas that are frequently inundated or overwashed with tides. Fringe mangroves are thin forests bordering waterbodies such the thin mangrove fringe found in VIIS and BUIS. Riverine mangroves occur in river floodplains and along tidal creeks and are daily inundated with tides, (e.g., the SARI estuary). Basin mangroves occur in depressions both along the coast and further inland. These may receive daily tidal inundation or only seasonal flushing. Red mangroves are more common along coastal areas and black and white mangroves more common inland. Black mangroves are dominant in areas with concentrated salinity due to evaporation (USFWS 1999). Hammock/berm forest mangroves are on elevated areas such as the "Buttonwood Ridge" in EVER. Dwarf or scrub mangroves that grow less than 5' in height occur in areas of EVER, BICY, and the Florida Keys (USFWS 1999).

Halophytic-tidal prairies and marshes

Halophytic prairies and marshes vary greatly in tidal inundation from frequent

daily flooding to occasional tidal flooding during storms (see Figure J.6-D). Typical vegetation includes coastal cordgrass (*Spartina spp.*) and black rush (*Juncus roemerianus*). Typical halophytic herbaceous prairie vegetation can include saltgrass (*Distichlis spicata*), smutgrass (*Sporobolus* spp.), keysgrass (*Monanthocloe littoralis*), saltwort (*Batis maritima*), glasswort (*Salicornia* spp.) and sea purslane (*Sesuvium* spp.) (Rutchey *et al*. 2005).

Salt ponds
Salt ponds occur in the VIIS, BUIS, and SARI inside the mangroves that are maintained through tidal seepage or periodic breaching of the coastal berm (see Figure J.6-E). Such salt ponds can reach hypersaline conditions as water is evaporated. These serve as important feeding areas for wading birds and shorebirds.

Coastal lakes and basins
Coastal lakes and basins occur in EVER in the area of mangroves and tidal prairies typically ranging from oligohaline to mesohaline conditions. The submerged aquatic vegetation support seasonal populations of coot, scaup, widgeon and pintail (Davis 2004b) (see Figure J.6-F).

Tidal flats
Tidal flats in Florida Bay and other coastal areas vary from calcareous, carbonate muds to sandy areas exposed during low tides and are popular feeding grounds for shorebirds and wading birds (see Figure J.6-G).

Beaches
Beaches in the SFCN vary from narrow beaches fringed by mangroves (see Figure J.6-H), to some areas of wider sandy beaches in BUIS, DRTO and EVER (see Figure J.6-I), calcareous mud/sand beaches (see Figure J.6-J), coralline beaches, and gravel beaches (see Figure J.6-K).

This coastal zone is valued for many reasons. Mangroves protect shorelines from erosion and dampen effects of wave action on coastal resources and nearby private property. Tidal wetlands and mangroves provide highly productive nursery habitat for juvenile fish, pink shrimp, bivalves and conch contributing to commercial and recreational fisheries. Wading birds congregate here to feed in tidal flats, estuaries, salt ponds, tidal marsh and mangroves. Many bird species nest in the mangrove trees. Beaches provide nesting habitat for protected sea turtles and terns. Halophytic prairies and buttonwood areas provide important habitat for rare plants such as orchids and bromeliads. Beaches and tidal wetlands provide recreational and fishing opportunities for park visitors.

The primary physical drivers in this system include climate, major weather events, currents, tides, topography/bathymetry, freshwater influx, sea level rise, sediment accretion, water quality (salinity, nutrients, turbidity, temperature, pH, DO), and

protection of the zone by offshore coral reefs or barrier islands. Some minor drivers include earthquakes in the Virgin Islands, nutrient inputs from seabird, shorebird, and wading bird colonies, and alligator enhancement of upper tidal channels. Important anthropogenic stressors in this zone include alterations in freshwater and sediment influx, invasive plants and animals, contaminants, disturbance from recreation, physical trash and debris, boat groundings, illegal collection, and dredging outside of parks. Anticipated changes in zone extent and biological attributes include movement of mangroves, beaches, and tidal wetlands inland due to sea level rise; changes in the extent, distribution, composition and structure of mangrove communities, tidal/halophytic prairies and marshes, coastal lakes, salt ponds and beaches due to the combined effect of alterations in freshwater inputs, sea level rise, sediment runoff, hurricanes and tropical storms, and invasive plant species; reductions in estuarine productivity; reductions in wading bird colonies; impacts of mercury bioaccumulation and other contaminants on top predators; introduction of new top predators; and declines, changes in community composition and/or increased invasive species among the following communities: fish, crustacean, wading birds, seabirds, shorebirds, and herpetofauna, including rare and listed species.

The major management issues in the Coastal Wetlands Ecological Zone include rehabilitation of freshwater and sediment inputs, reductions in or mitigation of contaminants and debris, control of invasive species and prevention of new introductions, management of recreation impacts, and protection and management of rare plants and animals.

Figure J.6-L shows the interrelationships among natural system drivers, anthropogenic stressors and zone extent and biological system attributes (e.g., primary producer dynamics and consumer interaction dynamics). The remainder of this conceptual model consists of describing the drivers and stressors in greater detail followed by a description of anticipated effects on system attributes coupled with potential local management actions. The section headings include

- Driver: Climate, temperature range
- Driver: Major weather events such as hurricanes and tropical storms
- Driver: Dynamic interaction among currents, tides, freshwater influx, salinity topography/bathymetry and tidal channels
- Stressor: Alterations in freshwater and sediment influx
- Driver: Soil accretion - Mangrove and wetlands trap sediments, trash and contaminants resulting in elevation rise
- Driver: Alligators, boaters and hunters keep tidal channels open (EVER, BICY, BISC? Only)
- Driver/stressor: Increased sea level rise
- Driver: Natural coral reef growth, herbivory, and erosion processes.
- Driver: Earthquakes in U.S. Virgin Islands

- Driver/Stressor: Water Quality – nutrients, turbidity, salinity
- Stressor: Water quality – Contaminants, pesticides, mercury, oil
- Stressor: Catastrophic oil spills, chemical spills and other major disasters
- Stressor: Physical trash, storm debris, abandoned fishing gear
- Stressor: Introduction and spread of non-native flora and fauna
- Stressor: Increased boat groundings and damage from improper boat moorings
- Stressor: Disturbance to wildlife due to visitation and recreation
- Stressor: Illegal collection
- Stressor: Dredging

These Physical Drivers, Key Background Attributes, and Anthropogenic Stressors are expected to influence the following key system attributes

- Change in extent and distribution of Coastal Wetlands Ecological Zone
- Change in primary producer dynamics, (i.e., vegetation composition, structure, and function; distribution and abundance of rare flora; percent native vegetation)
- Change in consumer dynamics, (i.e., fauna food web structure, guild composition and abundance, and distribution and abundance of rare species)



Figure J.6-A. Red mangroves along western edge of Biscayne Bay.



Figure J.6-B. Red mangrove (Rhizophora mangle) with stilt-like prop roots (left picture). *Black mangrove (Avicennia germinans) with upward reaching roots called pneumatophores that exchange gases (right picture).*



Figure J.6-C. Orchids and bromeliads growing as epiphytes on buttonwood (Conocarpus erectus).



Figure J.6-D. Salicornia marsh with dead black mangrove remnants from hurricane damage in EVER. A higher ridge of buttonwoods is in the background on the left.



Figure J.6-E. Salt Pond on St. John, U.S. Virgin Islands.



Figure J.6-F. Eco Pond near Flamingo, EVER.



Figure J.6-G. Tidal flats on east shore of Elliott Key during low tide.



Figure J.6-H. Thin beach along on eastern shore of Elliott Key, BISC.



Figure J.6-I. Sandy beach on Buck Island in BUIS, U.S. Virgin Islands.



Figure J.6-J. North shore of Florida Bay, EVER.



Figure J.6-K. Gravel beach on St. John, U.S. Virgin Islands.

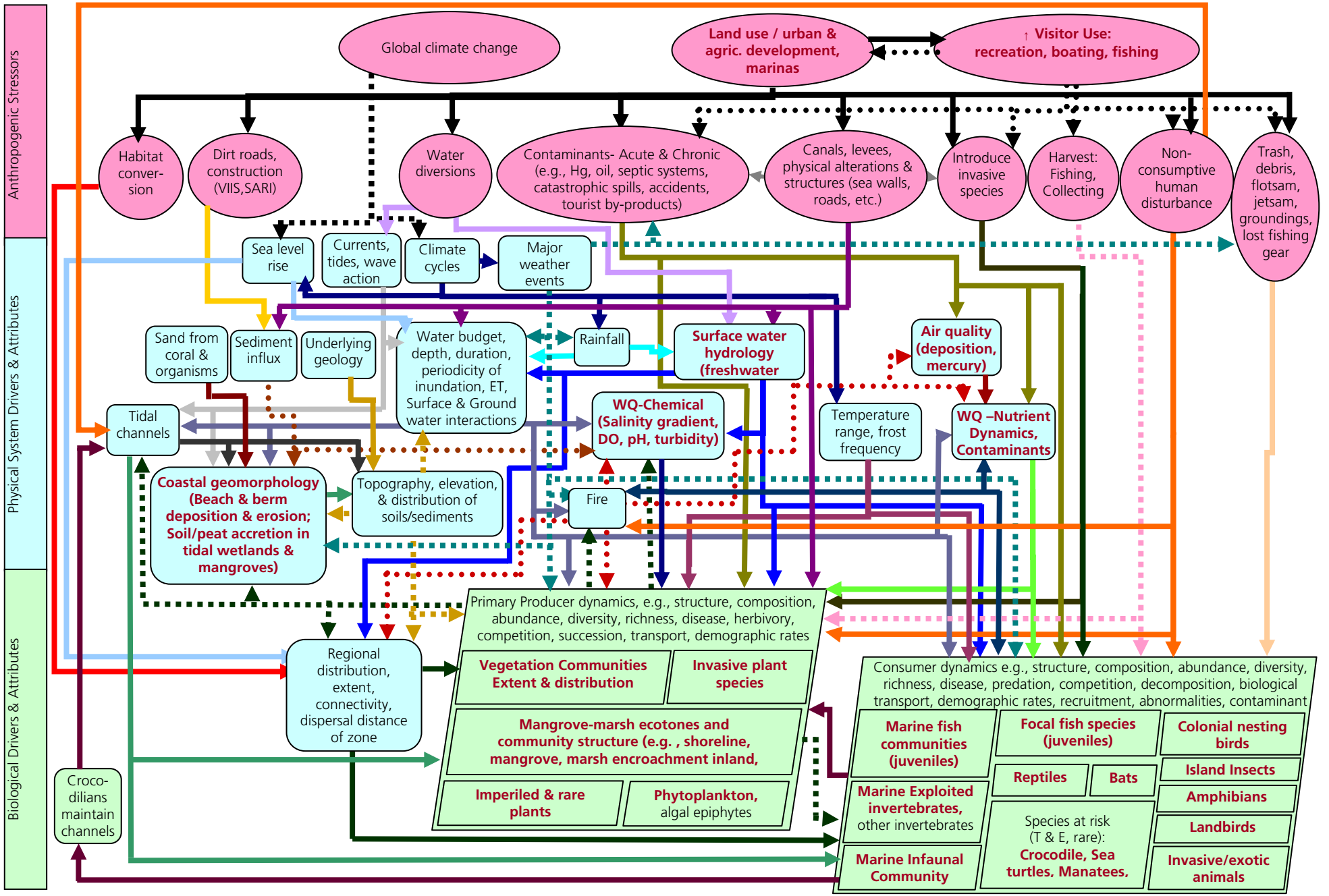


Figure J.6-L. Coastal wetlands ecological zone conceptual model diagram. Solid and dotted lines show assumed effects of anthropogenic stressors, physical and biological drivers and attributes. Boxes with **red print** directly relate to a proposed Vital Sign.

J.6.2 Physical Drivers, Key Background Attributes, and Anthropogenic Stressors

J.6.2a Driver: Climate, temperature range, frost frequency

The sub-tropical and tropical climate allows mangroves to dominate coastal wetlands in SFCN parks. Mangroves are very sensitive to frost damage with red mangroves being the most frost-sensitive and black mangrove the most cold-tolerant (USFWS 1999). This restricts them in wetlands in north Florida where *Juncus* and *Spartina* species dominate although areas of black mangrove forest can still be found. Frost may also cause a shift from mangroves to Brazilian pepper (Jimi Sadle, personal communication).

J.6.2b Driver: Major weather events such as hurricanes and tropical storms

Disturbance and destruction by major weather events such as hurricanes and tropical storms are major factors creating change in this zone and affecting the mosaic of mangrove communities, halophytic marshes, storm berms, beaches and coastal prairies. The effects range in severity depending on the storm, creating gaps or large areas of mangrove destruction and reinitiating plant succession processes. These storms can change local hydrology by creating breaks in coastal berms or depositing large amounts of sediment to form new berms. Storms add, remove, and redistribute sand along beaches, change the position of sand-bars and create or alter salt ponds. Flooding due to heavy rains, tidal surge, and burial with sediment can kill some plant communities (e.g., hurricane destruction of black mangroves in EVER) or distribute mangrove seedlings far inland (e.g., dwarf red mangroves in EVER) (Lodge 2005). Storms also transport and disperse flora and fauna; sometimes foster release of non-native fauna from zoos and collections (Waddell 2005); cause release of raw sewage; and cause debris impacts on shorelines. Invasive plant species can often quickly establish in newly disturbed areas, allowing them to get a foothold and spread into neighboring areas.

J.6.2c Driver: Dynamic interaction among currents, tides, topography/bathymetry and freshwater influx

Estuaries and coastal marshes are environments of extremes with wide ranges in salinity, hydrology ranging from periods of submersion to desiccation, extreme winds, storm surges and wave action. The dynamic interaction among currents, tides, topography, bathymetry and freshwater influx affect the extent, distribution and composition of red mangrove, black mangrove, white mangrove, buttonwood, beach, halophytic prairies and tidal marsh, coastal lakes and salt ponds, and tidal creeks, through processes of physical erosion and deposition, water depth, frequency and duration of inundation, and salinity range.

J.6.2d Stressor: Alterations in freshwater and sediment influx

Alterations in freshwater and sediment influx from coastal streams, sloughs and runoff occur due to freshwater diversions and artificial structures such as canals, dikes, weirs, and berms (EVER, SARI, BISC, BICY) impact the salinity gradient, siltation rates and plant succession. In EVER, the freshwater influx through Shark

River Slough and Taylor Slough was greatly reduced over the past 50 years due to large diversions of water south of Lake Okeechobee. This has resulted in increased salinities in Florida Bay (Rudnick 2004).

Many of the rivers in BISC have been converted to hardened canals, reducing the amount of estuarine habitat on the western side of the Bay and creating pulsed changes in the amount of freshwater and corresponding salinity levels, sometimes with scouring effect on benthic communities. Tidal creeks have all but disappeared and Biscayne Bay is thought to have become more saline than historical levels (Browder *et al*. 2004).

In the Cape Sable area of EVER, several canals and levees were created during the 1930's (including East Cape Canal, Homestead Canal, Slegel's Ditch, Houseman's Ditch, and Middle Cape Canal) to divert the water away from the Cape Sable area, in a failed attempt at creating "prime" real estate. These canals have changed the course of water from flowing through Whitewater Bay to flowing through Florida Bay and have altered local sediment transport with unclear impacts on local mangrove communities and coastal lakes.

The increases in salinities around Florida Bay and Biscayne Bay have stressed estuarine plant communities, reduced the value as nursery habitat for fish and crustaceans, and reduced submerged aquatic vegetation in coastal lakes and basins.

J.6.2e Driver/stressor: Sea level rise

Sea level rise is hypothesized to be a major change agent in this zone over the next century. Conservative estimates of sea level rise are *at least* a foot over the next century (Lodge 2005). This sea level rise is expected to have major impacts on the geomorphology, circulation patterns, salinity patterns and consequently on the mosaic of mangrove communities, halophytic marshes and prairies, beaches, salt ponds, coastal berms, and lakes.

Depending on the rate of sea level rise, two hypotheses exist:

- If sea level rise is slow, then accretion rates in mangrove swamps may be able to keep pace with rising sea level. However, the extent of mangrove communities may begin to extend further inland.
- If sea level rise is faster than soil accretion rates, then this means that tidal wetlands including mangroves and tidal marshes are expected to gradually move inland as sea level rises and as topography of land permits. In BISC and SARI, a similar movement is expected to occur, but eventually will be blocked by the limits of the urban development boundary. Further inland movement will depend on adjacent land-use decisions by adjacent land owners.

J.6.2f Driver: Soil accretion - Mangroves and wetlands trap sediments, trash and contaminants resulting in elevation rise

Mangroves and tidal wetlands trap sediments, trash and even contaminants. When mixed with detritus this results in gradual soil and elevation accretion. This process can keep pace with slow sea level rise. Mangroves and salt ponds also tend to trap sediments from the land runoff, reducing sediment impacts on nearby coral reefs.

J.6.2g Driver: Alligators & boaters keep tidal channels open (EVER, BICY, BISC Only)
Alligators enhance tidal creeks, keeping upper reaches open (Lodge 2005). Boating and hunting activity can also keep tidal creeks open.

J.6.2h Driver: Natural coral reef growth, herbivory, and erosion processes.
Fringe coral reefs protect coastlines by dampening the full force of wave action and storms. In addition, coral reefs and calcareous algae create much of the sand that supplies SFCN beaches. Thus, healthy coral reefs influence shoreline communities (see Marine Benthic Communities sub-model).

J.6.2i Driver: Earthquakes in U.S. Virgin Islands
Earthquakes could have negligible to major impacts on Caribbean islands parks (VIIS, BUIS, SARI), resulting in bluff sloughing, landslides or tsunami destruction.

J.6.2j Driver/Stressor: Water Quality – nutrients, turbidity, salinity, dissolved oxygen, pH
Where freshwater and saltwater meet, combinations of nitrogen and phosphorus contribute to highly productive estuarine environments. Reductions in freshwater flows into Florida Bay and Biscayne Bay have reduced this natural mixing with a corresponding drop in overall productivity. Mangroves and tidal estuaries can also absorb excess nutrients, thus improving local water quality. However, elevated concentrations of nitrogen and phosphorus can result in algal blooms, both planktonic and benthic forms. This can result in changes to the vegetation community composition and estuarine productivity and food web. In addition excessive algal and submerged aquatic vegetation (SAV) growth followed by vegetation dieoffs can result in dissolved oxygen sags that can negatively impact fish and benthic communities. Excess nutrients (nitrogen and phosporous) result from runoff from agriculture (EVER, SARI, VIIS, BISC), urban runoff (BISC, SARI, VIIS, BUIS), sewage effluent (VIIS from neighboring British Virgin Islands; SARI, DRTO from boats and local discharges), sewage from charter boats and cruise ships, and golf courses. Other local impacts can occur due to high seabird guano that affect nearby vegetation.

Sediment runoff and capture from upstream watersheds is a natural process in tidal wetlands. However, excessive sediment runoff is occurring due to local urban and inholding development in VIIS and SARI. This excessive runoff causes siltation of beaches and filling-in of marshes and salt ponds. Mangroves and marshes can trap some of this sediment. However, excessive sediment results in increases in water turbidity that impacts estuarine and nearby coral reef health.

J.6.2k Stressor: Water quality – Contaminants, pesticides, mercury, oil

Sources of contaminants in the Beaches, Mangroves and Tidal Wetlands zone include mercury from aerial deposition and watershed contamination, gasoline and contaminants from marinas, bottom paint on container ships (tributyl tin and cuprous oxide), pesticides in urban runoff and aerial deposition, water treatment plant effluent (BISC), landfills (BISC), creosote spills (BICY), industrial contaminants, and ballast and bilge water from commercial ships, and various wastes such as tires and vehicles dumped in canals. All these contaminants can have small but cumulative impacts on the system, depending on the scale of the problem. Red mangroves are especially sensitive to herbicides (USFWS 1999). Mercury is probably the biggest problem in south Florida parks. Aerial mercury deposition in EVER and BICY is thought to come from waste incineration and electricity production from burning fossil fuels. Mercury becomes methylated in marshes (biologically active) and becomes concentrated to toxic levels in fauna at higher trophic levels in the food chain (e.g., bass, wading birds, panthers).

J.6.2l Stressor: Catastrophic oil spills, chemical spills and other major disasters

With increased oil tankers and container ships traveling throughout the Caribbean and South Florida, there is an increased probability of a major contaminant disaster. The effects will depend on the contaminants involved. Oil spills have been found to have major long-term consequences on ecosystems and can take millions of dollars to restore ecosystem health (e.g., Tampa Bay spill in 1993)

J.6.2m Stressor: Physical trash, storm debris, abandoned fishing gear

Physical trash, storm debris and abandoned fishing gear (nets, lost or abandoned crab and lobster traps, fishing line monofilament and hooks) litter beaches in Florida and Caribbean parks. The source of this trash and debris is commercial and recreational boats, oceanic dumping, abandoned boats, storm debris, and park visitation. Trash, fishing lines and hooks, crab pot lines, and other debris entangles and kills wildlife such as pelicans, wading birds, sea turtles, terns, dolphins and manatees. Larger debris can damage vegetation. Debris on beaches may also deter or inhibit sea turtle nesting efforts. The trash and debris reduces visual quality for park visitors and can create health hazards for visitors when extreme.





Figure J.6-M (above). Entangled dead frigate bird on Buck Island, BUIS.

Figure J.5-N (left). Trash washed up on Elliott Key beach only 2 months after the large Baynanza cleanup at BISC.

J.6.2n Stressor: Introduction and spread of invasive flora and fauna

Problematic invasive plants in this zone include Brazilian pepper (*Schinus terebinthifolius*), lather leaf (*Colubrina asiatica*), and Australian pine (*Casuarina equisetifolia*). A more complete list is available in Appendix G. Invasive plants aggressively compete with and replace native vegetation, degrade or eliminate habitat for native fauna, and can create habitat that favors non-native fauna.

Invasive fish are some of the more problematic species in this zone. Non-native fish such as the Mayan Cichlid (*Cichlasoma urophthalmus*) have altered estuarine fish communities and food web dynamics in EVER with potential consequences to higher tropic levels such as wading birds. Other problematic species include rats (*Rattus rattus, R. norvegicus*), Burmese pythons (*Python molurus bivittatus*) (EVER, BICY) and other introduced constrictors, feral and domestic cats and dogs (VIIS, SARI, boundaries of EVER, BICY, BISC), bromeliad weevil (*Metamasius callizona*) on bromeliads (EVER, BICY), the marine toad (*Bufo marinus*), pigs (*Sus scrofa*) (VIIS, SARI, BICY), goats (*Capra hircus*)(VIIS), donkeys (*Equus asinus*)(VIIS), mongoose (*Herpestes javanicus)*(SARI, VIIS), and white-tailed deer (*Odocoileus virginianus*) (SARI).

J.6.2o Stressor: Increased boat groundings and damage from improper boat moorings

Improperly driven, loose, and improperly moored boats damage vegetation through boat groundings. Grounded boats can also cause local contamination problems as gasoline and other contaminants leak into the surrounding area.

J.6.2p Stressor: Disturbance to wildlife due to visitation and recreation
Unmanaged park visitation, boating and recreation can disturb seabird nesting colonies, woodstork, egret, and spoonbill rookeries. Increased trash also subsidizes native predators such as raccoons which then have increased impact on sea turtle nests, seabird nesting colonies, and wading bird nesting colonies.

J.6.2q Stressor: Illegal collection
Historically, illegal collection of sea turtle eggs, rare plants such as orchids and ferns, and reptiles such as indigo snakes has been a problem, and, although somewhat diminished at present due to strict enforcement by park personnel, continues to be a problem in some cases and can seriously impact native populations, even jeopardizing population survival.

J.6.2r Stressor: Dredging
Dredging to enhance boat access has historically altered bathymetry and shoreline in BISC, VIIS, and SARI, creating areas with dredge spoil deposits with salt-laden top soils. Dredging may still occur outside BISC, VIIS and SARI which could disturb contaminants and increase turbidity within the parks.

J.6.3 Anticipated Effects of Drivers and Stressors on Ecological Zone Extent and Biological System Attributes

J.6.3a Change in extent and distribution of the Coastal Wetlands Ecological Zone
The strongest impact over the long-term to the Coastal Wetlands Zone is likely to be due to sea level rise as the tidal wetlands move inland in all SFCN parks. In areas such as the western shore of BISC, this inland movement may be constrained by park boundaries and further inland movement will depend on adjacent land owner decisions.

J.6.3b Changes in primary producer dynamics
Changes are expected in the extent, distribution, composition and structure of mangrove communities, tidal/halophytic prairies and marshes, coastal lakes, salt ponds and beaches due to the combined effects of alterations in freshwater inputs, sea level rise and hurricanes and tropical storms. These alterations are difficult to predict. Mangrove community composition at a particular spot is a function of salinity, degree of tidal flushing, freshwater inputs, local topography, nutrients, soils, canopy closure, and time since disturbance. Figure J.6-O summarizes these interactions. Much of the direction of future change depends on how fast sea level rise occurs and the ability of soil accretion in the mangrove zone to keep up. Storms are a major disturbance and landscape change driver, causing large and unpredictable impacts on the landscape and vegetation, breaches in berms, new

berms, cutting off or reconnect salt ponds to the ocean, and so on. In Dry Tortugas National Park, a sand bar from Bush Key to Garden Key, cutting off the channel that formerly went between the two keys and altering locally currents, oxygenation, and sediment erosion and deposition processes. This sand bar was once again removed by Hurricane Katrina.

Future changes in Everglades National Park are particularly difficult to predict. Although the Comprehensive Everglades Restoration Plan will increase freshwater inputs into the park, the amounts are still being debated. The amount of freshwater input will influence estuarine lower food web productivity as well as how far inland the salinity gradient moves. The salinity gradient in turn will affect the distribution and inward march of salinity tolerant species such as mangroves. It is unclear whether this inland movement will occur as a slow progression inland of mangroves or whether hurricanes and storms will cause sudden changes in communities and local hydrology followed by slow decades of succession processes as soil peat and soil salinities are altered. How these changes occur could impact the rare plants found in the midst of this zone such as the rare bromeliads and orchids. Coastal lakes and basins are also affected where changes in salinity levels are already associated with decreased submerged aquatic vegetation (Rudnick 2004).

Invasive plant species remain a major concern and a strong agent of future change. Problematic species such as Brazilian pepper (*Schinus terebinthifolius*), lather leaf (*Colubrina asiatica*), and Australian pine (*Casuarina equisetifolia*) are aggressive invasive species that greatly alter vegetation structure and function for native species. Fortunately, effective controls exist for Australian pine. Controls for other species remain a challenge. In addition, preventing the establishment and spread of new problematic species (i.e., future introductions) will be an ongoing concern.

Other sources of change are more localized such as boat groundings, sediment runoff, herbicide use and tree-trimming by uninformed land-owners. However, if unmanaged these smaller stressors can also have a cumulative negative impact on the resources.

J.6.3c Changes in consumer dynamics

Mangrove estuaries are considered among the most productive in the world. Mangroves themselves contribute detritus, and mangrove roots provide substrate for algal growth – both of which greatly add to the estuarine and coastal productivity (see Figure J.6-O). Mangroves also provide nursery habitat for young fish and shellfish. The highly productive mangrove estuaries in turn provide productive nursery grounds for juvenile fish and invertebrates such as pink shrimp, bivalves and conch, thereby directly affecting the abundance, structure, and composition of fish and invertebrate communities. The dense mangrove roots and tidal marshes provide protection for the smaller juvenile fish which later emigrate out into the bays and coastal shelf areas, affecting sport and commercial fisheries including spotted seatrout, common snook, and pink shrimp (see Figures J.6-P, J.6-R). The high

abundance of fish and invertebrates, in turn, affect the nesting populations and distribution of colonies of wading birds and shorebirds such as wood storks, great egrets, roseate spoonbills, and terns.

Estuarine productivity varies with salinity, hydrology and nutrient status in the estuary which are all affected by freshwater input, tides, currents, and sea level. As low nitrogen, high phosphorous salt water mixes with high nitrogen, low phosphorous freshwater a highly productive interface is produced, particularly where Shark River Slough meets the Gulf of Mexico. Similarly, changes in the salinity gradient affect productivity in the estuaries. Decreases in freshwater inputs to Everglades National Park over the past 50 years have resulted in increased salinity levels in Florida Bay and in Biscayne Bay. This, in turn, has reduced estuarine productivity levels and fish production (Davis 2004b; Browder *et al*. 2004).

The salinity gradient also affects the distribution of crocodiles and alligators. Adult crocodiles are able to tolerate higher salinities than alligators, although juvenile crocodiles need salinities close to fresh water (Davis 2004b). As the salinity gradient has moved inland, Biscayne Bay and Florida Bay mangrove areas have become more saline, resulting in an overall reduction in brackish habitat that is hypothesized to have negatively impacted crocodile populations as these young reptilians are sensitive to extreme salinity levels.

In the Everglades, many wading bird colonies have greatly diminished in the mangrove areas around Florida Bay, presumably due to alterations in freshwater inputs, alterations in estuarine fish productivity and alterations in freshwater marsh and wet prairies fish and invertebrate productivity (Davis 2004b; Ogden 2004).

Alterations in freshwater inputs are less of a concern in VIIS and BUIS but could become a concern in SARI. Instead, increased sediment inputs are more of a concern. Tidal wetlands, salt ponds and mangroves can absorb some sediment runoff, but excessive runoff could increase turbidity and decrease productivity among the mangroves. Nutrient enrichment could also lead to algal bloom and submerged aquatic vegetation blooms which can then cause local dissolved oxygen problems for fish and aquatic invertebrates.

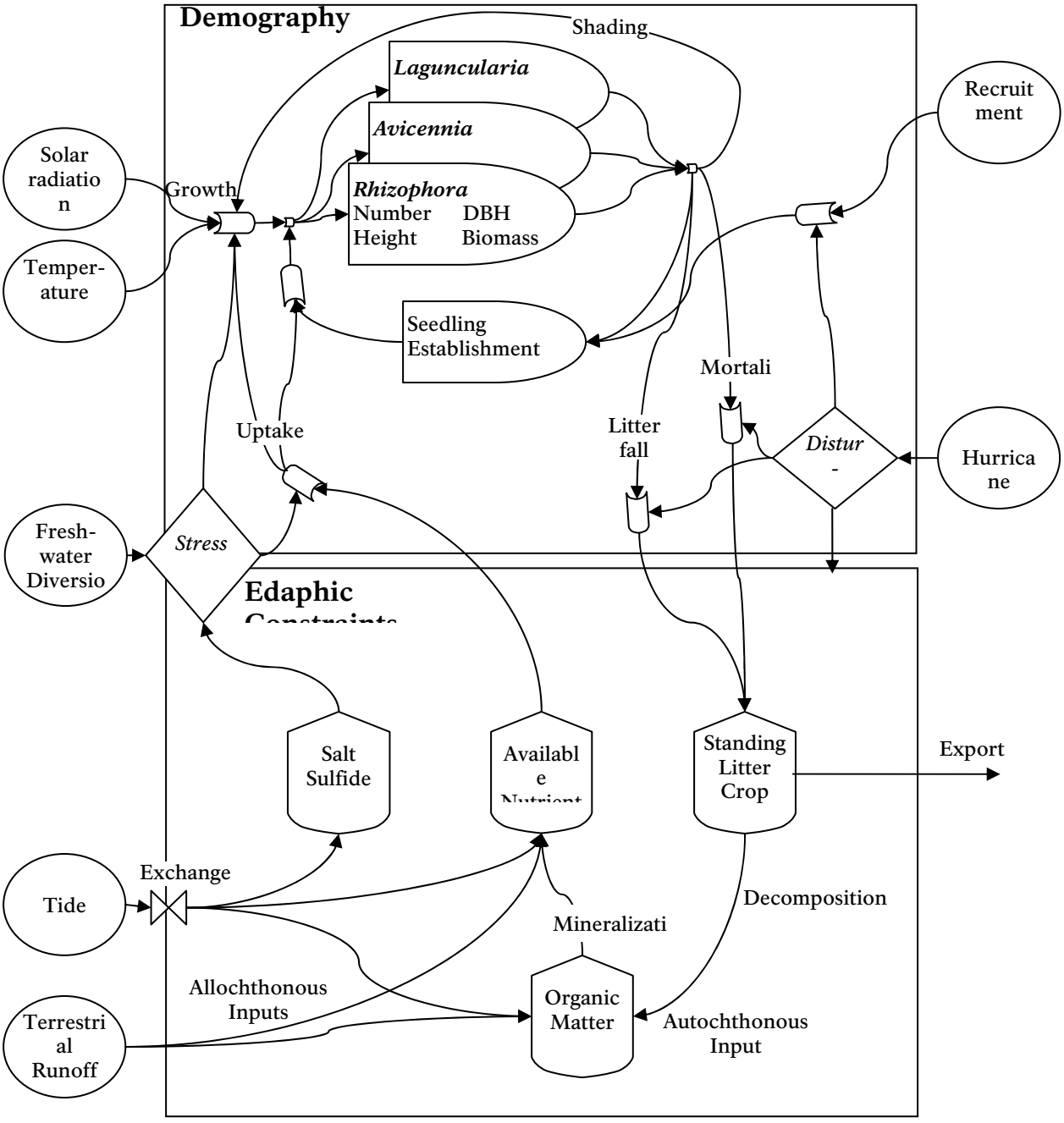


Figure J.6-O. Conceptual diagram of mangrove forest development including forcing functions and edaphic constraints. [Redrawn from Twiley *et al*. (1998); Chen and Twiley (1998)]

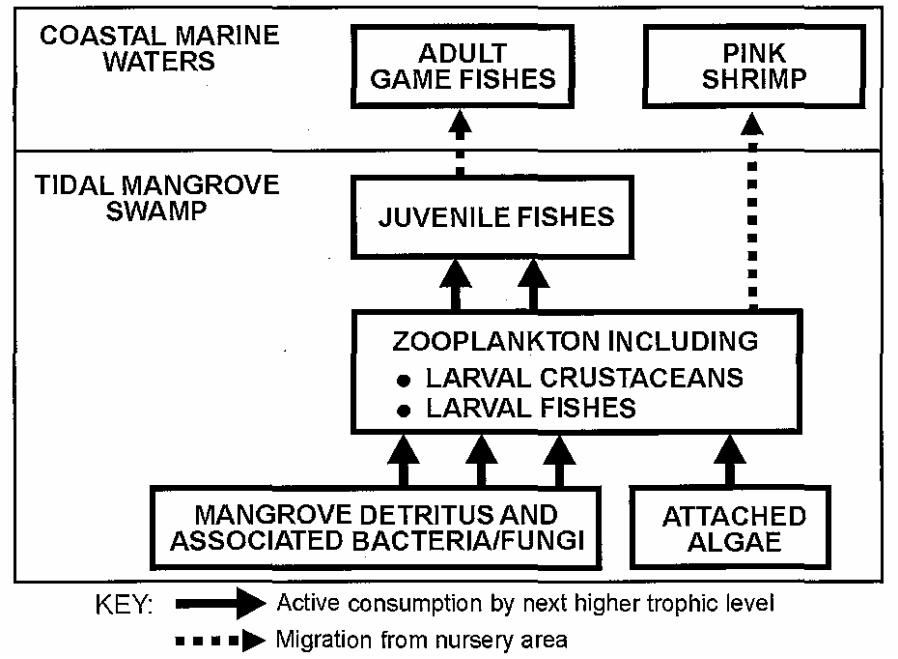


Figure J.6-P. Mangrove estuarine effects on food web (From Lodge 2005).



Figure J.6-Q. Fish among mangrove roots.

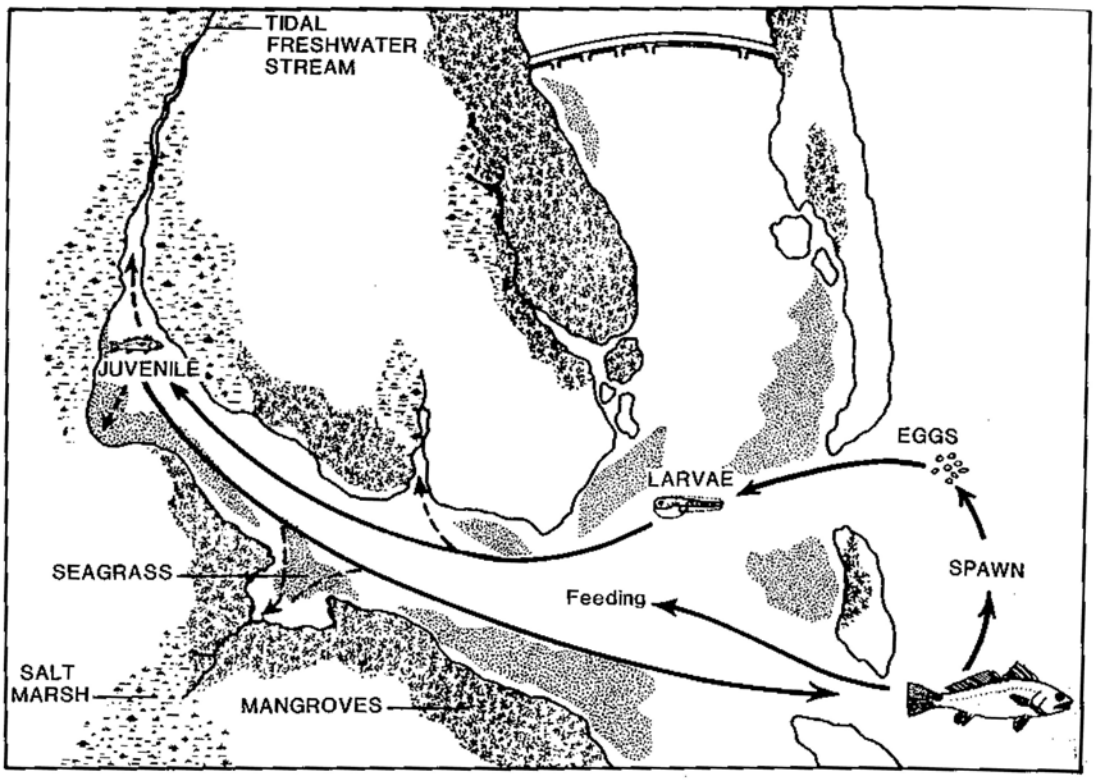


Figure J.6-R. Common life cycle of many estuarine fish and shellfish. (From Montague and Wiegert 1990; reproduced from Lewis *et al.* 1985)

Invasive estuarine species are a major concern in all parks. The Mayan cichlid has already severely altered estuarine fish communities in Florida Bay (Davis 2004b). Other introduced cichlids are listed in Appendix H. Many of these are popular aquarium species and this is a probable source of introduction. Invasive planktonic, invertebrate, and algal organisms, such as those introduced from ship bilge water and motors can also have large but difficult to predict impacts on the system (Kolar and Lodge 2001, 2002).

Contaminants such as mercury, pesticides, herbicides, and oil likewise can impact estuarine health. Mercury bioaccumulation is a major concern throughout the south Florida watersheds, with potential impacts on upper predatory fish, crocodilians and wading bird populations.

Some additional stressors affecting fauna include excessive trash levels as they entangle and kill wading birds, seabirds, sea turtles and other fauna and clutter sea turtle nesting beaches. Illegal collection of rare plants, indigo snakes and other species are a continuing concern. Sea turtles and seabird nesting colonies require special protection from raccoon and rat predation and humans where necessary.

J.6.4 Potential and ongoing local management actions

Following, is a list of potential and ongoing local management actions to manage stressors and, if necessary, system drivers in SFCN parks:

- EVER only– rehabilitation of system hydrology to more closely resemble historical hydrographs through Comprehensive Everglades Restoration Program (CERP)
- EVER only– local projects to limit saline intrusion until CERP begins to affect system
- BISC only – Potentially rehydrate coastal wetlands with treated reuse wastewater
- As necessary, work with neighboring lands or local governments to develop/implement best management practices for agriculture, urban areas, and construction zones
- Public education, signage, and communication with park interpretive staff regarding boater safety, trash disposal, park regulations, releasing of pets, sensitive areas, and overall protection of tidal wetland resources
- Rapid response to catastrophic vessel groundings to control problem and effective notification of authorities and cleanup experts. As necessary, develop area contingency plans for rapid response to vessel groundings. Cleanup and habitat restoration after oil/chemical spills
- Enforcement against illegal dumping
- Reduce incinerator and coal-burning emissions to reduce toxic metal deposition (i.e., mercury)
- As determined necessary, control invasive plant and animal species
- Seek to minimize new introductions of invasive species coupled with early detection at likely establishment sites
- Alter frequency and locations of regular trash pickup and frequency of park cleanup days with volunteers. Use animal-proof trash receptacles to avoid artificially subsidizing animals such as raccoons and rats.
- Creating seasonal or temporary closure areas that keep visitors away from sensitive nesting areas
- Enforcement of existing laws regarding collection of park resources and confiscation of eggs, plants and other specimens and revise laws as necessary
- As determined necessary, conduct additional actions to safeguard very rare species such as establishing additional populations, implementing protective measures, establishing ex-situ conservation collections, etc.
- As necessary due to damage from hurricanes or other extreme events, conduct mangrove restoration, wetland restoration, beach restoration
- Charge fees to grounded boat owners/companies who damage resources
- As necessary, develop new mooring zones

- Perform interagency consultation on proposed projects to minimize impacts

APPENDIX J.7

FLORIDA AND BISCAYNE BAYS ECOLOGICAL ZONE

J.7 Florida and Biscayne Bays Ecological Zone

The following conceptual model draws strongly from the following references: Browder *et al.*, (2004), Rudnick (2004), Lodge (2005), Waddell (2005), Thornberry-Ehrlich (2005b, 2005d), Fourqurean and Rutten (2003) and USFWS (1999). The reader is strongly referred to these references for more detailed information.

J.7.1 Summary

The primary focus of this ecological zone is Biscayne Bay and Florida Bay although other much smaller bays exist in both the Ten Thousand Islands region and in the U.S. Virgin Islands parks.

Florida Bay:
Florida Bay is a triangular-shaped, very shallow, carbonate mud and sand bay bordered on the southeast by the Florida Keys, on the north by the Everglades, and on the west by the Gulf of Mexico (see Figures J.7-A, J.7-B). Depths in most areas of the bay are 6 feet or less with many areas 3 feet or less. Much of the bottom historically has been covered by seagrass which shelters fish and shellfish and provides for much of the productivity in the bay. However, recent problems include seagrass dieoffs, algal blooms, and declining shellfish and sponge populations. Since the seagrass dieoff in 1987, the turbidity of the bay has increased.

Biscayne Bay:
Within the boundaries of Biscayne National Park, Biscayne Bay is a shallow bay bordered on the west by a thin boundary of mangroves buffering it from a rapidly urbanizing south Florida (see Figures J.7-C to J.7-G) . The Bay is bordered on the east by the northernmost extent of the Florida Keys. Depths in the bay are less than 15 feet with most considerably shallower. Light is able to reach the bottom throughout.

Both Florida Bay and Biscayne Bay are valued for their nursery habitat for pink shrimp and harvestable fish, abundance and diversity of fish and crustaceans, feeding habitat for seabirds, shorebirds, and wading birds, and rare and listed species such as manatees, crocodiles, sea turtles, and colonial nesting seabirds, shorebirds and wading birds. Recreational boating and fishing is popular in both parks. Commercial fishing is allowed in Biscayne Bay for fish, lobster, crabs, and pink shrimp. Biscayne Bay is also valued for its good water quality and clarity.

The main physical system drivers and background attributes in this zone include climate, physical structure and shallow bathymetry, circulation patterns, tides, ocean currents, freshwater inputs, sea level rise, major weather events, and water quality (i.e., nutrients, turbidity, dissolved oxygen, spatial and temporal salinity patterns).

Anthropogenic stressors in this zone include freshwater diversions, canals, levees, the Flagler Railway, nutrient enrichment, excessive turbidity, altered sediment runoff, contaminants, boat groundings, seagrass scarring, anchor damage, recreational disturbance and damage, overfishing and damaging fishing methods, boat collisions with wildlife, and physical trash and debris. Currently invasive species are not a large concern, but could become so in the future.

Anticipated changes in zone physical structure and biological attributes include changes in the physical structure, bathymetry, circulation patterns, turbidity, and salinity of both Florida Bay and Biscayne Bay due to the combined effect of sea level rise, changes in freshwater influx, and hurricanes and storms; changes in the extent, distribution, and composition of seagrass communities, algal communities, plankton communities, hard-bottom communities and tidal wetlands due to alterations in salinity, turbidity, nutrient influx, and possibly pH and disease; and changes in abundance, size, community composition and/or increased invasive species among the following communities: fish, crustaceans, seabirds, large herbivores and top predators, including rare and listed species.

Current major management issues in the Florida and Biscayne Bays Ecological Zone include rehabilitation of freshwater and sediment inputs, reductions in or mitigation of contaminants and debris, management of fishing, boating, and recreation, protection and management of rare species, and determining cause of major seagrass dieoff and recovery of seagrass beds. Control of invasive species could become a larger concern in the future.

Figure J.7-H shows the interrelationships among natural system drivers, anthropogenic stressors, extent of the Bay and biological attributes (e.g., primary producer dynamics and consumer interaction dynamics).

The remainder of this conceptual model consists of describing the drivers and stressors in greater detail followed by a description of anticipated effects on system attributes coupled with potential local management actions. Chapter J.9 “Marine Benthic Communities” is a sub-model explaining dynamics of primary producers and consumers in this system in greater detail. Inputs from the “Coastal” ecological zone (Chapter J.7) also affect this model. The section headings discussed include

- Driver: Climate, temperature range, rainfall
- Driver: Configuration and shallow bathymetry of bays, hydrology, circulation patterns, salinity patterns, and interaction with ocean currents
- Driver/Stressor: Sea level rise
- Driver: Tides, ocean currents and transport from west Florida and Gulf
- Driver: Organisms produce sediments
- Stressor: Construction of the Flagler Railway
- Stressor: Freshwater diversions, canals and levees

- Driver: Major weather events, (e.g., hurricanes and tropical storms)
- Driver/Stressor: Water Quality – nutrients, turbidity
- Stressor: Contaminants
- Driver: Inputs from Coastal Wetlands Zone
- Stressor: Boat groundings, seagrass scarring, anchor damage, recreational disturbance and damage
- Stressor: Water Quality - contaminants
- Stressor: Catastrophic oil, chemical or other disaster.
- Stressor: Fishing/overfishing of resources; illegal fishing; using damaging fishing methods
- Stressor: Increased boat collisions cause wildlife injury and death
- Stressor: Physical trash, debris and abandoned fishing gear
- Stressor: Introduction and spread of invasive species

These system drivers and stressors are expected to influence the following key system attributes:

- Change in configuration, bathymetry, circulation patterns, turbidity and salinity of Florida and Biscayne Bays
- Change in primary producer dynamics, (e.g., extent, distribution and composition of seagrass communities, loose sand and mud bottom, hard-bottom-communities and planktonic communities)
- Change in consumer dynamics, (e.g., fauna community structure and function, guild composition and abundance, and distribution and abundance of rare species)



Figure J.7-A. Park Map of Florida Bay



Figure J.7-B. North shore of Florida Bay at Flamingo in EVER.

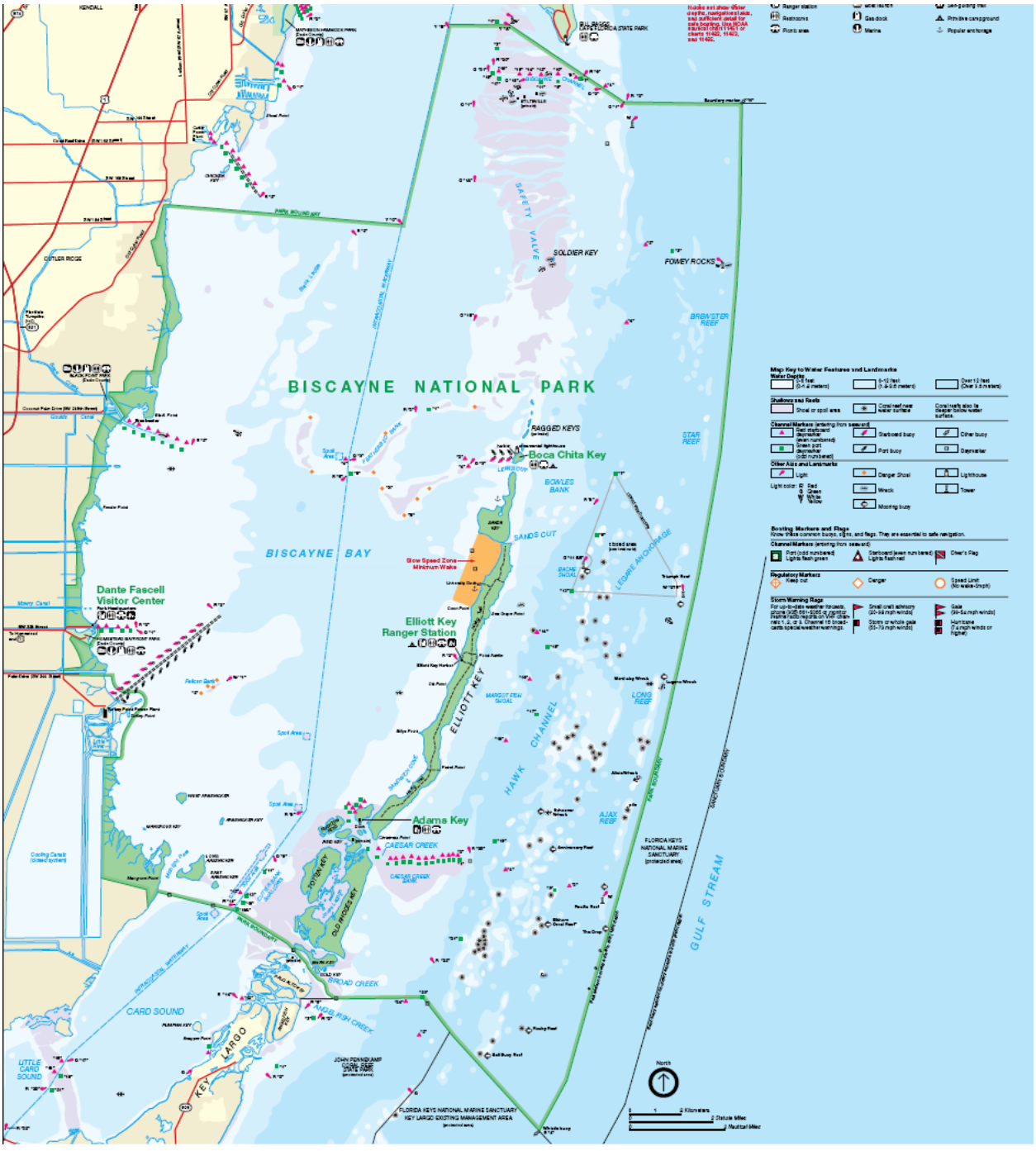


Figure J.7-C. Park Map of Biscayne National Park showing configuration of Biscayne Bay in relation to keys, shoal areas of "Safety Valve" area at the north-east end of the Bay, and linkage to Card Sound to the south of Bay.

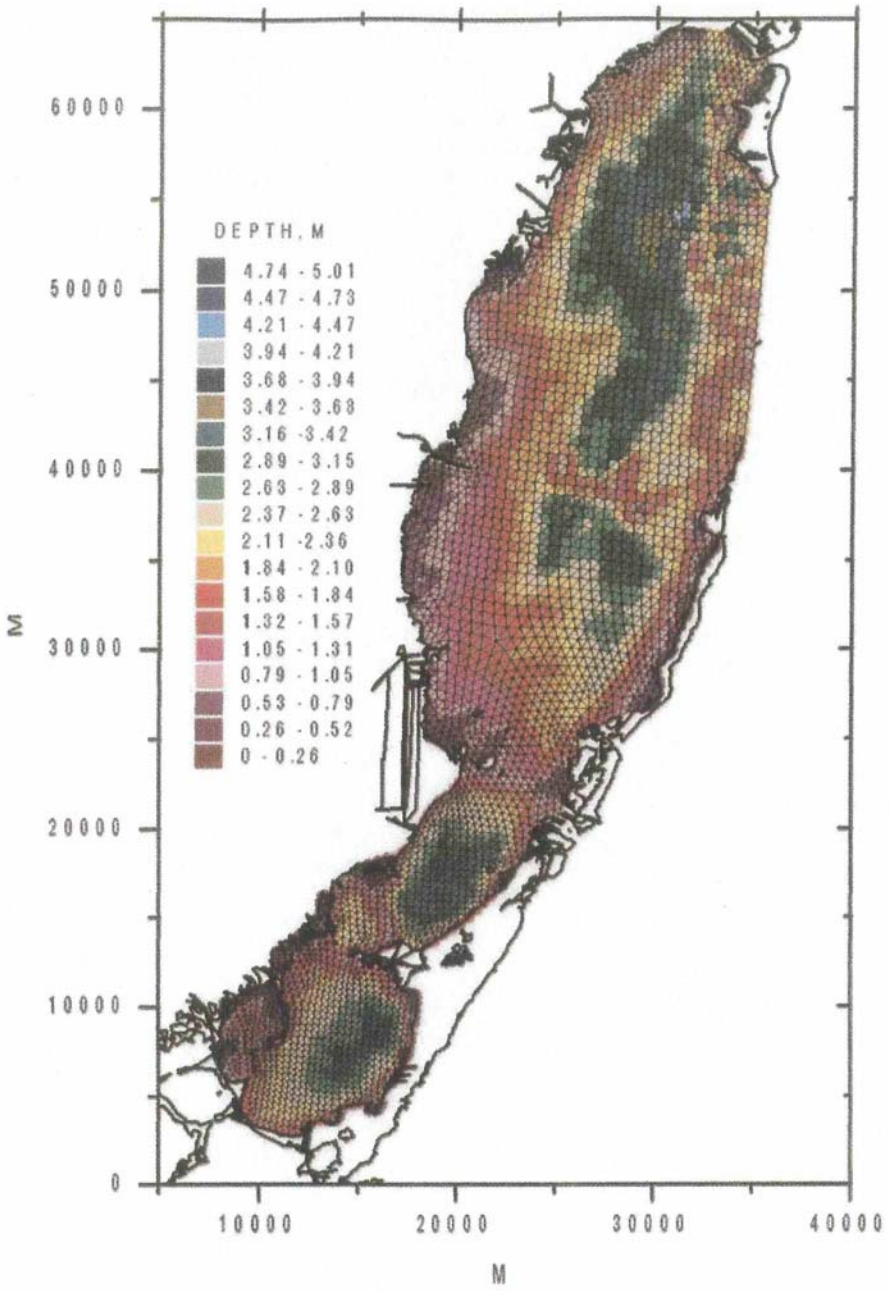


Figure J.7-D. Modeled depths in Biscayne Bay. [From Wang *et al*. 2003]

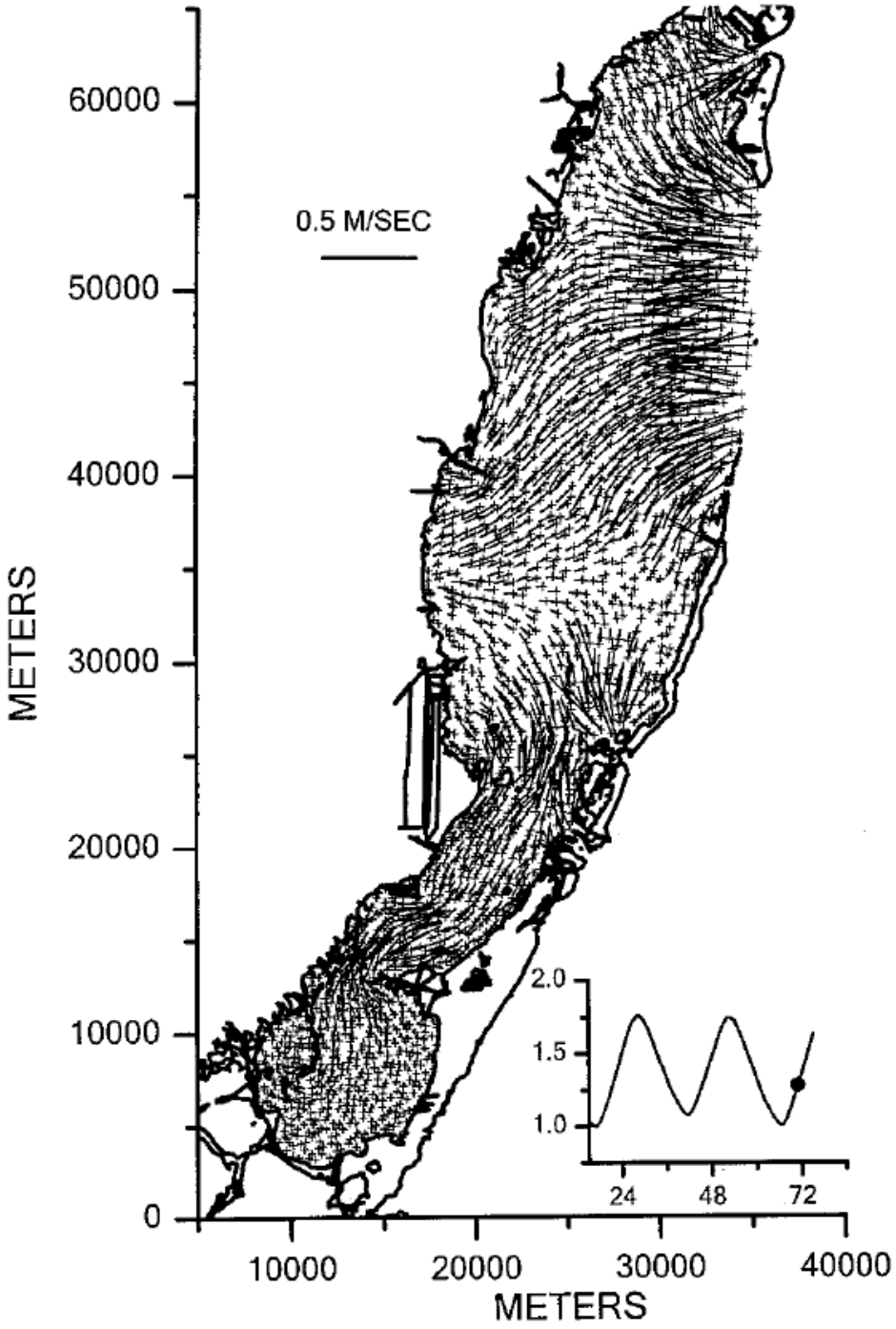


Figure J.7-E. Hydrodynamic model output velocity field for flood conditions in Biscayne Bay. Each velocity vector is plotted as a stick indicating magnitude and direction. + marks the location of the vector and the velocity scale is indicated in the graph. The inset graph in the lower right shows the depth variation at one point in the model and ● indicates the time of the velocity field. [From Wang *et al.* 2003]



Figure J.7-F. Biscayne Bay looking across mangroves on the western shore eastward towards (from left to right) the Ragged Keys, Boca Chita Key, and Sands Key along the eastern boundary of the Bay over 9 miles in the distance.



Figure J.7-G. Biscayne Bay looking southward along Elliott Key. Biscayne Bay is a popular area for recreational boating and fishing.

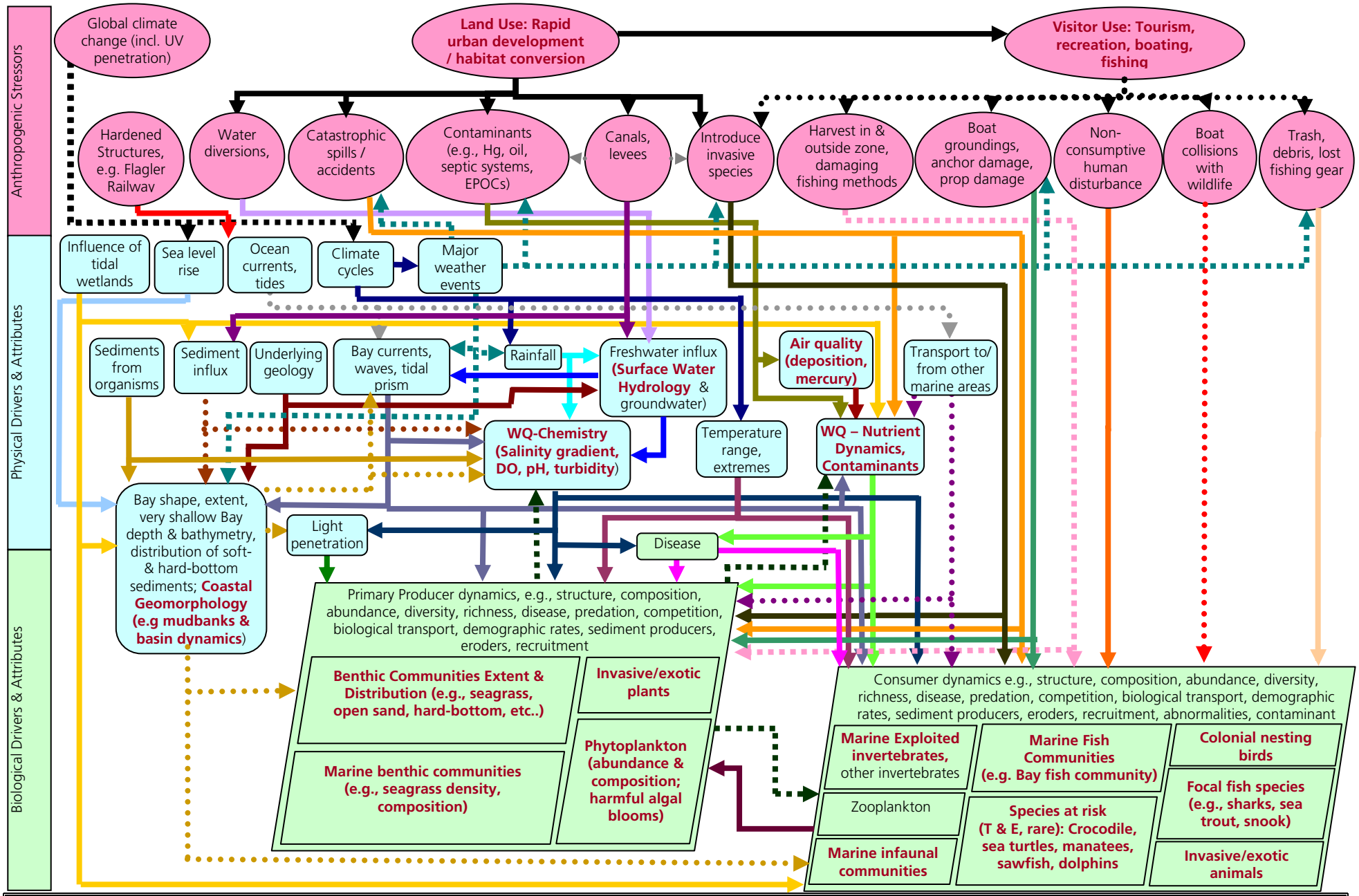


Figure J.7-H. Florida and Biscayne Bays Ecological Zone conceptual model diagram. Solid and dotted lines show assumed effects of anthropogenic stressors, physical and biological drivers and attributes. Boxes with **red print** directly relate to a proposed Vital Sign. (Use of dotted lines is to clarify and does not indicate lesser importance.)

J.7.2 Physical Drivers, Key Background Attributes, and Anthropogenic Stressors

J.7.2a Driver: Climate, temperature range, rainfall

The range of water temperatures in coastal South Florida affects the species present. For example, the shorelines of the Florida and Biscayne Bays are dominated by frost-sensitive mangroves rather than cordgrass, a more temperate species common to north Florida estuaries. The very shallow nature of Florida Bay especially allows for increased temperature variability during summer highs and winter lows. This inherent variability makes the bay less hospitable to benthic organisms which deal poorly with extreme temperature events (e.g., corals). Temperature also affects evaporation rates and when coupled with drought and poor circulation can result in areas of hypersaline water in central Florida Bay with salinities as high as 70 parts per thousand during extreme droughts (Rudnick 2004). Such hypersaline areas are thought to decrease pink shrimp survivorship (Rudnick 2004). Increased temperatures and decreased flows also cause increased salinity in southwest Biscayne Bay and along the bayside key shorelines (> 37 PSU). Rainfall can temporarily decrease salinity in the bays directly and indirectly (e.g., through increased runoff from canals in Biscayne Bay and from Taylor Slough in Florida Bay).

J.7.2c Driver: Freshwater and sediment influx from coastal rivers, canals, groundwater, and runoff

Freshwater influx from surface water and groundwater sources coupled with the effects of ocean currents and configuration of the bay affects the salinity gradient within the bays creating areas of fresh to brackish water to saline water.

J.7.2b Driver: Configuration and very shallow bathymetry of Florida Bay, including hydrology, circulation patterns and salinity

Water in Florida Bay is a mixture of water from the Gulf of Mexico, freshwater inputs from Shark River Slough and Taylor Slough, and more limited input from the Atlantic Ocean. The triangular shape, very shallow bathymetry, and complex array of islands, banks, and basins of Florida Bay influences water circulation patterns, salinity gradients, deposition and erosion processes (see Figure J.7-A). Circulation patterns determine the degree of mixing from Gulf of Mexico waters, residence time for water in the Bay, aeration and removal of sediments. The combination of tides and freshwater inputs can cause salinity to vary widely. The Bay is very shallow with a mean depth of 1 m with greater salinity in the eastern end than the west. This shallowness reduces circulation which can cause areas of hypersaline water and areas of high sulfide levels. Sediments are easily suspended, increasing turbidity, decreasing light penetration and productivity. The shallowness of the Bay led historically to large beds of seagrass in the 1970s and 1980s up until a seagrass dieoff in 1987. Wave action and scouring currents can affect establishment and continued existence of seagrass communities.

Figure J.7-C shows the general configuration of Biscayne Bay and Figure J.7-D shows modeled depths. The Keys along the eastern edge of the bay coupled with the shallow

shoals in the "Safety Valve" area greatly buffer the bay from wave action and storm surges. Ocean currents generally move northwards from Florida Bay to Card Sound past Cutter Bank into Biscayne Bay. Thus, any nutrient loading in the Keys can affect the Biscayne Bay, but waters from the heavily impacted Miami River are generally driven north away from the bay. Salinity in the southwestern portion of the Bay can increase due to evaporation and reduced circulation during

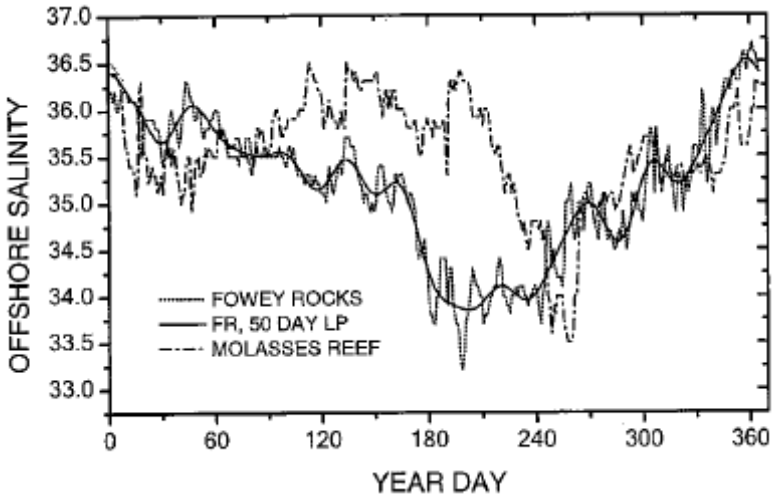


Figure J.7-I. Annually averaged (1994-1999) daily salinity for Fowey Rocks and Molasses Reef. [From Wang *et al.* 2003]

winter months. During summer wet months, salinity decreases can be seen as far out as Fowey Rocks (see Figure J.7-I). The output of a hydrodynamic model showing velocity vectors at different points in the Bay is shown previously in Figure J.7-E.

J.7.2c Driver/Stressor: Sea level rise

Depending on the rate of sea level rise in comparison with processes of sedimentation and deposition, sea level rise could increase water column depth in the bays, altering circulation patterns and salinity patterns, and could push mangroves and tidal wetlands further inland. Rising sea levels may also submerge smaller islands and deepen some of the shoals and mudbanks which could greatly change the water circulation dynamics within the bays. Again, the effects depend on the rate of sea level rise versus deposition.

J.7.2d Driver: Tides, ocean currents and transport from west Florida and Gulf

The ocean currents from western Florida and the Gulf of Mexico bring tropical marine species from near and far to Florida Bay and the Florida Keys and through into Card Sound and Biscayne Bay. Fish (larvae through adults) are routinely transported from the Dry Tortugas or the west coast of Florida to Florida Bay.

J.7.2e Driver: Organisms produce sediments

Algae, corals and other benthic organisms (e.g., sponges) precipitate carbonate from the water in the bays and nearby reefs, producing structures, such as cell walls, shells and endoskeletons that are converted to carbonate sediment as they die. This process contributes to sediment accumulation in the bays, decreasing water column height and circulation.

J.7.2f Stressor: Construction of the Flagler Railway

Construction of the Flagler Railway along the Florida Keys modified the natural circulation patterns between many of the Florida Keys and reduced oceanic flow between the Gulf of Mexico and the Atlantic Ocean, altering and probably reducing circulation and increasing flushing duration.

J.7.2g Stressor: Freshwater diversions, canals and levees

In Florida Bay, water diversions as part of Everglades water works have greatly decreased outflow from Taylor Slough and Shark River Slough to the bay, probably resulting in higher than historic salinity levels. Several canals and levees were created during the 1930's (including East Cape Canal, Homestead Canal, Slegel's Ditch, Houseman's Ditch, and Middle Cape Canal) to divert the water away from the Cape Sable area in a failed attempt at creating "prime" real estate. These canals have changed the flow of water from Whitewater Bay to Florida Bay and have altered sediment transport. These canals and levees are now degrading with potential further effects on the Bay and also on human safety.

In Biscayne Bay, the large water diversions have greatly decreased outflow from rivers and through wetlands into Biscayne Bay. Many of the rivers have been converted to hardened canals, reducing the amount of estuarine habitat on the western side of the Bay and creating pulsed changes in the amount of freshwater and corresponding salinity levels, sometimes with scouring effects on benthic communities. In addition, freshwater upwelling from groundwater has virtually disappeared since the massive water diversions occurred. With decreased freshwater influx, the brackish areas of the bay have become more saline and the brackish areas have moved back into the canals which lack the estuarine habitat. Conversion of rivers to canals along the west shore of the bay has resulted in the historic elimination of freshwater and brackish habitat and conversion to mangroves, reduction of mangrove habitat to fringe mangrove areas along the shoreline, and elimination of tidal creeks. Proposed expansion of the Turkey Point power plant could further impact water management and flows into southern Biscayne Bay.

J.7.2h Driver: Major weather events, (e.g., hurricanes and tropical storms)

Major weather events suspend sediments, increasing turbidity, and extreme storms can alter the bathymetry of the bays and circulation by shifting mudbanks, shoals and berms. Storms also impact marine benthic community structure, damage mangroves, cause seagrass "blowouts," transport and disperse native and non-native aquatic flora and fauna, and increase anthropogenic debris impacts to natural habitats (e.g., grounded abandoned boats). Major storms destroy mangrove forests, reducing

nursery habitat and nesting areas for many species. Storms can also cause pulses of contaminants from capsized boats, damaged marinas, storm surge and storm-water runoff, and spilled sewage.

J.7.2i Driver/Stressor: Water Quality – nutrients, turbidity

Water quality in Biscayne Bay within BISC generally meets or exceeds federal, state and local standards. The good water clarity drives a productive benthic ecology and influences distribution of seagrass beds. North-moving ocean currents drive water discharged from the more heavily impacted Miami River northward away from BISC. However, increased nutrient and sediment input can come from canal discharge, marinas, urban runoff from lawns, vessel discharges, sewage overflows, malfunctioning septic systems and construction sites. This can negatively impact local water clarity and benthic communities. A large algal bloom occurred in 2007 in east Florida Bay through south Biscayne Bay and even moving out onto the reefs of BISC. Causes are still unclear but roadway construction impacts are suspected.

Excessive nutrients occasionally cause algal blooms in central and east Florida Bay and affect seagrass community structure. Nutrients (Nitrogen [N] and Phosphorus [P]) come from the Everglades, agricultural and urban areas (including septic systems in very porous limestone) throughout the Keys and southeast Florida, and possibly brought in by ocean currents from West Florida (Tampa to Naples) and the Gulf of Mexico. The extent to which phosphorous-loading in agricultural areas south of Lake Okeechobee reaches Florida Bay is unclear. Nitrogen fixation and denitrification also occur in Florida Bay sediments and rates may exceed nitrogen input from the Everglades watershed. These in turn are affected by salinity levels and by the seagrass community structure. Seagrass communities improve water quality through the uptake of nutrients, thereby reducing algal growth.

Healthy seagrass beds are important to good water quality in the bays. Seagrass communities help reduce turbidity by trapping and binding sediments, resulting in clearer water. Conversely seagrass mortality can open up areas that allow sediment resuspension and increased turbidity. Without seagrass to bind the sediments, the shallow nature of Florida Bay especially allows easy sediment suspension due to wave action and boat traffic. The increased turbidity can then lead to further seagrass mortality in an ongoing feedback loop. Dying seagrass can also decrease levels of dissolved oxygen during decomposition, reducing the ability for other fauna to survive in these areas.

J.7.2j Stressor: Contaminants

Contaminants include trace metals, organic chemicals (from agriculture pesticides, lawn chemicals, asphalt), canal discharge, industrial discharge, boat bottom paint, and vessel discharges. Canal water entering Biscayne Bay has lower dissolved oxygen, higher turbidity, and increased contaminants compared with the bay, causing local impacts to water clarity and benthic communities. Several active and historic landfills are located west of the western shore of BISC and are a possible concern as

sources for contamination. In addition, contaminated water injected into the Florida aquifer may be able to impact the Biscayne Bay. Plans are underway to dredge the Miami River which could release contaminants into the area. Although general water flow will carry contaminants away from BISC, bioaccumulation by local fauna may carry the contaminant burden into the park waters. In addition there continue to be new emerging pollutants of concern (EPOCs) such as estrogens in treated sewage effluent and estrogen mimics.

Contaminant problems in Florida Bay include pesticides and mercury inputs from Everglades and the Florida Keys, however, the extent of this problem in the Bay is unclear.

J.7.2k Driver: Inputs from Coastal Wetlands Zone (see other models)

The stressors and drivers that directly impact Coastal Wetlands and Marine Benthic Communities are covered in separate conceptual models. Of particular concern however, is the large seagrass dieoff that occurred in Florida Bay in 1987, from which the system has yet to recover and for which the causes are still being researched. These marine benthic communities plus mangrove and tidal wetlands provide the primary productivity in the system that drives the higher trophic food web levels, as well as nursery habitat and cover for juvenile fish and shrimp.

J.7.2l Stressor: Boat groundings, seagrass scarring, anchor damage, recreational disturbance

Increased boat groundings, and damage from anchors and propellers damage seagrass beds and sometimes mangroves. The cumulative impact from thousands of boat-to-resource contacts severely impacts and even destroys the resources. Boat groundings also stir up sediments, can alter local bathymetry, and cause local contamination problems as fuel and other contaminants leak into the area.

J.7.2m Stressor: Catastrophic oil, chemical or other disaster

The Intercoastal Waterway is a large boating channel (essentially a marine 'super-highway') that parallels the Florida coast, runs through the middle of Biscayne Bay, through Card Sound and Barnes Sound, and then just east of the EVER boundary in Florida Bay. The abundance of so many vessels (recreational, commercial and container ships, all types increasing in numbers per year), concentrated in close proximity to extremely shallow water areas, increases the probability of catastrophic vessel groundings or other major contaminant disaster (e.g., oil spills, container vessel capsized). The exact effects will depend on the contaminant involved. Oil spills will have major long-term consequences on ecosystem and complete restoration is rarely accomplished (if ever) and can take millions of dollars (e.g., Tampa Bay spill in 1993). Turkey Point Nuclear Power Plant which sits on the southwest shore of Biscayne Bay has the potential to cause grave damage to the area if anything catastrophic were to happen at that site – tankers carrying fuel oil to Turkey Point Nuclear Power Plant travel through Biscayne Bay have already run aground four times.

J.7.2n Stressor: Fishing/Overfishing; illegal fishing; using damaging fishing methods

Biscayne Bay is a popular site for commercial and recreational fishing including fish, blue crab, stone crab and pink shrimp. Currently, only recreational fishing is allowed inside Everglades National Park. However, recreational fishing has increased by over 400% in the past two decades in South Florida. These fisheries require careful management otherwise overfishing, illegal fishing, or using illegal/damaging fishing methods could result in declines. Overfishing can directly deplete fish stocks below sustainable levels, cause harvesting of fish before sexual maturity, deplete associated fishery stocks (i.e., "bycatch"), and negatively affect benthic communities via trophic cascades. Fishing in general changes the size structure of targeted species and can result in changes in population genetics over time, as genes supporting rapid growth are disproportionately removed from the population. Additionally the use of improper or inappropriate fishing gear and traps damages benthic communities and ultimately impacts fisheries. Trawling still occurs in Biscayne Bay which can damage benthic habitats.

J.7.2o Stressor: Increased boat collisions cause wildlife injury and death

Unmanaged high boat speeds have resulted in collisions with manatees, frequently resulting in death of this Federal endangered species. Other species such as sea turtles are also casualties. Boat traffic can result in increased turbidity, marine noise, wave action, soundscape impacts, and possibly disruption of marine wildlife.

J.7.2p Stressor: Physical trash, debris and abandoned fishing gear

Physical trash, debris, abandoned fishing gear (nets, lost or abandoned crab and lobster traps, fishing line monofilament and hooks), and abandoned boats from tourists, commercial and recreational boats, oceanic dumping, and urban areas trap, entangle and kill wildlife such as birds and sea turtles; damage benthic communities and seagrass; reduce visual quality for park visitors; and can create health hazard for visitors.

J.7.2q Stressor: Introduction and spread of invasive species

Currently, invasive species do not appear to be a large issue in Florida and Biscayne Bays but new introductions are always a concern. Marine fish, estuarine fish, invertebrates, plants and algae have all been introduced. Species mentioned by Waddell (2005) as being of concern in the Keys include Mayan cichlid (*Cichlasoma urophthalmus*) and pacific algae (*Caulerpa brachypus*). Sources of new introductions include ship ballast water, released aquarium pets, propellers and boat engines.

J.7.3 Anticipated Effects of Drivers and Stressors on Ecological Zone Extent and Biological System Attributes

Further details of effects on Marine Benthic Communities and Coastal Wetlands are discussed in chapters J.9 and J.6 respectively.

J.7.3a Change in configuration, bathymetry, circulation patterns, turbidity, and salinity of Florida Bay

Both bays have become more saline with the reduction of freshwater inputs due to water diversions and channelizing of the Everglades over the past 50 years. The bathymetry, circulation patterns and salinity patterns of Florida and Biscayne Bays are expected to change through time as CERP/Mod Waters increase freshwater flux into the bays, sea level rises, and as storms alter mudbanks, berms, shoals, islands, and areas around Whitewater Bay and Cape Sable. Circulation patterns in the very shallow Florida Bay especially may be strongly affected by sea level rise, although sedimentation may keep pace with sea level. Mangroves and tidal wetlands may recede inland resulting in an increase in the size of the bays, although the western boundary of BISC is rapidly urbanizing, which will restrict the inland movement of mangroves.

J.7.3b Change in primary producer dynamics, (e.g., extent, distribution and composition of seagrass communities, unconsolidated sand and mud bottom, hard-bottom-communities and planktonic communities)

The extent and health of the seagrass beds within the Bay as well as the mangroves and tidal marshes bordering the bay all contribute to primary and secondary productivity within the bays. The extent, distribution and composition of seagrass communities, hard-bottom communities and tidal wetlands are expected to be affected by changes in the configuration, bathymetry, circulation patterns and salinity in the Bay, by changes in nutrient influx and water quality, and by extreme weather events, and by effects such as disease and introduced species (see Marine Benthic Communities sub-model for more details).

Seagrass covers about 64% of Biscayne Bay (Browder *et al*. 2004) and appear to be doing well. Florida Bay was characterized by large seagrass beds in the 1970s and 1980s and the shallow nature of the Bay allows for large seagrass beds, provided that turbidity is kept to a minimum. However, a large seagrass dieoff occurred in 1987, the causes of which are still unclear. Suggestions such as disease, overgrowth due to excess nutrients, sulfide toxicity have been suggested. Regardless of cause, the beginning of a dieoff of seagrass can produce a positive feedback effect as the dead seagrass no longer holds down the soft substrate which is then resuspended, increasing turbidity, resulting in stress to nearby seagrass areas. Currently seagrass in Florida Bay has also been associated with a slimemold disease in areas of high salinity. It is hoped that the large seagrass communities will recover in extent and quality in Florida Bay.

Mangroves and tidal wetlands also add to the productivity of the bay, providing nursery habitat and cover for juvenile fish and crustaceans. Reductions in the extent of mangroves and marshes along western Biscayne Bay appear to have negatively impacted system productivity. In addition, with the reduction of freshwater influx to the bays, the areas of brackish water have diminished. This affects the structure and composition of seagrass communities as well as algae, plankton, zooplankton and invertebrates within the Bay. Excessive nutrients, excessive sediment, herbicides, pesticides and other contaminants from urban runoff, construction zones, marine areas, and influx from canals and malfunctioning septic systems can also affect these levels with cascading effects to upper trophic levels.

The algal blooms that have occurred in northeastern Florida Bay, Barnes Sound, Card Sound and southern Biscayne Bay are a serious concern for management and are presumed to be a result of nutrient enrichment due to agriculture and/or construction.

J.7.3c Change in consumer dynamics, (e.g., fauna food web structure, guild composition and abundance, and distribution and abundance of rare species)

These extent, distribution, composition and productivity of seagrass, plankton, algae, tidal wetlands and mangroves strongly influence the community structure and abundance of higher trophic levels of fish, crustacean, mollusk and benthic grazer communities in Florida and Biscayne Bays. Approximately 70 percent of the area's recreationally and commercially important fishes, crustaceans, and shellfish spend a portion of their young lives in the bays' protective environment. These in turn affect populations of seabirds, wading birds, dolphins and large fish. Seagrass, mangroves and tidal wetlands provide nursery habitat and shelter for juvenile fish and pink shrimp. Fish, shrimp, and other fauna migrate between the bays and the productive coral reefs and areas outside the bays. Manatees and sea turtles spend considerable time foraging in the bays' seagrass habitats.

The rapid increase in local human populations has lead to great increases in fishing and boating as well as increased urbanization and demands on water resources. Reductions in the extent of mangroves and tidal marsh in Biscayne Bay have greatly reduced nursery habitats for juvenile fish species, shrimp and crabs, causing local declines in species such as red drum, sea trout, juvenile snook and tarpon, and oysters. Reductions in freshwater input have severely restricted and in places eliminated brackish water and brackish estuarine habitat within the Biscayne Bay and Florida Bay, restricting habitat for brackish water species such as crocodiles, manatees, juvenile fishes, and sessile benthic organisms. Altered hydrology, altered salinities, declining estuarine productivity, the seagrass dieoff in Florida Bay, and possible overfishing inside and outside the parks are all thought to have contributed to decreased pink shrimp and fish harvests in past decades. In addition, the effects of mercury toxicity on upper trophic levels are unclear and may also be affecting higher trophic level species. Effects of pesticides and other toxics may be making species such as dolphins more vulnerable to disease. Collisions with boats continue to be a

major problem for manatees. Currently the level of invasive species in the bays appears low with the possible exception of diseases such as seagrass disease and sea turtle disease, for which the origin is unclear. However, introduced algae, invertebrates, and fish have produced rapid changes in other bays and estuaries and remain a concern.

As a consequence of these changes, biota in Florida and Biscayne Bays are under stress. Fish communities are changing. Manatees are on the decline. However, it is hoped that rehabilitation of hydrology by the Comprehensive Everglades Restoration Plan will reinvigorate the bays' ecosystems, increase productivity, revitalize seagrass beds and improve recreational fishery harvests.

J.7.4 Potential and ongoing local management actions

Following is a list of potential and ongoing local management actions to manage stressors and, if necessary, system drivers in Florida Bay and Biscayne Bay (see also the Biscayne National Park Fisheries Management Plan at http://www.nps.gov/bisc/manage/fisheriesmanagementplan.htm):

- Rehabilitation of south Florida hydrology to more closely resemble historical hydrographs through Comprehensive Everglades Restoration Program (CERP/ModWaters)
- Potentially rehydrate Biscayne coastal wetlands with treated wastewater
- Maintenance or alterations in canals around Whitewater Bay and Cape Sable
- Limiting nutrient enrichment of water entering WCA's and EVER park waters from agricultural runoff (CERP/ModWaters)
- Develop and implement best management practices for other urban areas, agricultural areas and construction zones that affect runoff containing nutrients and pesticides into Florida Bay, Biscayne Bay, and coastal west Florida
- Enforce water quality, illegal dumping, poaching and other regulations
- Implement area contingency plans for rapid response to catastrophic vessel groundings to control problems and effective notification of authorities and cleanup experts. Cleanup and habitat restoration after oil/chemical spills.
- Seagrass habitat restoration, if necessary
- Enforcement of scientifically based regulations (review and revision if necessary) regarding minimum and maximum fish and shellfish take size, bag limits, and that restrict fishing gear and traps to those least destructive to environment and resulting in reduced unwanted by-catch.
- Public education and signage regarding park rules, fishing regulations, boat safety, releasing of unwanted pets, and minimizing impact on resources and wildlife.
- Limit boat speeds (with enforcement) in areas with manatees and research other methods to reduce collisions.

- As determined necessary, creating seasonal or temporary closure areas that keep visitors away from sensitive areas.
- Perform interagency consultation on proposed projects to minimize impacts.

APPENDIX J.8

COASTAL SHELF AND DEEP OCEANIC ECOLOGICAL ZONES

J.8 Coastal Shelf and Deep Oceanic Ecological Zone

The following conceptual model draws from the following references: Waddell (2005) and USFWS (1999).

J.8.1 Summary

The Coastal Shelf and Deep Oceanic Ecological Zone includes the marine park areas with the exception of Florida Bay and Biscayne Bay which is covered in other models (see Figure J.8-A and J.8-B). Thus, this zone includes the marine areas of VIIS, BUIS, SARI, DRTO, BISC east of the Keys, and a small area of EVER northwest of Florida Bay. Included in this zone are soft- and hard-bottom benthic communities, the light-driven photic zone in the water column and the deep, aphotic zone. Much less is known about the deep aphotic zone which is only found in the deeper areas of BUIS 2001 expansion, the SARI underwater canyon, and the deeper areas of VICR.

The "Coastal Shelf and Deep Oceanic Ecological Zone" is valued for its commercial and recreational fishing (fish, lobster, crabs, conch, and shrimp), recreational boating, recreational diving and snorkeling, coral reefs and seagrass beds, abundance and diversity of marine life, and food web support for wide-ranging megafauna such as whales, sea turtles, dolphins, sharks, and large fish.

The main physical system drivers include climate, bathymetry, currents, circulation patterns, salinity gradient, depth of light zone, major weather events, water quality (nutrients, turbidity, DO), ocean upwelling, and sediment producing organisms. The main anthropogenic stressors in this zone include nutrient enrichment, sedimentation, contaminants, boat groundings, seagrass scarring, anchor damage, overfishing and damaging fishing methods, boat collisions with wildlife, and physical trash and debris. Introduced species are not currently a major stressor but new introductions could become so.

Anticipated changes in zone physical structure and biological attributes of particular note include changes in the bathymetry, distribution of hard-bottom and soft-bottom sediments, circulation patterns, salinity gradient and depth of the light zone due to the combined effect of sea level rise, changes in freshwater influx, excessive sediment runoff, and hurricanes and storms; changes in the extent, distribution and composition of seagrass communities, coral reef communities, tidal wetlands and planktonic productivity; and changes in abundance, size, and community composition of fish, crustacean, mollusk and benthic grazer communities as well as larger herbivores and top predators, including rare and listed species.

Current major management issues in the Coastal Shelf and Deep Oceanic Ecological Zone include reduction of sediment inputs, reductions in or mitigation of contaminants and debris, management of fishing, boating, and recreation, and

protection and management of rare plants and animals. Control of invasive species could become a larger concern in the future.

Figure J.8-C shows the inter-relationships of drivers, stressors and system attributes. The remainder of this conceptual model consists of describing the drivers and stressors in greater detail followed by a description of anticipated effects on system attributes coupled with potential local management actions. Chapter J.9 "Marine Benthic Communities" is a sub-model explaining dynamics of primary producers and consumers in this system in greater detail. Inputs from the Coastal Wetlands Ecological Zone (Chapter J.6) also affect this model. The section headings discussed include:

- Driver: Climate, temperature range, rainfall
- Driver: Bathymetry, hydrology, circulation patterns, salinity gradient, depth of light zone
- Driver: Ocean Currents, upwelling and transport
- Driver: Organisms producing sediments
- Driver: Major weather events, (e.g., hurricanes and tropical storms)
- Driver/Stressor: Water Quality – nutrients, turbidity
- Driver: Red tide
- Stressor: Water Quality - contaminants
- Stressor: Increased boat groundings and damage from improper boat moorings
- Stressor: Catastrophic oil, chemical or other disaster.
- Stressor: Overfishing of resources; illegal fishing; using damaging fishing methods
- Stressor: Increased boat collisions cause wildlife injury and death
- Stressor: Physical trash, debris and abandoned fishing gear
- Stressor: Introduction and spread of invasive species

In the subsequent section the effects of these Physical Drivers, Key Background Attributes, and Anthropogenic Stressors on the following key system attributes are discussed:

- Change in bathymetry, distribution of hard-bottom and soft-bottom sediments, hydrology, circulation patterns, salinity gradient, depth of light zone
- Change in primary producer dynamics, (e.g., extent, distribution, composition of seagrass communities, coral reef communities, tidal wetlands, planktonic productivity)
- Change in consumer dynamics, (e.g., fauna community structure and function, guild composition and abundance, and distribution and abundance of rare species)

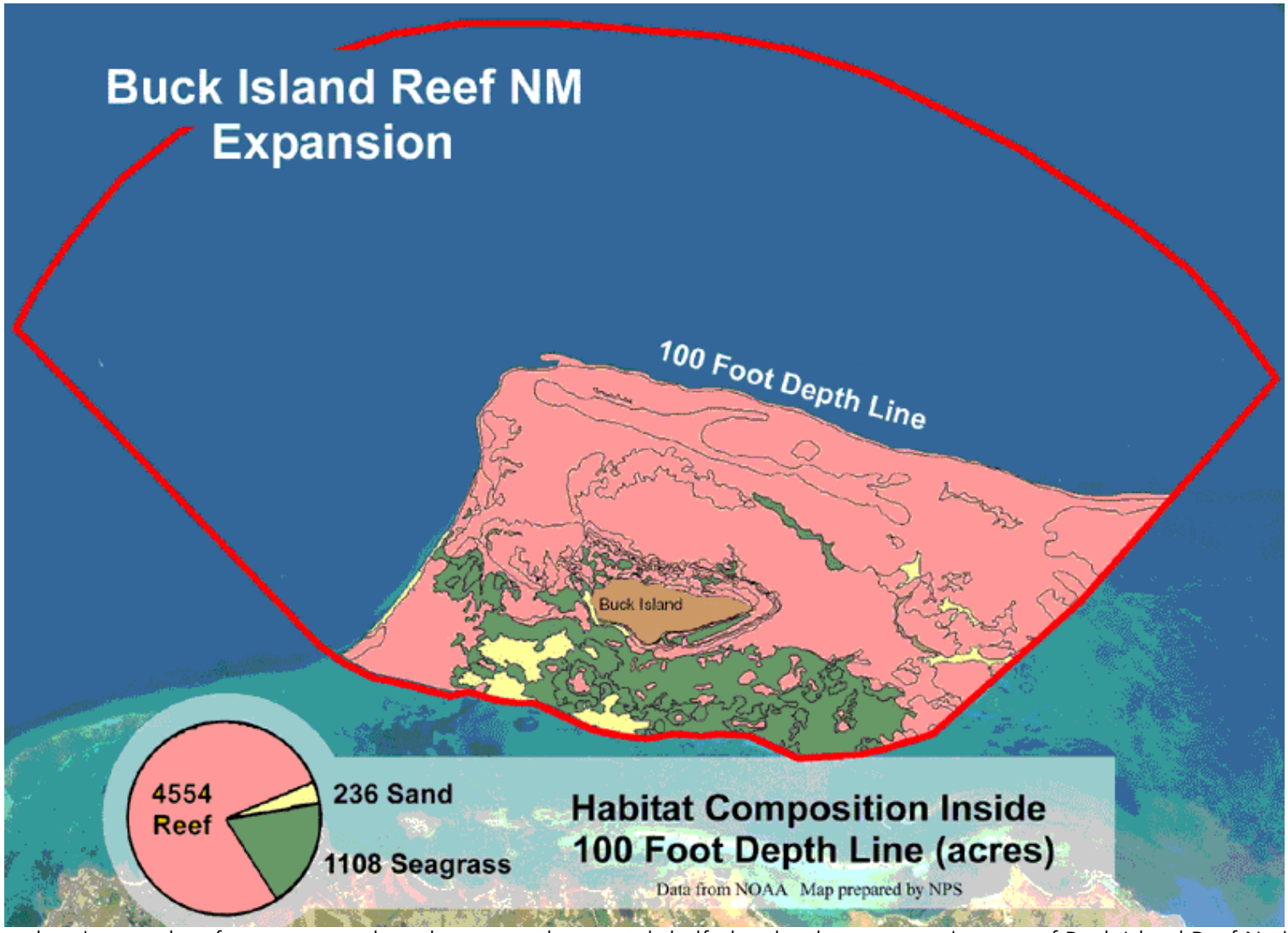


Figure J.8-A. Map showing coral reef, seagrass, and sand areas on the coastal shelf plus the deeper oceanic areas of Buck Island Reef National Monument.

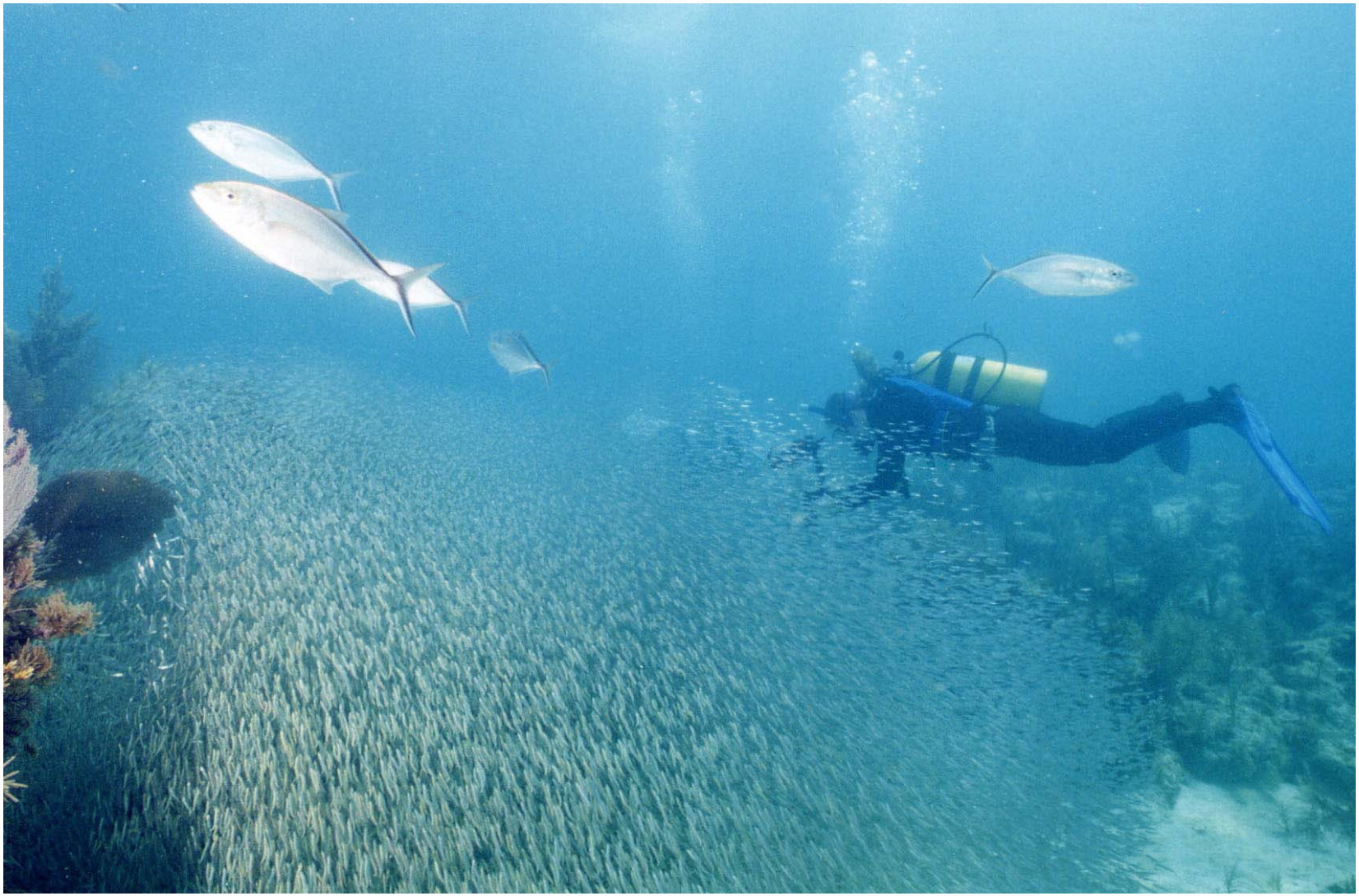


Figure J.8-B. Diver exploring coral reef in coastal shelf portion of BISC.

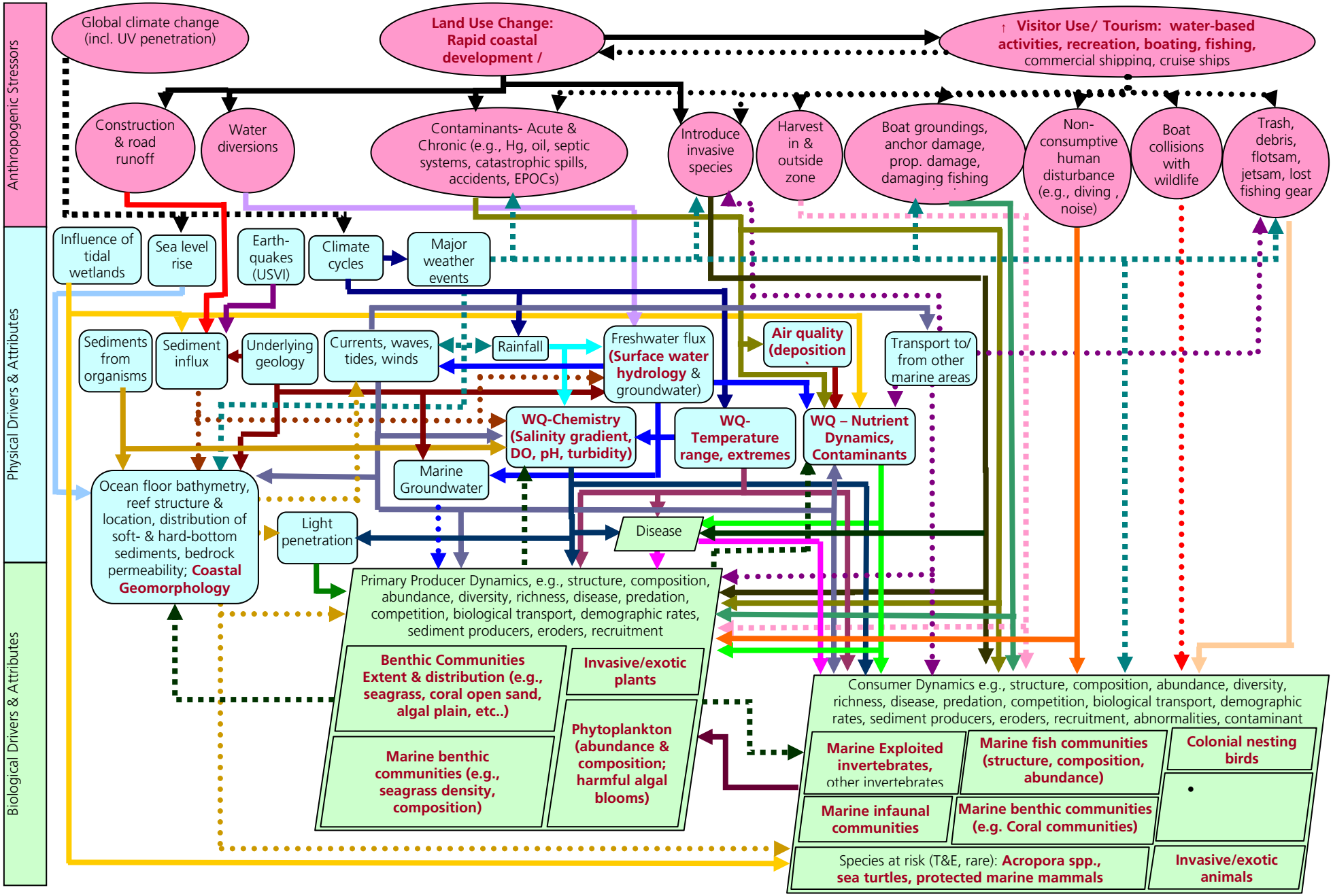


Figure J.8-C. Coastal Shelf / Deep Oceanic Ecological Zone conceptual model diagram. Solid and dotted lines show assumed effects of anthropogenic stressors, natural system drivers, and biological attributes upon each other. Boxes with **red print** directly relate to a proposed Vital Sign. (Use of dotted lines is to clarify and does not indicate lesser importance)

J.8.2 Physical Drivers, Key Background Attributes, and Anthropogenic Stressors

J.8.2a Driver: Climate, temperature range, rainfall

Climate, especially temperature range and hours of sunlight, is a basic driver in this system. The range of water temperatures affects the species present. For example, BISC contains the northernmost extent of coral reefs. Temperatures also affect the ranging of species such as manatees and pelagic fish. Rain causes sediment influx and freshwater influx from terrestrial areas.

J.8.2b Driver: Bathymetry, hydrology, circulation patterns, salinity gradient, depth of light zone

Local bathymetry and water currents interact creating a variety of underwater environments. The distribution of hard-bottom pavement versus soft-bottom sand and mud strongly impacts the resulting benthic communities that develop. Wave action and scouring currents can affect establishment and continued existence of seagrass and coral communities. The combination of tides and freshwater inputs in sub-tidal areas can cause salinity to vary widely affecting marine communities. Larval transport is a function of circulation patterns, which influences recruitment and food web dynamics.

The depth of the light zone is another major factor in marine communities. Light driven benthic communities such as coral reefs and seagrass beds only extend as far down as sufficient light will reach to allow them to grow. Similarly, phytoplankton in the water column is only found in the photic zone in the ocean. The aphotic zone is a detritus driven system rather than a photosynthesis driven system.

Coral reefs are another driver, buffering the shoreline from ocean waves and creating areas of calmer water which favor some marine organisms and also allow settling of sediments.

J.8.2c Driver: Ocean currents, upwelling and transport

Ocean currents and upwelling bring nutrients, oxygen, and cold water from deep aphotic zones resulting in increases in productivity of phytoplankton and sometimes causing algal "blooms" and secondary blooms. Currents also influence ocean temperatures within parks and influence the influx and outflux of biota through parks, especially wide ranging species such as schools of fish (e.g., marlins, sailfish, tuna), sharks, whales, turtles, etc.

J.8.2d Driver: Organisms producing sediments

Algae, corals and other organisms contribute to sediment accumulation as carbonate is precipitated from the water, producing shells, coral sand and carbonate sediment.

J.8.2e Driver: Major weather events (e.g., hurricanes and tropical storms)

Major weather events can drastically alter bathymetry, destroy coral reefs, stir up sediments, and increase sediment runoff from nearby land. These storms periodically

disturb and re-initiate succession processes in marine habitats. Storms also disperse both native and non-native aquatic flora and fauna and increase anthropogenic debris impacts to natural habitats (e.g., grounded abandoned boats). Storms can alter sand communities, moving large amounts of sand and changing the distribution of those sediments

J.8.2f Driver/Stressor: Water Quality – nutrients, turbidity

Excessive nutrients can cause algal blooms that could affect seagrass community structure, planktonic community structure, and cause algal overgrowth in coral reefs. Excess nutrients (N, P) come from agricultural and urban areas including malfunctioning septic systems, sewage effluent, and ocean liner discharges. VIIS can also be affected by sewage effluent by the British Virgin Islands. Seagrass communities improve water quality by uptaking nutrients, thereby reducing planktonic algal growth.

Sediment runoff from the land is a problem from new residential building and roads at VIIS and SARI. Earthquakes and storms can increase erosion problems at any of the Virgin Islands. Sediment runoff can increase turbidity and negatively impact seagrass beds and coral reefs.

Seagrass communities also reduce turbidity by trapping and binding sediments, resulting in clearer water with low suspended sediment. Conversely seagrass mortality can open up areas that allow sediment resuspension and increased turbidity. Without seagrass to bind the sediments, they are easily re-suspended due to wave action and boats. The increased turbidity can then lead to further seagrass mortality in an ongoing feedback loop.

J.8.2g Driver: Red tide

Red tide is a phenomenon caused by an outbreak of dinoflagellates, a type of plankton. These dinoflagellates contain neurotoxins which cause dieoffs in fish and larger fauna. Red tides typically affect the Gulf coast of Florida and may rarely make it to Dry Tortugas.

J.8.2h Driver: Marine Benthic Community and Mangroves, Beaches, and Tidal Wetlands Zone

The stressors and drivers that directly impact Marine Benthic Communities and Mangroves Beaches and Tidal wetlands are covered in separate conceptual models. These marine benthic communities plus mangrove and tidal wetlands provide the primary productivity in the system that drives the higher trophic food web levels, as well as nursery habitat and cover for juvenile fish and crustaceans.

J.8.2i Stressor: Water Quality - contaminants

Contaminants include trace metals, organic chemicals (from agriculture pesticides, lawn chemicals, asphalt, and atmospheric deposition), industrial discharge, boat bottom paint, ballast water, and vessel discharges.

J.8.2j Stressor: Boat groundings, anchor damage, recreational disturbance and damage
Increased boat groundings and damage from anchors and propellers damage seagrass beds, coral reefs, and mangroves. The cumulative impact of this damage from many, many boats through time can severely impact and even destroy the resources. Boat groundings also stir up sediments, can alter local bathymetry and cause local contamination problems as gasoline and other contaminants leak into the area.

Recreation can cause damage as snorkelers and divers touch, grab, kick, and otherwise damage the fragile coral reefs. Lobster divers sometimes overturn coral heads while trying to grab their catch.

J.8.2k Stressor: Catastrophic oil, chemical or other disaster
With increased ship traffic, there is an increased probability of catastrophic vessel groundings or other major contaminant disaster (e.g., oil vessels, container vessels). The effects will depend on the contaminant involved. Oil spills will have major long-term consequences on ecosystems and can take millions to restore ecosystem health (e.g., spill outside Tampa Bay in 1993).

J.8.2l Stressor: Overfishing of resources; illegal fishing; using damaging fishing methods
Overfishing, illegal fishing, using illegal methods or using damaging fishing methods can result in declines in fisheries and changes in fish communities and benthic communities as the largest fish are removed and overfishing continues "down the food web." Inappropriate fishing gear can severely damage benthic communities and trap non-target species such as sea turtles and dolphins.

Regional overfishing throughout the Caribbean and Atlantic can strongly impact species at the top of the food web such as large fish, sharks, whales, and sea turtles with unclear impacts on the rest of the food web within parks.

J.8.2m Stressor: Increased boat collisions cause wildlife injury and death
Unmanaged high boat traffic and boat speeds can result in collisions with wildlife such as manatees, whales, and other large fauna, frequently resulting in injury or death. Boat traffic can result in increased turbidity, marine noise, wave action, and possibly disturbance to marine wildlife such as whales.

J.8.2n Stressor: Physical trash, debris and abandoned fishing gear
Physical trash, debris, and abandoned fishing gear (nets, lost or abandoned fish, crab and lobster traps), abandoned boats from immigrants, tourists, commercial and recreational boats, oceanic dumping, and urban areas can trap, entangle and kill marine wildlife such as fish, whales, dolphins, sea turtles, and birds; damage benthic communities, seagrass and coral reefs; reduce visual quality for park visitors; and can create health hazards for visitors if extreme.

J.8.2o Stressor: Introduction and spread of invasive species

Currently invasive species do not appear to be a large issue with the exception of new diseases in the Coastal Shelf and Deep Oceanic Zone. New diseases have been found in coral reefs, seagrass, and fauna such as sea turtles and dolphins – the origins of which are unclear. Marine fish, estuarine fish, invertebrates, plants and algae have all been introduced. Introduced species mentioned by Waddell (2005) as being of concern in the Keys include lionfish (*Pterois volitans*), orange cup coral (*Tubastrea coccinea*), and pacific algae (*Caulerpa brachypus)*. Sources of new introductions include ship ballast water, released aquarium pets, propellers and boat engines. The lionfish escaped into Biscayne Bay when Hurricane Andrew destroyed a private aquarium (Hare and Whitfield 2003).

J.8.3 Anticipated Effects of Drivers and Stressors on Ecological Zone Extent and Biological System Attributes

Further details of effects on Marine Benthic Communities and Coastal Wetlands are discussed in chapters J.9 and J.6 respectively.

J.8.3a Change in bathymetry, distribution of hard-bottom and soft-bottom sediments, hydrology, circulation patterns, salinity gradient, depth of light zone

Changes in bathymetry and local circulation patterns occur primarily as the result of storms or possibly dredging outside the parks. For example, a winter storm connected Bush Key with Garden Key in DRTO causing changes in local circulation patterns and sediment dynamics. Changes in the depth of the light zone can be caused by increases in turbidity due to sediment runoff, stirring up of sediments, or by algal blooms. The depth of the photic (light) zone has profound impacts on the extent, distribution and composition of seagrass, coral reef and planktonic communities. Localized and ephemeral salinity changes along the shore are only expected due to rain events.

J.8.3b Change in primary producer dynamics (e.g., extent, distribution, composition of seagrass communities, coral reef communities, tidal wetlands, planktonic productivity)

The extent, distribution and composition of seagrass communities, coral reef communities, tidal wetlands and planktonic productivity all provide the base primary productivity in the coastal shelf and deep oceanic food web. Extent and health of these communities is degraded by excess nutrient enrichment and sediment (VIIS, SARI), damage from recreational disturbance, anchor damage, and boat groundings; hurricanes and tropical storms; overfishing and consequent impacts to upper trophic food web; using inappropriate fishing traps, nets and other fishing gear that damage reefs and seagrass; warming ocean temperatures causing coral bleaching and contaminants such as herbicides and other toxics. Non-indigenous species do not appear to be a large concern at present although this could change. Coral and seagrass disease are a major concern however. Many of these stressors can be expected to get worse over time, if unmanaged, due to rising human population near the parks and rising tourism and recreation within the parks.

Coral reefs appear to be declining in total cover and community composition as is detailed in the Marine Benthic Communities model. This is a great concern as coral reefs provide the food for higher trophic levels. In addition coral reefs provide a valuable protection for coastlines and bays, dampening wave action and buffering against storms. However, coral reef growth and recovery is very slow while stressors can cause damage quickly.

Similarly seagrass beds also supply the basic productivity for the food web and provide nursery habitat for juvenile fish and crustaceans. Seagrass communities can absorb some excess nutrients and contaminants. However, excess nitrogen and phosphorus over the long-term can cause shifts in community structure. The cumulative damage due to boat groundings and anchors can be large if not managed and start feedback loops as gouged areas are made larger through time.

Planktonic communities are a vital part of the food web. Their abundance and composition is affected by the level of nutrients available and the depth of the photic zone. Excessive turbidity decreases the depth light can penetrate. And excessive nutrients can cause algal blooms and shifts in community composition.

Sea level rise could cause some changes in the distribution of coral reefs and seagrass beds, if, for example, coral growth in the deepest reefs is not able to prevent the reef from sinking below the photic zone. However, this is expected to be a slow process and eventually may be offset by more coral growth in shallow areas.

J.8.3c Change in consumer dynamics (e.g., fauna community structure and composition, guild composition and abundance, and distribution and abundance of rare species)
The extent, distribution, composition and productivity of seagrass, coral reefs, plankton, algae, and tidal wetlands strongly influence the community structure and abundance of higher trophic levels of fish, crustacean, mollusk and benthic grazer communities. These in turn affect populations of large fish, sharks, seabirds, dolphins, and sea turtles. Seagrass and tidal wetlands provide nursery habitat and shelter for juvenile fish and crustaceans and manatees and sea turtles spend considerable time foraging in seagrass habitats.

Overfishing and "fishing down the food chain" have had strong impacts on fish communities as larger carnivorous fish are first removed, then the smaller carnivorous fish, followed by the herbivores. This change in the fish community structure as well as abundance has in turn strongly impacted coral reef and seagrass communities. The overall number and size of fish caught has declined. BUIS and VICR do not allow fishing and are in effect experiments in the concept of creating marine sanctuaries that are expected to increase fish size and improve community structure both inside and outside the no-take zones.

Upper trophic level fauna such as sharks, dolphins, whales, and sea turtles have been showing declines at least in part due to alterations in the lower food web; mortality as they are entangled in fishing nets, gear, trash and debris; contaminants and bioaccumulation of toxins; and even injury or death by boat collisions.

J.8.4 Potential and ongoing local management actions:

Following is a list of potential and ongoing local management actions to manage stressors in the Coastal Shelf and Deep Oceanic Ecological Zone:

- Establish mooring buoys and/or mooring zones to reduce anchor damage; maintain accurate park maps to prevent groundings
- Develop and implement best management practices for agriculture, urban areas, and construction zones that affect runoff into the bay
- Public education and signage regarding park rules, fishing regulations, boat safety, and minimizing impact on resources and wildlife (e.g., whales)
- Enforce water quality, illegal dumping and other regulations
- Rapid response to catastrophic vessel groundings to control problem and effective notification of authorities and cleanup experts. As necessary, develop area contingency plans for rapid response to vessel groundings. Cleanup and habitat restoration after oil/chemical spills
- Enforcement of scientifically based regulations (review and revision if necessary) regarding minimum and maximum fish and shellfish take size, bag limits, and that restrict fishing gear and traps to those least destructive to environment and resulting in reduced unwanted by-catch.
- Creation and enforcement of no-take zones. If no-take zones are shown to be effective in rebalancing food web and increasing fishing outside zones, then consider utilizing in new areas.
- Location and removal of abandoned fish gear
- Perform interagency consultation on proposed projects to minimize impacts

APPENDIX J.9

MARINE BENTHIC COMMUNITIES SUB-MODEL

J.9 Marine Benthic Communities Sub-Model

The following conceptual model draws strongly from the following references Waddell (2005), Drayton *et al*. (2005), Sobel and Dahlgren (2004), Fourqurean and Rutten (2003) and USFWS (1999).The reader is strongly referred to these references for more detailed information.

J.9.1 Summary

The purpose of the marine benthic communities sub-model is to explain in greater detail the drivers and stressors on coral reefs, seagrass, and associated fish and crustacean communities that are mentioned in the Florida Bay, Biscayne Bay, and Ocean Shelf and Deep Oceanic Ecological Zone conceptual models.

Seagrass

Seagrasses are submerged vascular plants that typically establish in large beds on the soft-bottom sediments such as sand or mud found in Florida Bay, Biscayne Bay, SARI estuary, and to the inside of fringing reefs, ranging in depths from just within the sub-tidal zone to up to 70 feet deep (see Figure J.9-A). Seagrass communities in southern Florida and Caribbean parks typically consist of shoal grass (*Halodule wrightii)*, manatee grass (*Syringodium filoiforme)*, and turtle grass (*Thalassia testudinum)*. Widgeon grass (*Ruppia maritima*) can be found in areas of lower salinity. Johnson's seagrass (*Halophila johnsonii)* can be found in northern Biscayne Bay and star grass (*Halophila engelmannii)* and paddlegrass (*Halophila decipiens)* can be found sparsely distributed in south Florida waters. Turtle grass is typically viewed as the climax species, tending to dominate in areas of stable salinity, stable sediments and high light availability. Shoal grass and manatee grass tend to be more common in frequently disturbed areas and deeper areas (Fourqurean *et al*. 2002). Seagrass reproduce both sexually through underwater flowers, fruits and seeds, and reproduce asexually via rhizomes. Johnson's seagrass is only known to reproduce asexually.

Seagrass are highly productive marine plants that provide food, cover, and nursery habitat for many fish and invertebrates such as Queen conch, shrimp, and spiny lobster, feeding grounds for the West Indian manatee and sea turtles, and foraging habitat for many seabirds such as osprey and brown pelicans. Seagrass also protect reefs by trapping sediment runoff from land and stabilizing bottom sediments thereby improving water clarity. They rapidly utilize nutrients, improving water quality, and also diminish water speed, slowing wave action against shorelines. Seagrass leaves also provide a substrate for many epiphytic algae and small organisms to grow, which in turn are eaten by snails, fish and other marine fauna.

Seagrass is one of the primary contributors to dissolved oxygen in the water column as part of photosynthesis during the day.

Coral reefs

Coral reefs are made of small, sessile animals called polyps which form a symbiotic relationship with microscopic dinoflagellate algae (zooxanthellae). The zooxanthellae assist with skeletal growth, producing sugars through photosynthesis for the polyps which in turn supply nutrients and shelter. The polyps are also suspension feeders, feeding primarily at night using their tentacles with stinging nematocysts. Corals secrete calcium carbonate which gradually builds up the physical structure of the reef over hundreds to thousands of years (growth rates of most corals are on the scale of millimeters per year). The major reef-building corals are the branching corals such as Staghorn coral (*Acropora cervicornis*) and Elkhorn coral (*A. palmata*); brain corals (*Colpophyllia natans, Diploria clivosa, D. labyrinthiformis* ,and *D. strigosa*), and massive boulder corals (*Montastraea cavernosa, M. annularis and M. annularis complex*, *Stephanocoenia michelinii*, and *Siderastrea siderea*).

Corals reproduce asexually by budding, forming colonies of genetically identical individuals (clones). Corals also reproduce sexually. Some corals reproduce sexually through release of free-swimming gametes (broadcast spawners) that fertilize in the open water and form into microscopic larvae. Other corals retain their eggs (brooders) and release them as fertilized free-swimming larvae. The larvae swim/drift searching for appropriate substrate (bare, hard-substrate, preferably colonized by encrusting algae) on which to settle. There, the larva metamorphose into a sessile polyp, secreting a skeleton and grow into the coral colony. Some branching corals also spread through fragmentation.

Coral reefs are valued as a highly productive system that supports high biodiversity (estimates of 1,000,000 species live in coral reefs), large numbers and biomass of fish and invertebrates including commercially and recreationally valuable species, plus many rare and unique species; as beautiful and popular underwater tourist attractions for snorkelers and scuba divers; as barriers that diminish the force of waves and protect the shoreline; and as producers of much of the sand that form beaches (see Figures J.9-B through J.9-D).

Algal plains

Algal plains are also found around the U.S. Virgin Islands and South Florida, although less is known about them than the seagrass beds and coral reefs. These are diverse communities of macroalgae, especially green calcified algae, growing on soft bottom sediments in depths from very shallow water to areas 45 feet or more. Although these areas appear to support a variety of flora and faunal species, they have not been greatly studied. It is assumed they are affected by many of the stressors discussed in this model, but they are not specifically addressed further.

Fish, invertebrates, and sea turtles often move back and forth between the seagrass communities, reef communities, algal plains, and edges of the mangrove estuaries. In addition many of the drivers and stressors on these systems are similar.

The major physical drivers in marine benthic communities include substrate, major weather events, light penetration, sea level rise, and water quality (nutrients, temperature, dissolved oxygen, salinity, and clarity). Anthropogenic stressors include overfishing, damaging fishing methods, turbidity, nutrient enrichment, contaminants, and physical damage from boat groundings, propellers, anchors, tourists, and abandoned fishing gear. Introduced species are not currently a major problem in South Florida and Virgin Islands parks, but could become more so in the future. Disease, herbivory and food web dynamics are important biological drivers in this system. Anticipated changes in marine benthic communities due to the drivers and stressors include changes in the coral reef community extent, distribution, percent cover, composition and structure, especially with regards to the major reef-building corals; changes in seagrass community extent, distribution and composition; changes in fish and crustacean abundance, size, community composition, and genetic structure; and changes in herbivore and predatory guilds including top predators.

Currently the major management issues include rehabilitation of freshwater inputs and sediment inputs, reductions in or mitigation of contaminants and debris, management of fishing, boating, and recreation, protection and management of rare species, and determining causes of and responses to diseases and bleaching. Control of invasive species could become a larger concern in the future.

Figure J.9-E shows as a conceptual illustration of the relationship between seagrass beds and coral reefs moving from the shoreline to the coastal shelf edge. Figure J.9-F shows a simplified marine community food web to assist understanding of the impacts of drivers and stressors on the system.

The remainder of this conceptual model consists of describing the drivers and stressors in greater detail followed by a description of anticipated effects on biological attributes and a description of potential local management actions. The section headings discussed include

- Driver: Substrate –soft-bottomed versus hard-bottomed sediment
- Driver: Major weather events, (e.g., hurricanes and tropical storms)
- Driver: Light penetration
- Stressor: Increased sediments in water column
- Driver/Stressor: Increased sea level rise
- Driver/Stressor: Water Quality – nutrients
- Driver/Stressor: Water temperatures, salinity, dissolved oxygen
- Driver/Stressor: Coral and seagrass diseases
- Stressor: Overfishing and damaging fishing methods

- Driver: Large Herbivores (historical?)
- Stressor: Water Quality - contaminants/pollutants
- Stressor: Physical damage from boat groundings, anchors, tourists, abandoned fishing gear, damaging fishing methods
- Stressor: Introduction and spread of invasive species

In the subsequent section, the effects of these Physical Drivers, Key Background Attributes, and Anthropogenic Stressors on the following key system attributes are discussed:

- Changes in coral reef community extent, distribution, percent cover, composition and structure
- Changes in seagrass community extent, composition and distribution
- Changes in marine consumer food web structure and function

Other drivers and stressors such as water diversions, canals, and catastrophic spills are discussed instead in the ecological zone models (e.g., Section J.7 (Florida and Biscayne Bays Ecological Zone) and Section J.8 (Coastal Shelf and Deep Oceanic Ecological Zone)).



Figure J.9-A. Seagrass bed in Biscayne National Park.



Figure J.9-B. Elkhorn coral (Acropora palmate) at Hawksnest reef on north side of St. John, U.S. Virgin Islands.



Figure J.9-C. Coral garden at Buck Island Reef National Monument.

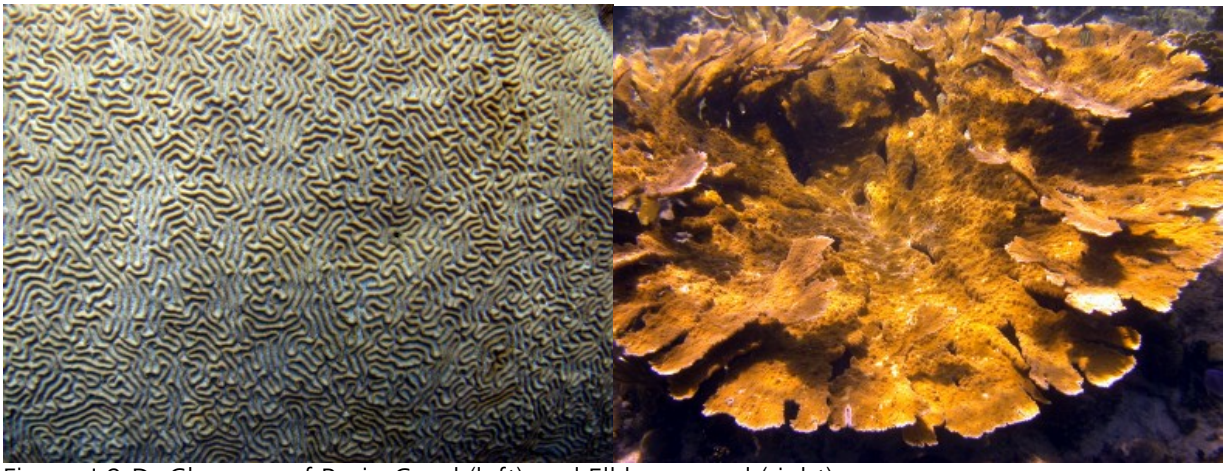


Figure J.9-D. Close-up of Brain Coral (left) and Elkhorn coral (right).

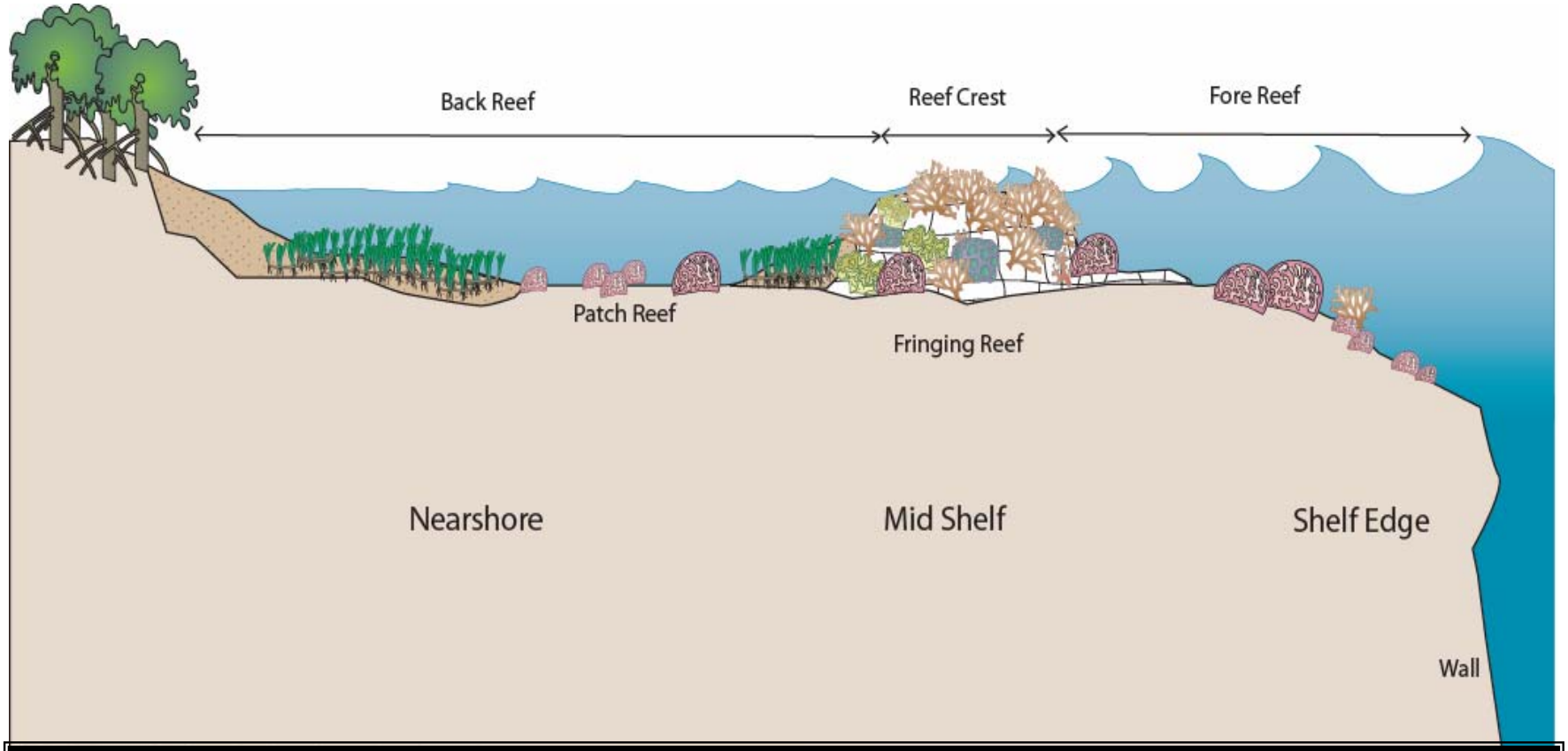


Figure J.9-E. Relationship between different areas of coral reefs and seagrass beds. The reef zone is divided into the fore reef, reef crest, and back reef. Examples of fringing reef and patch reefs are shown. Seagrass beds are found on the soft-bottom sands and muds. Mangroves line the shorelines. SARI has a coral reef with a deep trench and wall habitat.

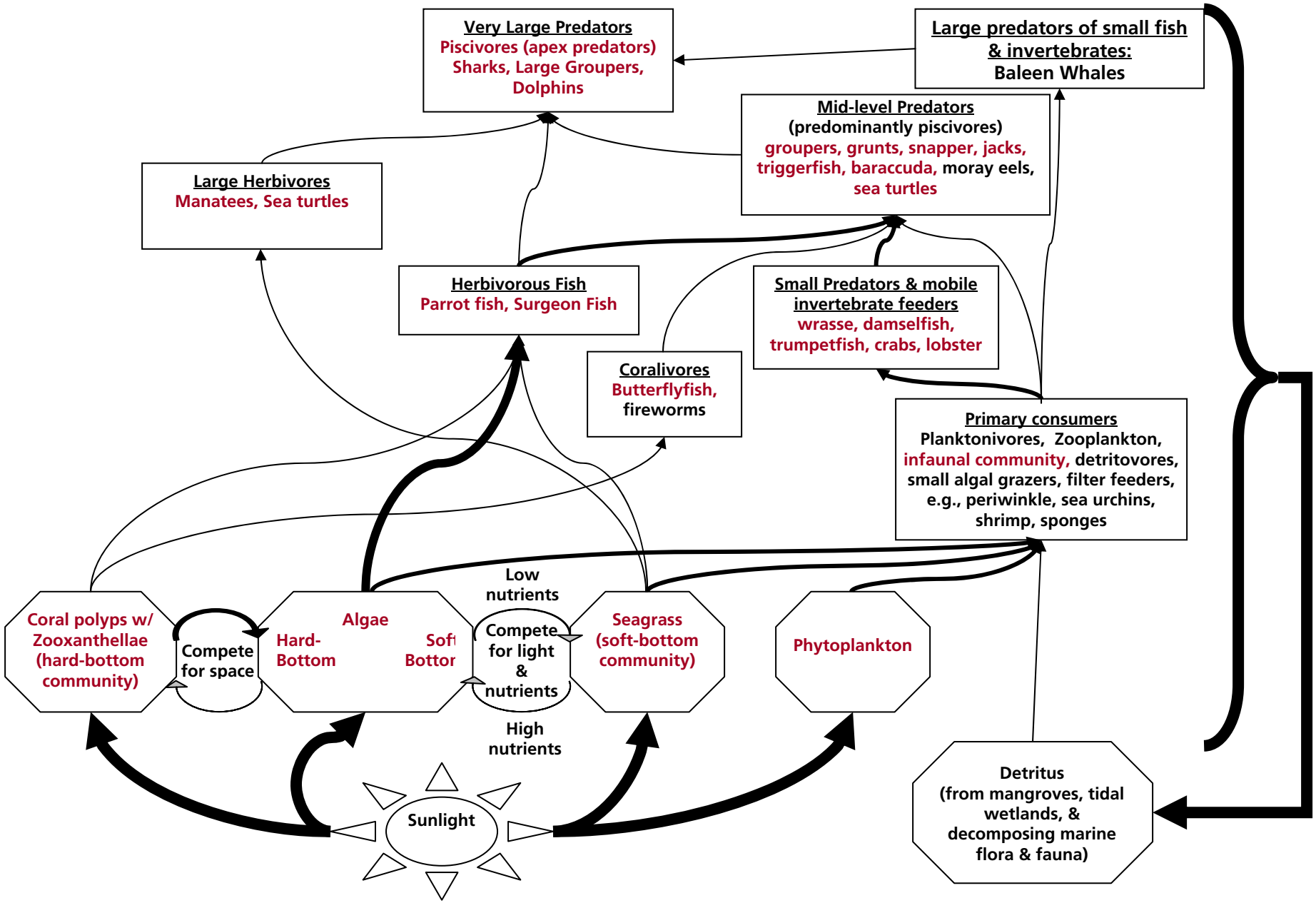


Figure J.9-F. Simplified conceptual model of marine community food web in south Florida and Caribbean parks. The width of the connecting line represents the hypothesized effect strength. Sea turtles are located in both "Large Herbivores" & "Mid-level Predators" boxes.

J.9.2 Natural System Drivers and Anthropogenic Pressures

J.9.2a Driver: Substrate –soft-bottomed versus hard-bottomed sediment

Currents, local freshwater inputs, and local bathymetry affect the distribution of soft-bottomed and hard-bottomed sediments. Seagrass establish in sands and muds often to the calmer inside of fringing reefs and in estuaries. Corals establish on hard surfaces as they are quickly smothered on soft-bottomed substrates.

J.9.2b Driver: Major weather events (e.g., hurricanes and tropical storms)

Hurricanes can have a major destructive impact on coral reefs and seagrass beds through many physical processes including overturning coral heads, burying areas of seagrass and coral, breakage and tumbling of corals, and causing "blowouts" in areas of seagrass beds where the seagrass rhizomes are destroyed. U.S. Virgin Islands was hit by 10 hurricanes between 1979 and 2003 with Hurricane Hugo alone causing a 40% decline in living coral cover in surveyed areas in Lameshur Bay, St. John (Drayton *et al*. 2004).

Storms also can temporarily increase turbidity and cause other problems such as sewage spills, large sediment runoff, chemical spills, escape of exotics, and abrasion/scouring of reefs and seagrass beds with storm debris.

J.9.2c Driver: Light penetration

Other than substrate, light is a primary factor controlling the local distribution and depth of seagrass beds and coral reefs. In relatively clear waters of south Florida and the Caribbean, seagrass can grow in water up to 20-23 feet deep and sometimes as deep as 33 feet in Florida (USFWS 1999) and as deep as 70 feet in the U.S. Virgin Islands (Drayton *et al*. 2004). Depth can affect species composition. For example, *Halophila* spp. appear to tolerate deeper depths than turtle grass, manatee grass or shoal grass (USFWS 1999).

Coral reefs can be found in depths ranging from shallow sub-tidal to areas as deep as 150 feet depending on water clarity (Drayton *et al*. 2004). Non reef-building corals can be found at even deeper depths. Reef-building corals are dependent upon sunlight due to a symbiotic relationship with their zooxanthellae.

Light penetration is affected by water depth, suspended solids, and amount of planktonic organisms in the water column.

J.9.2d Stressor: Increased sediments in water column

Sediments from island runoff are a concern in the U.S. Virgin Islands where increased development is clearing land, leaving the soil vulnerable to erosion. Dirt and gravel roads are especially problematic as sudden rain events cause rapid erosion. "*Typically, an undisturbed tropical forest may deliver 1 gram/m^2/year of sediment to the bay below. An active, unpaved road, graded every 2 years may deliver 20,000 grams/m^2/year. Even abandoned unpaved roads increase sedimentation to the bay*

below (approximate rate: 2000 grams/m^2/year)." (Ramos-Sharron and MacDonald, In Press)

These sediments decrease water clarity, negatively impacting both seagrass and coral reefs. If the volume of sediment is large, it can even bury areas of seagrass beds and smother reefs.

Storms can also stir up sediments and even deposit large amounts of sand and mud on top of seagrass beds and reefs, effectively burying them. Boat wakes also can stir up sediments, decreasing water clarity. With large numbers of boats this increased turbidity can become nearly constant, impacting local seagrass communities. Snorkeling and diving activities can increase suspended sediment on coral reefs due to improper buoyancy control and fin kicking techniques.

Dredging also stirs up sediments, decreasing water clarity, although currently dredging is not occurring within the parks. Beach sand nourishment activities can also increase turbidity. However, both these activities are highly regulated.

When seagrass dieoffs occur, the sediments that their roots have trapped can become re-suspended causing stress to nearby communities including seagrass beds and reefs.

J.9.2e Driver/Stressor: Increased sea level rise

Past sea level rise has caused the extinction of ancient coral reefs. Corals are dependent upon the zooxanthellae to assist with skeletal growth. Zooxanthellae require sunlight; therefore, if sea level rise is faster than coral reef growth and accretion, coral reef distribution would be negatively affected. However, this is a slow process. A faster response to changes in sea level could happen in Florida Bay as rising sea level changes circulation patterns within the Bay and affects mangrove distribution along the northern edge of the Bay.

J.9.2f Driver/Stressor: Water Quality – nutrients

Seagrass beds and coral reefs are typically oligotrophic (low nutrient) systems. Additional nutrients cause changes in seagrass inter-specific competition, changes in algal growth, and phytoplankton blooms. Seagrass communities can, to some degree, absorb some temporary nutrient influxes through direct uptake thereby improving water quality for nearby reefs. However, long-term nutrient enrichment can cause changes in seagrass community composition (see Figure J.9-G) and also increases the growth of algal epiphytes which diminish seagrass productivity. In fact, seagrass communities are often considered an indicator of water quality as eutrophication is associated with their loss (Fourqurean *et al*. 2002). Nutrient enrichment also increases phytoplankton growth and algal blooms which diminish water clarity in both seagrass beds and coral reefs, stressing both systems.

Finally, nutrient enrichment can increase benthic macroalgal growth on coral reefs. Nutrient enrichment encourages increased turf and macroalgal growth on coral reefs

which, if unchecked by herbivores, can overgrow corals, shading and abrading them, and can colonize open hard-bottom areas preventing coral larval settlement. Other problems may exist as well. Nitrogen enrichment may also be a contributing factor to coral bleaching (Lapointe *et al.* 2002).

Nutrient enrichment comes as runoff from land areas (malfunctioning septic tanks, urban runoff, sewage spills, agriculture), cruise ship discharges and boats. A 1999 study ranked Florida 2nd and U.S. Virgin Islands 3rd in the nation for number of reported beach closings due to water pollution (Drayton *et al.* 2004). The "fluid" boundaries of these marine parks make them extremely

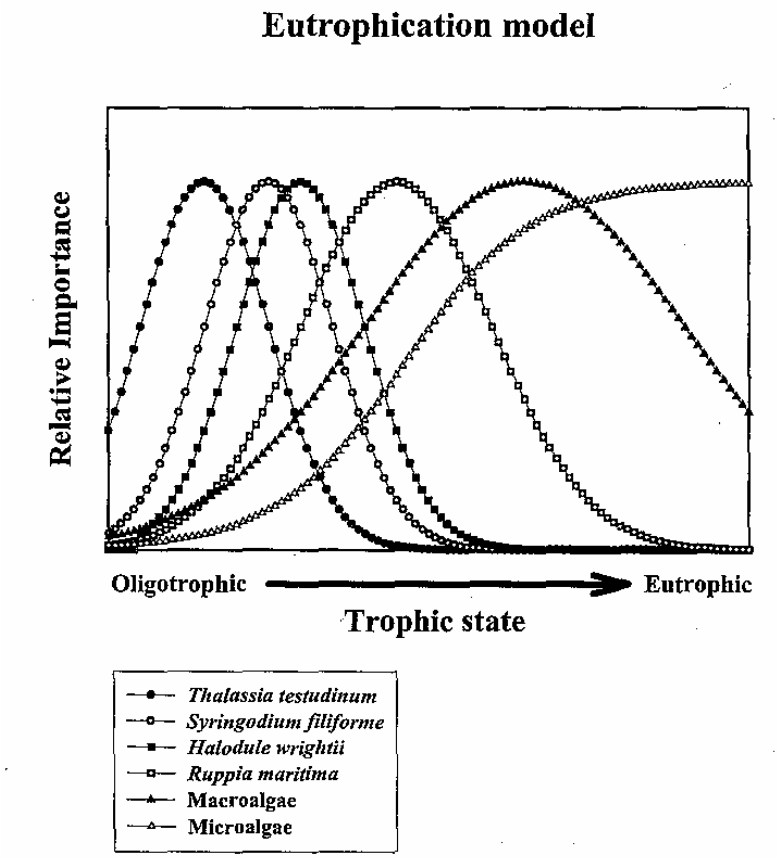


Figure J.9-G. A conceptual illustration of changes in seagrass community composition with increased eutrophication in near-shore marine waters of south Florida [From Fourqurean and Rutte 2003].

vulnerable to threats (e.g., nutrients, pollutants) from adjacent (upstream, upwind) properties and countries (e.g., VIIS affected by what flows out of the neighboring British Virgin Islands).

J.9.2g Driver/stressor: Water temperatures, salinity, dissolved oxygen

Temperature and salinity affect the distribution and community composition of seagrass beds. The three dominant seagrass species, turtle grass, manatee grass, and

shoal grass, prefer temperatures between 20-30°C (68-86 °F), with shoal grass able to withstand wider temperature variations than the other two species (USFWS 1999). The optimal salinity for seagrass ranges from 24 to 36 parts per thousand, (36 parts per thousand is average seawater). Shoal grass is able to tolerate wider ranges in salinities. Widgeon grass is actually a freshwater species with a strong salinity tolerance (USFWS 1999) and thus, if found more commonly in freshwater to brackish areas. This tolerance for a range of salinities makes seagrass common inhabitants of estuaries.

Coral require clean, clear, warm, salt water. Most coral species prefer temperatures between 20-28°C (68-82°F) (Drayton *et al*. 2004). Biscayne National Park contains the northernmost extent of the Florida Keys, but hard-bottomed reef communities continue further northward to Palm Beach County.

Coral bleaching occurs when coral polyps expel their zooxanthellae. The algae give the coral their color, therefore corals without zooxanthellae have clear tissue, which causes them to look white or "bleached" due to the color of the skeleton below the tissue. Coral bleaching occurs as a response to stress, (e.g., elevated sea water temperatures). If bleaching (time without zooxanthellae) is short, the coral has a high potential for recovery once the stress abates. If the stress is prolonged, the coral may die. Coral bleaching events have occurred in the U.S. Virgin Islands in 1987, 1998 and 2005 with mild bleaching occurring in fall, 1999. Bleaching events occurred in the Florida Keys in 1983, 1987, 1990, 1997, and 1998. The 1998 event was a world-wide phenomenon and coincided locally with some of the warmest seawater temperatures on record. Prior to 2005, most colonies in the U.S. Virgin Islands recovered within 6 months. (Rogers and Miller 2001). Beginning in summer 2005, 5 USVI *Montastraea annularis* dominated coral reefs monitored by SFCN suffered extensive bleaching followed by massive disease outbreaks and losses of coral tissue of 53-79% (Miller et al, 2008). In the Florida Keys, blade fire coral suffered 80-90% mortality during the 1998 event (NOAA 2001). Global warming could lead to increased ocean temperatures and an increased frequency of high temperature events, placing additional stress on coral reefs.

J.9.2h Driver/Stressor: Coral and seagrass diseases

Coral disease is currently one of the greatest concerns in coral reef management. Diseases such as white band disease, white plague disease, black band disease, and white pox disease are causing coral mortality throughout the Caribbean. White plague disease has been observed on 18 species of coral in the U.S. Virgin Islands including the major reef-building species (Miller *et al*. 2003). Figure J.9-I provides an example of the rapid rate of spread in just 15 days. The diseases kill the coral polyps leaving dead skeletons behind which are soon covered by algae. Currently the diseases are not well understood. Suggestions of exotic origins for the disease have included container ship ballast water, sewage effluent, and African dust. Work is underway to better understand and in some cases, identify, the disease-causing agents. In the case of white plague, the causal agent appears to be bacterial

(*Aurantimonas coralicida).* However, many questions remain such as how the organism spreads from reef to reef, whether it is a local or an exotic disease, whether the coral are more vulnerable due to higher than normal water temperatures or poor water quality, how to stop or slow the disease, and what long-term effect this will have on reef communities. What is clear however, is that in just a matter of days, coral is killed which takes centuries to grow.

Seagrass disease and dieoffs are another major concern. In the 1970s Florida Bay was known for its extensive seagrass beds. Then in 1987 a large dieoff of seagrass occurred (approximately 4000 ha), the causes of which are still unclear. Hypotheses include reductions in freshwater inputs and consequent increases in Bay salinities and decreased circulation, high temperatures, a buildup of sulfides in decaying seagrass matter, seagrass disease, or a combination of the above. A slimemold disease found in the Bay appears more common at higher salinities but its role in the dieoff is unclear (Rudnick 2004). The seagrass dieoff was accompanied by sediment resuspension and algal blooms which severely stressed remaining seagrass beds and led to a dieoff of sponges (Fourquerean *et al*. 2002). However, the decline in the seagrass had consequences on the rest of the food web. As a measurable indicator, pink shrimp harvest declined from 10 million pounds in 1986 to 4 million pounds in 1987 (USFWS 1999).

Disease outbreaks in the Caribbean have also contributed to mass mortalities of fish, sea fans, sea urchins, and sponges (NOAA 2001) and are affecting other organisms such as sea turtles. In 1983, 90% of the long-spined sea urchin (*Diadema antillarum*) suffered a Caribbean-wide dieoff due to disease (NOAA 2001). They are only now starting to become more abundant.

J.9.2i Stressor: Overfishing and damaging fishing methods

Overfishing and damaging fishing methods in coral reefs and marine communities are causing severe changes to the food web that are impacting the coral reefs. Modern fishing methods such as gill nets and long lines allow fishermen to fish more efficiently and in deeper waters than was historically possible. Fishermen can now set nets along parrotfish daily migration pathways between the coral reefs and seagrass beds allowing the capture of entire schools (Drayton *et al*. 2004). Seine nets allow harvesting of large numbers of fish while the weights dragging along the bottom disrupt reefs and seagrass beds. Lost fish traps or "pots" continue "ghost-fishing," capturing and killing fish. Figure J.9-F shows an overly-simplified conceptual model of a marine community food web in south Florida and Caribbean parks. Extensive fishing has reduced communities of the very large predators (apex piscivores, sharks, large groupers, goliath groupers). Normally a drop in top predators would be associated with increases in trophic levels

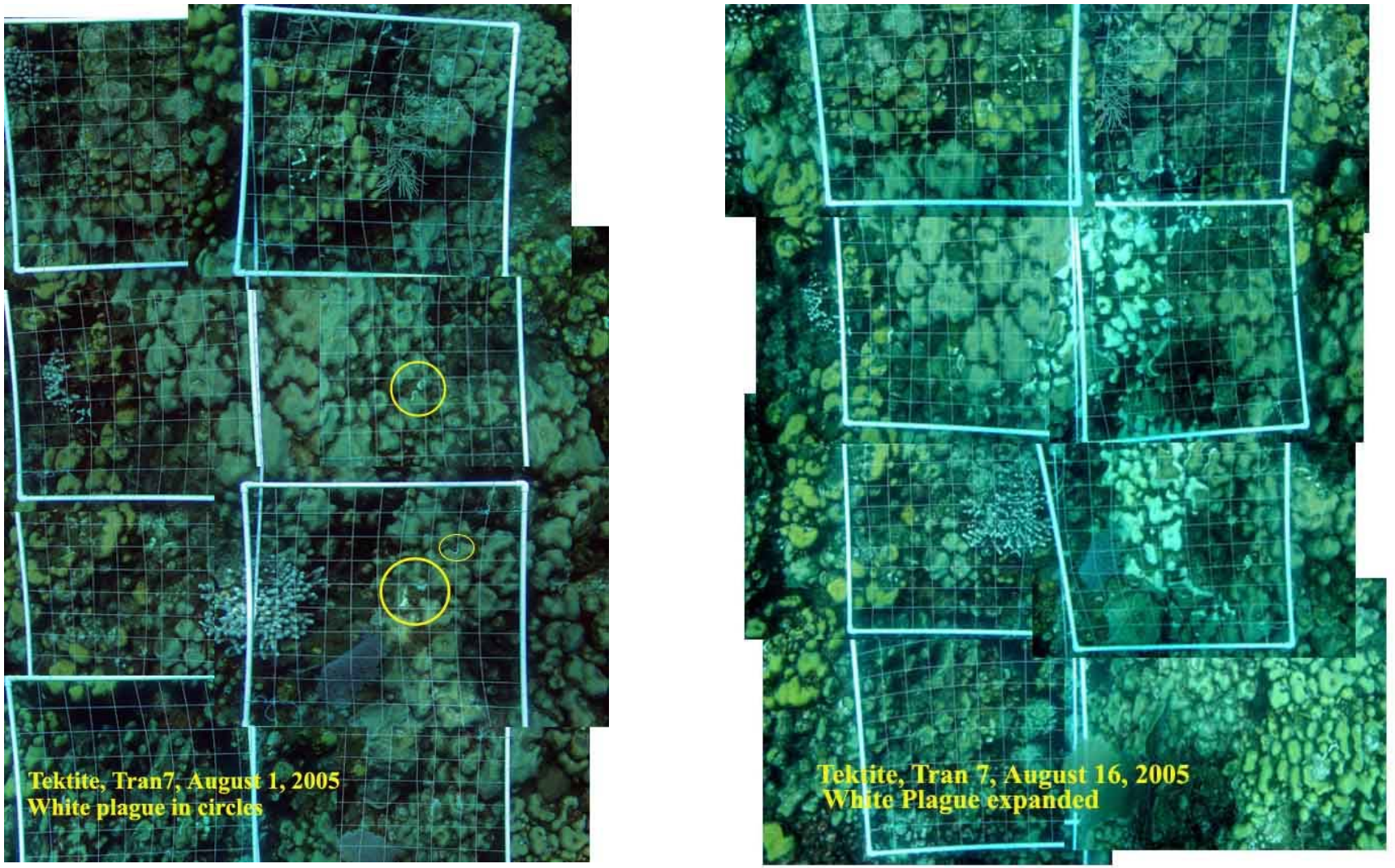


Figure J.9-I. Progress of White Plague disease in 15 days. These pictures were taken at "Tektite" reef on the south side of St. John, USVI just 15 days apart. The disease is barely discernable on the left hand pictures and is highlighted with circles. In the right-hand picture, the large, whitened diseased areas are clearly visible (This coral, *Montastraea annularis* grows ca. 2mm/year at this depth). [Photos by Jeff Miller and Rob Waara, NPS-SFCN].

directly below them. However, when one type of fish becomes rare, fishing has continued "fishing down the food web" or serial depletion, decreasing stocks of mid-level predators and herbivorous fish, taking smaller and smaller fish as the larger ones are depleted. This has severely altered the food web in marine communities. Even spawning populations were fished, reducing some stocks such as goliath groupers to extremely low levels.

As a consequence, in areas where fishing continues, many of the larger fish species in the coral reefs and seagrass beds are now rare. Average fish size of remaining species has decreased. And many are harvested before becoming sexually mature. The consequences on the food web are not completely understood. However, the reduction in herbivorous fish reduces the control on the growth of turf and macroalgae which inhibit coral growth and larval settlement. Increased algal abundance on reefs occurred with the Caribbean-wide dieoff of approximately 90% of the major reef herbivore, the long-spined sea urchin (*Diadema antillarum*) (see Figure J.9-J). The overfishing at the top of the food web has probably had other effects such as impacting the abundance of coral bioeroders, but these changes are less clearly understood.

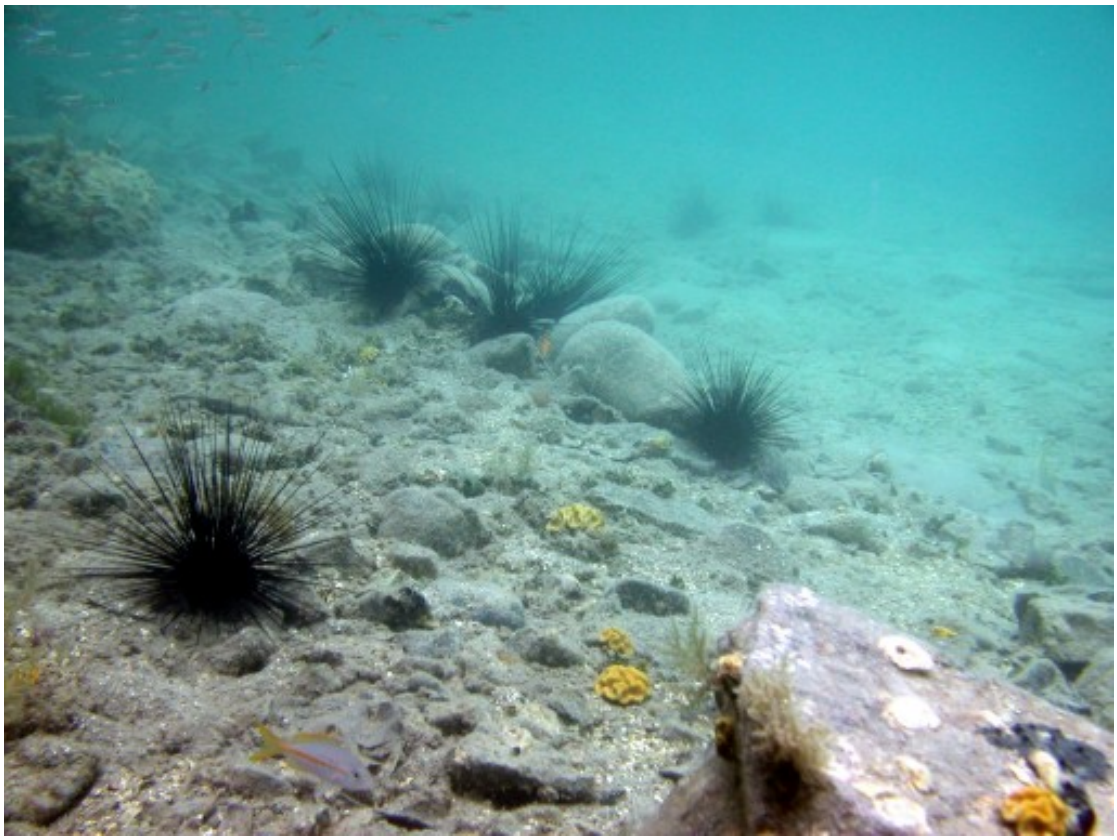


Figure J.9-J. Long-spined sea urchins (*Diadema antillarum*) are important herbivores on reefs. After overfishing reduced other herbivores, a Caribbean dieoff of sea urchins due to disease removed a last critical herbivore and is linked to algal overgrowth on coral reefs. Sea urchins now appear to be recovering.

J.9.2j Stressor: Water Quality – contaminants/pollutants

Seagrass and corals can be severely stressed by pollutants. Herbicides in urban and aquatic runoff negatively impact seagrass communities. Oils, pesticides, heavy metals, industrial chemical all negatively impact sensitive coral communities and free-swimming larvae. Impacts of increased estrogens and pharmaceuticals in treated sewage effluent are unclear, but are of increasing concern. Boat bottoms are being painted with cupreous oxide and tri-buytl tin to prevent biofouling and these paints and metals can leach into the water column, reefs and sediments. With increasing urbanization and increasing numbers of cruise ships occurring in the U.S. Virgin Islands and the Florida Keys, contaminants are an increasing concern.

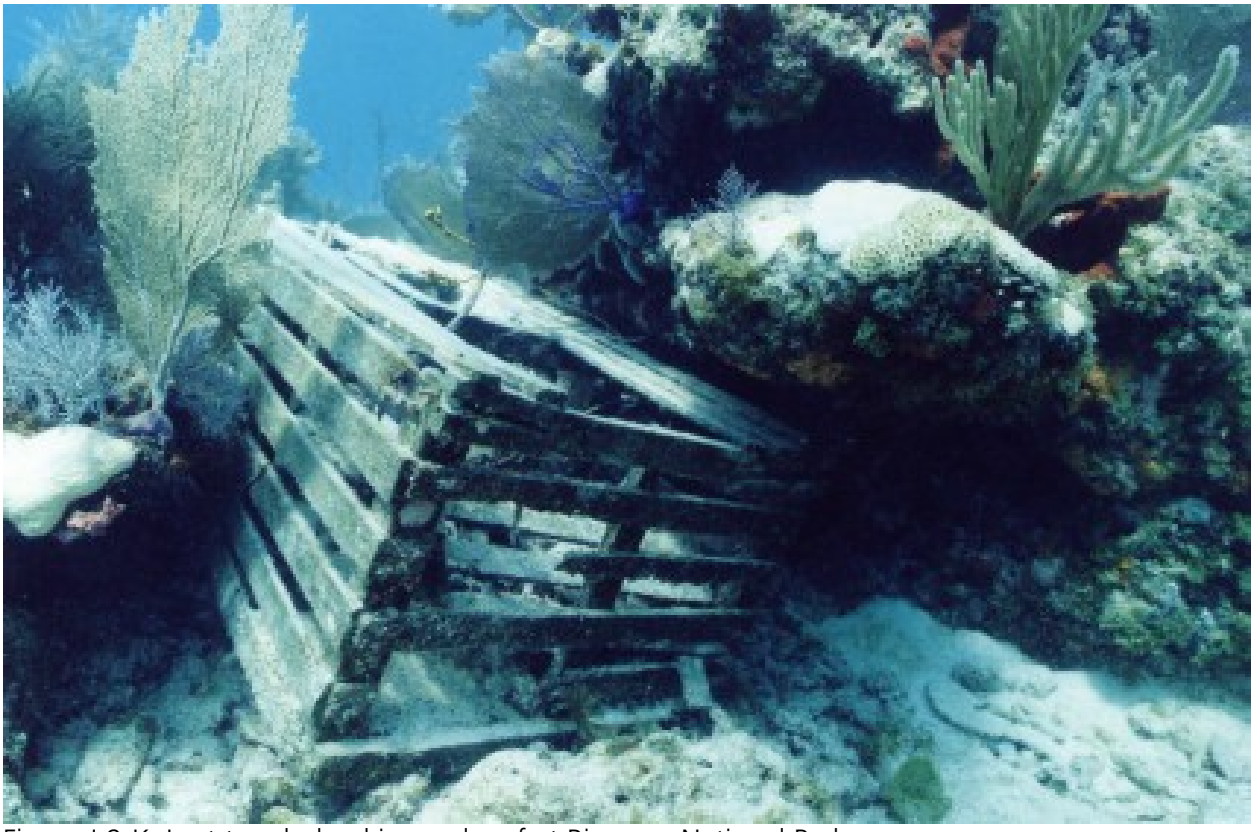
J.9.2k Stressor: Physical damage from boat groundings, anchors, tourists, abandoned fishing gear, damaging fishing methods

Damage from boat groundings, anchors and propellers scar seagrass beds and coral reefs and, given the high amount of boat traffic, are a major concern in SFCN marine park areas. Boat groundings and damage in seagrass beds can create shallow to deep gouges, cutting through rhizomes, and stirring up sediments. Wave action can then act upon these cuts, increasing their size through time. Groundings and damage to coral reefs can rip apart and fragment coral that took hundreds of years to grow. Major groundings can "break the back" of the reef, breaking through the outer layer and exposing the interior limestone to erosion. The cumulative impact of this damage from many boats through time can severely impact and even destroy the resources. Often removing the grounded vessel causes additional damage to resources adjacent to the original grounding site. Anchor damage by a small cruise ship in VIIS showed no recovery a decade after the incident (Rogers and Garrison 2001). Boat groundings also stir up sediments, can alter local bathymetry and cause local contamination problems as gasoline and other contaminants leak into the area.

Snorkelers and scuba divers, can damage the reef by touching and kicking the corals, and suspending sediments. Given the large visitation pressure that focus upon coral reefs, this chronic damage is cumulative, especially in popular viewing areas. In addition, illegal collection can be a problem with tourists collecting coral and organisms as souvenirs.

Today in Biscayne National Park, lobster divers sometimes move coral colonies in an effort to reach their prey, and spear fishing can damage resources. Historically, across the Caribbean, extremely damaging methods were once used such as dynamite, but these methods are now outlawed within the parks. However, lost fishing traps or "pots" and lost nets cause physical damage as waves move them back and forth across reefs and seagrass areas, and continue to remove "fish" long after they are lost (see Figure J.9-K).

Recovery of seagrass beds from propeller scars and groundings can take from 3-15 or more years (USFWS 1999). Recovery of coral reef damage from groundings can take centuries.


Figure J.9-K. Lost trap lodged in coral reef at Biscayne National Park.

J.9.2l Stressor: Introduction and spread of invasive species

Currently invasive species do not appear to be a large issue with the exception of new diseases. New diseases have been found in coral reefs, seagrass, and fauna such as sea turtles – the origins of which are unclear. Marine fish, estuarine fish, invertebrates, plants and algae have all been introduced but most do not appear to have become invasive. Introduced species mentioned by NOAA (Kendall *et al.* 2005) as being of concern in the Keys include lionfish (*Pterois volitans, P. miles*), and pacific algae (*Caulerpa brachypus*). Orange cup coral (*Tubastrea coccinea*) is also mentioned but primarily appears to be establishing on artificial reefs. Mayan cichlid (*Cichlasoma urophthalmus*) has established in both Florida and Biscayne Bays. Sources of new introductions include ship ballast water, released aquarium pets and plants, boat propellers and engines. The lionfish escaped into the ocean from Miami when Hurricane Andrew destroyed a private aquarium (Hare & Whitfield 2003).

Although invasive species are currently not a big stressor on SFCN marine benthic communities, invasive species have had devastating impacts on other systems around the world and bear watching (e.g., *Caulerpa taxifolia* was originally an aquarium plant accidentally introduced to the Mediterranean Sea where it spread rapidly into

large monospecific sheets. Small infestations have also been found in California and aggressively exterminated before they could spread.)

J.9.3 Anticipated Effects of Drivers and Stressors on Biological System Attributes

The marine ecosystem is interconnected. Healthy reefs are dependent upon healthy seagrass and mangrove communities which buffer reefs from land-based nutrient enrichment and sedimentation problems. Healthy reefs are also strongly dependent upon balanced fish and invertebrate food webs with sufficient levels of herbivores to keep algal overgrowth in check. In turn, healthy fish and invertebrate communities are dependent upon healthy seagrass beds, coral reefs, and mangroves. Thus, although anticipated effects on coral reef communities, seagrass communities and the marine consumer food web are described separately, they should be seen as inter-related.

J.9.3a Changes in coral reef community extent, distribution, percent cover, composition and structure

Coral reef communities are already under stress Caribbean-wide. Outbreaks of coral disease, increased coral bleaching, nutrient enrichment and sedimentation problems, contaminant problems, and altered food webs are all taking their toll on the coral reefs. Losses of live coral cover are rarely, if ever, "recovered," with that lost substrate being colonized by algae for decades. There is growing concern over apparent declines in coral cover (NOAA 2001), declines in the main reef-building corals, and over the apparent lack of successful re-growth or recruitment of the main reef-building corals. In fact staghorn coral (*Acropora cervicornis*) and Elkhorn coral (*A. palmata*) cover have been reduced to such a degree that, coupled with the lack of evidence of successful reproduction, these species have been listed as threatened under the Endangered Species Act. With increasing urban development and tourism coupled with global climate change and intense fishing pressures, these problems are expected to only get worse and careful park management will be required to mitigate these pressures.

J.9.3b Changes in seagrass community extent, composition and distribution

Seagrass communities are very susceptible to nutrient enrichment, sedimentation problems, and changes in salinity. Disease outbreaks and new invasive species are also a concern. With increasing human population in South Florida and the US Virgin Islands coupled with the large-scale Comprehensive Everglades Restoration Program, seagrass community extent, distribution, and composition is expected to change in response as described above.

In addition, West Indian manatees and sea turtles both graze in seagrass beds. Sea turtles also hunt in coral reefs for sponges, crabs, etc. However, numbers of manatees and sea turtles are vastly reduced over historical numbers due to hunting pressures on sea turtles, collisions with boats, entanglement in nets, altered habitats, etc. Thus, it is unclear what impact the herbivory of large numbers of sea turtles and

manatees historically had on seagrass structure and composition and how different present systems are in the absence of these large herbivores. If communities of West Indian manatees and sea turtles begin to recover, they may also impact the competitive relationships among different types of seagrass.

J.9.3c Changes in marine consumer food web structure and function

Marine fish and invertebrate communities are under considerable pressure due to overfishing and damaging fishing methods, contaminants and changes in mangroves, seagrass, and coral reefs (including habitat loss). The largest changes in parks that allow commercial and recreational fishing have been a loss or severe reduction in the large top predators in the system and reductions in the numbers and size of mid-level predators, herbivores and some crustaceans such as lobsters. Careful park management will be needed to prevent and/or recover from such problems within the park boundaries.

Buck Island Reef National Monument has been established as a no-fishing zone and a section of Dry Tortugas National Park has a Resource Natural Area (RNA) zoned in the current General Management Plan. While controversial, the concept is that the creation of no-take sanctuaries will allow coral reef and seagrass beds to recover along with a balanced marine food web. Healthy fish communities in no-take zones are expected to increase to the point that there will be spillover effects around the zones, increasing the size, and number of fish and crustaceans caught by commercial and recreational fisheries outside the no-take zones. However, at present the zones are still in early phases and need careful evaluation.



Figure J.9-L. Blue tangs at U.S. Virgin Islands

J.9.4 Potential and ongoing management actions in marine benthic communities

Following is a list of potential and ongoing local management actions to manage stressors and, if necessary, mitigate system drivers in SFCN parks:

- Enforcement of scientifically based regulations (review and revision if necessary) regarding minimum and maximum fish and shellfish take size, bag limits, seasons, and that restrict fishing gear and traps to those least destructive to environment and resulting in reduced unwanted by-catch
- Evaluate the effectiveness of no-take zones regarding how well they allow reef, seagrass, fish communities, and crustacean communities to recover and successfully reproduce, and the degree that they improve harvests in nearby waters outside of the parks. Modify zones as necessary
- Public education, signage, and communication with park interpretive staff regarding boater safety, park regulations, sensitive areas, and overall protection of coral resources
- Establish mooring buoys and mooring areas to reduce anchoring damage in park
- Install aids to navigation and maintain accurate navigation maps
- Hold grounded boat owners/companies who damage resources financially responsible for repairing damage
- Rapid response to catastrophic vessel groundings to control problem and effective notification of authorities and cleanup experts. As necessary, develop area contingency plans for rapid response to vessel groundings. Cleanup and habitat restoration after oil/chemical spills
- Protect and/or restore coral reefs and seagrass beds, their processes and interactions as determined necessary due to boat groundings, hurricanes, etc.
- As necessary, develop/ implement best management practices for agriculture, urban areas, and construction zones to reduce sediment runoff, nutrient enrichment, and pollution runoff into marine park areas. Convert dirt roads to paved roads to prevent sediment runoff
- Enforce water quality, illegal dumping and other regulations to reduce contaminants
- Seek to minimize new introductions of disease (possibly through controlling ballast water releases from ships and other methods)
- Seek to minimize new introductions of invasive species (through public education regarding release of aquarium pets and plants, communication with bait shops, awareness of area divers of invasive species to be on lookout for, possibly through controlling ballast water releases from ships and other methods)
- Determine and implement methods to treat or prevent spread of coral disease
- As determined necessary, create seasonal or temporary closure areas that keep visitors away from sensitive areas

- Enforcement of existing laws regarding collection of park resources and confiscation of coral and other specimens and revise laws as necessary
- As determined necessary, conduct additional actions to safeguard very rare species such as establishing additional populations, implementing protective measures, etc.
- Perform interagency consultation on proposed projects to minimize impact

APPENDIX J.10

PARK-SPECIFIC CONCEPTUAL MODELS

APPENDIX J.11

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APPENDIX J.11 Literature Cited

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APPENDIX K

SFCN FEDERAL, STATE, AND TERRITORIAL ENDANGERED SPECIES, THREATENED SPECIES, AND SPECIES OF SPECIAL CONCERN

South Florida Caribbean Network
2006

Appendix K. SFCN Federal, State, and Territorial Endangered Species, Threatened Species, and Species of Special Concern

Printed 9/17/2008

			Legal Status			Presence Status							References							Habitats						
Taxa	Common name	Scientific name	Federal Status	Florida Status (19, 20)	VIIS Status (21)	EVER	BICY	BISC	DRTO	VIIS	BUIS	SARI	EVER	BICY	BISC	DRTO	VIIS	BUIS	SARI	Wet prairies & marshes	Forested uplands & wetlands	Island interior	Coastal Wetlands	Florida & Biscayne Bays	Coastal shelf/ Deep Oceanic
Bird	Roseate spoonbill	*Ajaia ajaja*		SSC		P	P	P					16	4	10								f,b,r			
Bird	Cape Sable seaside sparrow	*Ammodramus maritimus mirabilis*	FE	SE		P	P						1, 8, 16, 22, 25, 32	1, 3, 4, 8, 22, 25						f,b,r						
Bird	Florida Grasshopper Sparrow	*Ammodramus savannarum floridanus*	FE	SE		P	P						32	31												
Bird	Limpkin	*Aramus guarauna*		SSC		P	P						16	4						f,b,r						
Bird	Great Blue Heron	*Ardea herodius*			VE	P	P	P		P		P					27		26	f	b,r		f			
Bird	Burrowing owl	*Athene cunicularia*		SSC		P							16							f	f,r		f,b,r			
Bird	Ivory-billed woodpecker	*Campephilus principalis*	FE	SE		H, E							1(historic), 16								f,b,r					
Bird	Great (Common) Egret	*Casmerodius albus*			VE	P	P	P		P		P					27		26	f	b,r		f			
Bird	Snowy Plover (Cuban)	*Charadrius alexandrinus*		ST	VE			P							30											
Bird	Piping plover	*Charadrius melodus*	FT	ST		P	P	P		P			1, 8, 16, 22, 25, 32	1	1, 9, 22, 25, 30	1, 8, 22, 25	22, 25						f,b,r			
Bird	White-crowned pigeon	*Columba leucocepala*		ST	VE	P	P	P		P	P	P	16, 32	4	10		27	28	12, 26		f	f	f,b,r			
Bird	Kirtland's warbler	*Dendroica kirtlandii*	FE							P							22, 25				r					
Bird	Little blue heron	*Egretta caerulea*		SSC		P	P	P					16	4	10				12	f	f,b,r	f	f,b,r			
Bird	Reddish egret	*Egretta rufescens*		SSC		P	P	P					16	4	10								f,b,r			
Bird	Snowy egret	*Egretta thula*		SSC	VE	P	P	P		P	P	P	16	4	10		27	28	26	f	f,b,r	f	f,b,r			
Bird	Tricolored heron	*Egretta tricolor*		SSC		P	P	P					16	4	10					f	f,b,r	f	f,b,r			
Bird	White ibis	*Eudocumus albus*		SSC		P	P	P					16	4	10					f	f,b,r	f	f,b,r			
Bird	Peregrine falcon	*Falco peregrinus*	FE	SE		P	P	P	P	P	P	P	8, 16, 22, 32	3, 4, 8	8, 9, 30	8, 22	1,27	28	26		f,r					
Bird	Southeastern American kestrel	*Falco sparverius paulus*		ST		P		P					16		10					f	f,b,r					
Bird	Florida Sandhill Crane	*Grus canadensis pratensis*		ST		P	P						16, 32	4						f,b,r						
Bird	American oystercatcher	*Haematopus palliatus*		SSC		P	P						16	4									f,b,r			

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																				Wet prairies & marshes	Forested uplands & wetlands	Island interior	Coastal Wetlands	Florida & Biscayne Bays	Coastal shelf/ Deep Oceanic
Taxa	**Common name**	**Scientific name**	**Federal Status**	**Florida Status (19, 20)**	**VIIS Status (21)**	**EVER**	**BICY**	**BISC**	**DRTO**	**VIIS**	**BUIS**	**SARI**	**EVER**	**BICY**	**BISC**	**DRTO**	**VIIS**	**BUIS**	**SARI**						
Bird	Bald eagle	*Haliaeetus leucocephalus*	FT? Proposed delisting	ST		P	P	P					1, 8, 16, 22, 25, 32	1, 3, 4, 8, 22, 25	1, 8, 9, 22, 25, 30					f	b,r		f,b,r	f		
Bird	Least Bittern	*Ixobrychus exilis*			VE	P	P	P				P							26	f,b,r						
Bird	Wood stork	*Mycteria americana*	FE	SE		P	P	P					1, 8, 16, 22, 25, 32	1, 3, 4, 8, 22, 25, 31	1, 8, 9, 22, 25, 30					f	b,r		f,b,r			
Bird	Black crowned night heron	*Nycticorax nycticorax*			VE					P		P					27		26							
Bird	Osprey	*Pandion haliaetus*		SSC		P	P	P					16	4	30				12	f	f,b,r	f	f,b,r	f	f	
Bird	Brown pelican	*Pelecanus occidentalis*	FE-Delisted	SSC		P	P	P	P	P	P	P	16, 32	4	10	29	1, 22, 25,27	1, 7, 25, 28	12, 26				f,b,r	f	f	
Bird	Red-cockaded woodpecker	*Picoides borealis*	FE	SSC		E	P						1 (historic), 8, 16, 22, 25, 32	1, 3, 4, 8, 22,25							f,b,r					
Bird	Least Grebe	*Podiceps dominicus*			VE					P		P					27		26							
Bird	Black skimmer	*Pynchops niger*		SSC		P	P	P					16	4	10, 30								f,b,r	f	f	
Bird	Clapper rail	*Rallus longirostris*			VE	P	P	P				P							26	f,b,r			f,b,r			
Bird	Snail kite	*Rostrhamus sociabilis*	FE	SE		P	P						8, 16, 22, 25	3, 4, 8, 22, 25						f	b,r					
Bird	Least tern	*Sterna antillarum*		ST	VE	P	P	P	P	P	P	P	16, 32	4	10, 22, 25, 30	29	27	25	26				f,b,r	f	f	
Bird	Roseate tern	*Sterna dougaillii*	FT	ST		P		P	P	P		P	8, 16, 22, 25, 32		22, 25, 30	8, 22, 25, 29	13, 22, 25, 27		26				f,b,r	f	f	
Fish	Small-toothed sawfish	*Pristis pectinata*	FE			P		P					23		22, 23, 25					x			x	x		
Herpetofauna	American alligator	*Alligator mississippiensis*	FT/SA	SSC		P	P	P					1, 8, 18, 25	1, 3,4, 8, 25	8, 9, 22, 25					f,b,r	f,b,r		f.r			

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Taxa	Common name	Scientific name	Federal Status	Florida Status (19, 20)	VIIS Status (21)	EVER	BICY	BISC	DRTO	VIIS	BUIS	SARI	EVER	BICY	BISC	DRTO	VIIS	BUIS	SARI	Wet prairies & marshes	Forested uplands & wetlands	Island interior	Coastal Wetlands	Florida & Biscayne Bays	Coastal shelf/ Deep Oceanic	
Herpetofauna	St. Croix ground lizard	*Ameiva polops*	FE								P							1, 25				r	f,b,r			
Herpetofauna	Loggerhead sea turtle	*Caretta caretta*	FT	ST		P		P	P		P		1, 8, 18, 22, 25		1, 8, 9, 22, 25	8, 22, 25		25					b	f	f	
Herpetofauna	Green sea turtle	*Chelonia mydas*	FE	SE		P		P	P	P	P		1, 8, 18, 22, 25		1, 8, 9, 22, 25	8, 22, 25	1, 22, 25	15, 25					b	f	f	
Herpetofauna	American crocodile	*Crocodylus acutus*	FE	SE		P	P	P	P				1, 8, 18, 22, 25	1	1, 8, 9, 22, 25	11							f,b,r	f		
Herpetofauna	Leatherback sea turtle	*Dermochelys coriacea*	FE	SE		P		P	P	P	P		1, 8, 18, 22, 25		1, 8, 9	8	1, 22, 25	1, 14,15 , 25					b	f	f	
Herpetofauna	Eastern indigo snake	*Drymarchon corais couperi*	FT	ST		P	P	P					1, 8, 18, 22, 25	1, 3, 4, 8, 22, 25	1, 8, 9, 22, 25					?	f,b,r		f,b,r			
Herpetofauna	Hawksbill sea turtle	*Eretmochelys imbricata*	FE	SE		P		P	P	P	P		8, 18, 22, 25		1, 8, 9, 22, 25	8	1, 22, 25	1, 7, 15, 25					b	f	f	
Herpetofauna	Gopher tortoise	*Gopherus polyphemus*		SSC		P							18										f,b,r			
Herpetofauna	Striped mud turtle	*Kinosternon baurii*		SE		P							18							f,b,r	f,b,r		f,b,r	f,r		
Herpetofauna	Kemps Ridley sea Turtle	*Lepidochelys kempii*	FE	SE		P		P	P				8, 18, 22, 25		1, 9	8							b	f	f	
Invertebrate	Miami blue butterfly	*Hermiargus thomasi benthunebakeri*	C			P							22, 25								f,b,r	f,b,r				
Invertebrate	Florida tree snail	*Ligus fasciatus*		SSC			P	P						4	10						f,b,r					
Invertebrate	Stock Island tree snail	*Orthalicus resee*	FT	SE		P							8, 22, 25								f,b,r					
Invertebrate	Schaus swallowtail	*Papilio aristodemus ponceanus*	FE	SE		P		P					8		8, 9, 22, 25						f,b,r					
Invertebrate-Aquatic	Staghorn coral	*Acropora cervicornis*	FT					P	P	P	P	P			22, 23, 25	23	23	23	23						X	
Invertebrate-Aquatic	Elkhorn coral	*Acropora palmata*	FT					P	P	P	P	P			22, 23, 25	23	23	23	23						X	

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Invertebrate-Aquatic	Pillar coral	*Dendrogyra cylindrus*		SE				P							10				12						X	
Mammal	Right whale	*Balaena glacialis*	FE	SE				P							1										f,r	
Mammal	Sei whale	*Balaenoptera borealis*	FE	SE				P							1										f,r	
Mammal	Finback whale	*Balaenoptera physalus*	FE	SE				P							1										f,r	
Mammal	Humpback whale	*Megaptera novaeangliae*	FE	SE				P		P					1		22, 25								f,r	
Mammal	Everglades mink	*Mustela vision evergladensis*		ST			P						17	4						f,b,r	f,b,r		f,b,r			
Mammal	Key Largo woodrat	*Neotoma floridana smaili*	FE	SE		P		P					8		1, 22, 25						f,b,r	?				
Mammal	Key Largo cotton mouse	*Peromyscus gossypinus allapaticola*	FE	SE		P		P					1, 8		22, 25						f,b,r	?				
Mammal	Mountain lion	*Puma concolor*	T (S/A)				P							4						f	f,b,r		f			
Mammal	Florida panther	*Puma concolor coryi*	FE	SE		P	P						8, 17, 22, 25	3, 4, 8, 22, 25						f	f,b,r		f			
Mammal	Big Cypress fox squirrel	*Sciurus niger avicennia*	PT	ST		P	P						25	4						f	f,b,r		f,b,r			
Mammal	West Indian manatee	*Trichechus manatus*	FE	SE		P	P	P	P	P			1, 8, 17, 22, 25	3, 4, 8, 22, 25	1, 8, 9, 22, 25	8, 22, 25	1, 22, 25						f,b,r	f		
Mammal	Florida black bear	*Ursus americanus floridanus*		ST		P	P						17	4						f	f,b,r		f,b,r			
Plant	Cinnecord, Florida acacia	*Acacia choriophylla*		SE				P							2							X				
Plant	Twisted acacia	*Acacia tortuosa*		SE		H							2								?	X	?			
Plant	Triangle cactus	*Acanthocereus tetragonus*		ST		P		P					2		2											
Plant	Paurotis palm, Everglades palm	*Acoelorraphe wrightii*		ST		P	P	P					2	2,5,	2											
Plant	Golden leather fern	*Acrostichum aureum*		ST		P	P	P					2	2,5,	2, 10											
Plant	Giant leather fern	*Acrostichum danaei folium*		ST				P							10											
Plant	Fragrant maidenhair	*Adiantum melanoleucum*		SE		P							2									X				
Plant	Fan maidenhair	*Adiantum tenerum*		SE		P							2													
Plant	Sensitive joint-vetch, Meadow joint-vetch	*Aeschynomene pratensis*		SE		P	P						2	2,5,6												
Plant	Egger's agave	*Agave eggersiana*			VE							P							12							
Plant	White colic-root, bracted colic-root	*Aletris bracteata*		SE		P	P						2	2,5,												
Plant	Mexican alvaradoa	*Alvaradoa amorphoides*		SE		P							2													
Plant	Clusterspike false indigo, Crenulaate lead-plant	*Amorpha herbacea var. crenulata*	FE	SE		P							1, 2, 8, 22, 25							x	X					
Plant	Wright's flowering fern	*Anemia wrightii*		SE		P							2							x	X					
Plant	Pineland-allamanda, Pineland golden trumpet	*Angadenia berteroi*		ST		P	P						2	2,5,6												
Plant	Sea rosemary	*Argusia gnaphalodes*		SE		P		P	P				2		2	2										

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Plant	Blodgett's silverbush	*Argythamnia blodgettii*	Candidate	SE		P		H					1, 2, 22, 25		1, 2						X	X				
Plant	Marsh's Dutchman's pipe	*Aristolochia pentandra*		SE				P							2											
Plant		*Asplenium dentatum*		SE		P							2													
Plant	Eared spleenwort	*Asplenium erosum*		SE			H							2,							X					
Plant	Bird's-nest fern, Wild birdnest fern	*Asplenium serratum*		SE			P							2,6												
Plant	Carter's orchid	*Basiphyllaea corallicola*		SE		P							2								X					
Plant	Pinepink	*Bletia purpurea*		ST		P	P	P					2	2,5,6	2											
Plant	Pineland strongback	*Bourreria cassinifolia*		SE		P							2								X	X				
Plant	Bodywood, Pigeon berry	*Bourreria succulenta*		SE		P		P					2		2											
Plant	Spider orchid	*Brassia caudata*		SE		E							2								X					
Plant	Fakahatchee bluethread	*Burmannia flava*		SE			P							2,6												
Plant	Key brysonima, Long Key locustberry	*Byrsonima lucida*		ST		P		P					2		2											
Plant	Yellow nicker	*Caesalpinia major*		SE				P							2							X				
Plant	Manyflowered grasspink	*Calopogon multiflorus*		SE			P							2,												
Plant	Spicewood, Pale lidflower	*Calyptranthes pallens*		ST		P	P	P					2	2,5,	2											
Plant	Thomas' lidflower	*Calyptranthes thomasiana*	FE							P							1, 22, 25									
Plant	Myrtle of the river, Spicewood	*Calyptranthes zuzygium*		SE		P							2													
Plant	Leafless bentspur orchid	*Campylocentrum pachyrrhizum*		SE			P							2,6							X					
Plant	Narrow strap fern, Narrow-leaved strap fern	*Campyloneurum angustifolium*		SE			H							2,6							X					
Plant	Tailed strap fern	*Campyloneurum costatum*		SE			H							2,							X					
Plant	Winter cinnamon, Wild Cinnamon	*Canella winterana*		SE		P		P					2		2											
Plant	Powdery strap airplant	*Catopsis berteroniana*		SE		P	P						2	2,6												
Plant	Florida strap airplant	*Catopsis floribunda*		SE		P	P						2	2,6												
Plant	West Indian cock's comb	*Celosia nitida*		SE		P		P					2		2											
Plant	Fragrant pricklyapples	*Cereus eriophorus var. fragrans (Harrisia fragrans)*	FE			H							22, 25								X	X				
Plant	Dildoe cactus	*Cereus pentagonus*		ST				P							10											
Plant	Deltoid spurge, Redland sandmat	*Chamaesyce deltoidea deltoidea*	FE			P							22, 25													
Plant	Wedge sandmat, Pineland sandmat	*Chamaesyce deltoidea ssp. Pinetorum*	C	SE		P							1, 2, 22, 25													
Plant	Garber's spurge	*Chamaesyce garberi*	FE, FT?	SE		P							1, 8, 22, 25													
Plant	Southern Florida sandmat	*Chamaesyce pergamena*		ST		P	P		P				2	2		2										
Plant	Porter's sandmat	*Chamaesyce porteriana*		SE		P	P	P					2	2,5,6	2, 10											
Plant	White sunbonnets	*Chaptalia albicans*		ST		P							2													
Plant	Southern lipfern	*Cheilanthes microphylla*		SE		P							2								X					
Plant	Florida Keys Cape Sable thoroughwort	*Chromolaena frustrata, Eupatorium frustratum (syn.)*	C	SE		P							1 (historic), 2, 22, 25								?					
Plant	Satin leaf	*Chrysophyllum oliviforme*		ST		P	P	P					2	2,5,	2, 10						X	X				

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Plant	Balsam apple	*Clusia rosea*		SE				P							10											
Plant	Silver palm (commercially exploited)	*Coccothrinax argentata*		ST		P		P					2		2, 10						X	X				
Plant	Coconut palm	*Cocos nucifera*		ST				P							10											
Plant	Coffee colubrina, Greenheart	*Colubrina arborescens*		SE		P	P	P					2	2,5,6	2						X	X				
Plant	Cuban nakedwood	*Colubrina cubensis var. floridana*		SE		P							2								X					
Plant	Soldierwood	*Colubrina elliptica*		SE		P		P					2		2						X	X				
Plant	Butterflybush, Curacao bush	*Cordia globosa*		SE		P	P						2	2												
Plant	Gieger tree	*Cordia sebestena*		SE				P							10											
Plant	Quailberry, Christmasberry	*Crossopetalum ilicifolium*		ST		P	P						2	2							X					
Plant	Maidenberry Florida crossopetalum	*Crossopetalum rhacoma*		ST		P		P					2		2						X	X				
Plant	Pepperbush	*Croton humilis*		SE			P							2,5,6							X					
Plant	Florida tree fern, Red-hair comb fern	*Ctenitis sloanei*		SE		P	P						2	2							X					
Plant	Blodgett's swallowwort	*Cynanchum blodgettii*		ST		P	P						2	2,5,6							X					
Plant	Cowhorn orchid, Cigar orchid	*Cyrtopodium punctatum*		SE		P	P						2	2,6												
Plant	Brown's Indian rosewood	*Dalbergia brownii*		SE		P		P					2		2						X	X				
Plant	Florida prairie clover	*Dalea carthagenensis var. floridana*	C	SE		E	P						1, 2, 22, 25	1,2,5						X	X					
Plant	Caribbean crabgrass	*Digitaria filiformis var. dolichophylla*		ST		P		P					2		2											
Plant	Everglades crabgrass, Twospike crab grass	*Digitaria pauciflora*	C	SE		P	P						1, 2, 22, 25	2						X	X					
Plant	Milkbark	*Drypetes diversifolia*		SE		P		P					2		2											
Plant	Guiana-plum	*Drypetes lateriflora*		ST		P	P	P					2	2,5,6	2											
Plant	Longview orchid	*Eltroplectris calcarata*		SE		P							2								X					
Plant	Dollar orchid	*Encyclia boothiana var. erythronioides*		SE		P		P					2		2, 10											
Plant	Clamshell orchid, cockleshell orchid	*Encyclia cochleata*		SE		P	P						2	2,5,6												
Plant	Florida butterfly orchid	*Encyclia tampensis*		C?			P	P						2,5,6	10											
Plant	Dingy-flowered star orchid	*Epidendrum anceps*		SE		E	P						2	2,5,6												
Plant	Hare-Lipped orchid	*Epidendrum bifidum*			VE							P							12							
Plant	Fringed star orchid	*Epidendrum ciliare*			VE							P							12							
Plant	Umbrella star orchid	*Epidendrum floridense*		SE		P	P						2	2,6												
Plant	Night-blooming epidendrum, Night-scented orch	*Epidendrum nocturnum*		SE		P	P						2	2,5,6												
Plant	Stiff-flower star orchid	*Epidendrum rigidum*		SE		P	P						2	2,5,6												
Plant	Sanibel Island love grass	*Eragrostis tracyi*		SE			P							2,									X			
Plant	Blacktorch	*Erithalis fruticosa*		ST		P							2													
Plant	Redberry ironwood	*Eugenia confusa*		SE		P		P					SE		2, 10											
Plant	Red stopper	*Eugenia rhombea*		SE				P							2, 10							X				
Plant	Binweed dwarf, Morning-glory	*Evolvulus convolvuloides*		SE		P							2													
Plant	Caribbean princewood, princewood	*Exostema caribaeum*		SE		P		P					2		2											
Plant	Small's milkpea	*Galactia smallii*	FE	SE		H							1,2													
Plant	Bey Rich's hooded orchid	*Galeandra beyrichii*		SE		P							2								X					
Plant	Beach verbena, Coastal mock vervain	*Glandularia maritima*		SE		P	P						2	2,6												
Plant	Wild cotton, Upland cotton	*Gossypium hirsutum*		SE		P	P						2	2,												
Plant	Tropical govenia	*Govenia utriculata*		SE		H							2								X					
Plant	Holywood ITIS	*Guajacum sanctum*		SE				P							2,10						X					
Plant	Lignum-vitae	*Guaicacum officinale*			VE							P							12							
Plant	West Indian tufted airplant	*Guzmania monostachia*		SE		P	P						2	2,6												
Plant	Snowy orchid	*Habenaria nivea*		ST			P							2,6												

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Plant	Needleroot airplant orchid	*Harrisella porrecta*		ST			P							2,5,6												
Plant	Simpson's applecactus	*Harrisia simpsonii*		SE		P		P					2		2											
Plant	Poeppig's rosemallow	*Hibiscus poeppigii*		SE		P	P						2	2												
Plant	Manchineel	*Hippomane mancinella*		SE		P		P					2		2, 10											
Plant	Hypclate, Inkwood	*Hypelate trifoliata*		SE		P							2													
Plant	Tawnberry, Tawnberry holly	*Ilex krugiana*		ST		P							2													
Plant	Delicate violet orchid	*Ionopsis utricularioides*		SE		H	P						2	2,5,6							X					
Plant	Calcareous morning-glory	*Ipomoea microdactyla glory*		SE		P							2													
Plant	Rockland morning-glory	*Ipomoea tenuissima*		SE		P	H						2	2,												
Plant	Pineland clustervine	*Jacquemontia curtisii*		ST		P	P						2	2,5,6												
Plant	Skyblue clustervine	*Jacquemontia pentanthos*		SE		P	P						2	2,5,6												
Plant	Beach clustervine	*Jacquemontia reclinata*	FE					P							22, 25											sand dunes
Plant	Joewood	*Jacquinia keyensis*		ST		P		P					2		2, 10											
Plant	Florida Keys thoroughwort	*Koanophyllon villosum*		SE		P							2													
Plant	White fenrose	*Kosteletzkya depressa*		SE		P							2									X				
Plant	Depressed shrubverbena	*Lantana depressa*		SE		P							2													
Plant	West coast lantana, Sanibel shrubverbena	*Lantana depressa var. sanibelensis*		SE		P	P						2	2,5,6												
Plant		*Leiphaimos parasitica*		SE		P		P					2		2											
Plant	Catesby's lily, Pine lily	*Lilium catesbaei*		ST			P							2,												
Plant	Small's flax	*Linum carteri var. smallii*		SE		P	P						2	2,5,6												
Plant	Pantropical widelip orchid	*Liparis nervosa*		SE			E							2,							X					strand swamp
Plant	Holly vine fern	*Lomariopsis kunzeana*		SE		P							2								X					
Plant	Nodding club-moss	*Lycopodiella cernua*		C			P							2,												
Plant	Longgland orchid	*Macradenia lutescens*		SE		E							2								X					
Plant	Stingbush	*Malphigia infestissima*			VE							P							12							
Plant	Cow-itch, Cowage cherry	*Malphigia woodburyana*			VE							P							12							
Plant	Wolly nipple	*Mammilaria nivosa*			VE							P							12							
Plant	Wild sapodilla	*Manilkara jaimiqui subsp. emarginata*		ST		P		P					2		2											
Plant	Hidden orchid	*Maxillaria crassifolia*		SE		E	P						2	2,5							X					
Plant	Florida mayten	*Maytenus phyllanthoides*		ST		P		P					2		2											
Plant	Pineland blackanthers	*Melanthera parvifolia*		ST		P	P						2	2,5,6												
Plant	Climbing vine fern	*Microgramma heterophylla*		SE		P	P	E					2	2,5,	2											
Plant	Sea lavender	*Mollatonia gnaphalodes*		SE				P							10											
Plant	Twinberry, Simpson's stopper	*Myrcianthes fragrans*		ST		P	P	P					2	2,5,6	2											
Plant	Giant sword fern	*Nephrolepis biserrata*		ST		P	P						2	2,5,6												
Plant	Ribbon fern	*Nevrodium lanceolatum*		SE				E							2							X				
Plant	Wild basil, Wild sweet basil	*Ocimum campechianum*		SE		P	H						2	2												
Plant	Clubbed creepingfern	*Odontosoria clavata*		SE		P							2													
Plant	Burrowing four o'clock	*Okenia hypogaea*		SE		E		P					2		2											
Plant	Florida dancinglady orchid	*Oncidium ensatum*		SE		P	P						2	2,							X					
Plant	Mule-ear orchid	*Oncidium undulatum*		SE		P							2								X					
Plant	Hand fern	*Ophioglossum palmatum*		SE		E	P						2	2,5												
Plant	Semaphore pricklypear	*Opuntia corallicola*	C	SE				P							1, 2, 22, 25							X				
Plant	Erect pricklypear	*Opuntia stricta*		ST		P	P	P	P				2	2	2, 10	2										
Plant	Royal fern	*Osmunda regalis var. spectabilis*		C			P							2,5,6												

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Plant	Ribbon fern	*Paltonium lanceolatum*		ST				P							10								X			
Plant	Chapman's bristlegrass	*Paspalidium chapmanii*		SE		P							2													
Plant	White flower passionflower	*Passiflora multiflora*		SE		P		P					2		2											
Plant	Pineland passionflower	*Passiflora pallens*		SE		P	P						2	2,5												
Plant	Goatsfoot	*Passiflora sexflora goatsfoot*		SE		P							2								X					
Plant	Swampbush	*Pavonia paludicola*		SE		P							2								?		X			
Plant	Plume polypody	*Pecluma plumula*		SE		P							2								X					
Plant	Comb polypody	*Pecluma ptilodon var. caespitosa*		SE			H							2,												
Plant	Cypress peperomia	*Peperomia glabella*		SE			E							2,6							X					
Plant	Low peperomia	*Peperomia humilis*		SE		P							2								X					
Plant	Florida peperomia, Baby rubberplant	*Peperomia obtusifolia*		SE		P	P						2	2,5,6												
Plant	Yerba linda	*Peperomia rotundifolia*		SE			P							2,6							X					
Plant	Mahogany mistletoe	*Phoradendron rubrum*		SE				P							2							X				
Plant	Southern fogfruit	*Phyla stoechadifolia*		SE		P	P						2	2												
Plant	Bitterbrush	*Picramnia pentandra*		SE		P							2								X					
Plant	Florida Keys blackbean	*Pithecellobium keyense*		ST		P		P					2		2											
Plant	Flor de Llanten	*Pleurothallis gelida Llanten*		SE		E							2								X					
Plant	Pineland pointsettia, Everglades pointsettia	*Poinsettia pinetorum*		SE		P							2													
Plant	Ghost orchid, Palmplolly	*Polyradicion lindenii*		SE		E	P						2	2,5,6												
Plant	Greater yellowspike orchid	*Polystachya concreta*		SE		P	P	E					2	2,5,6	2											
Plant	Mrs. Britton's shadow witch	*Ponthieva brittoniae*		SE		P							2								X					
Plant	Small Prescott's orchid	*Prescotia oligantha*		SE		P							2								X					
Plant	West Indian cherry	*Prunus myrtifolia*		ST		P							2													
Plant	Sargent's cherry palm	*Pseudophoenix sargentii*		SE				P							2, 10							X				
Plant	Mangroveberry, Long-stalk stopper	*Psidium longipes*		ST		P							2													
Plant	Bahama ladder brake	*Pteris bahamensis*		ST		P	P	P					2	2,5,6	2											
Plant	Darlingplum	*Reynosia septentrionalis*		ST		H		P					2		2											
Plant	Mistletoe cactus	*Rhipsalis baccifera*		SE		P							2								X					
Plant	Small-leaf snoutbean	*Rhynchosia parvifolia*		ST		P							2													
Plant	Swartz's snoutbean	*Rhynchosia swartzii*		SE			P	P						2	2						X	X				
Plant	Royal palm, Florida royal palm	*Roystonea regia*		SE		P	P						2	2,5,6												
Plant	Bahama sachsia	*Sachsia polycephala*		ST		P							2													
Plant	Leafless beaked lady's-tresses	*Sacoila lanceolata*		ST		P	P						2	2,												
Plant	Fakahatchee beaked orchid	*Sacoila lanceolata var. paludicola*		ST		P							2													
Plant	Gullfeed	*Scaevola plumieri*		ST		P		E	P				2		2	2										
Plant	Florida boxwood	*Schaefferia frutescens*		SE		P		P					2		2											
Plant	Ray fern	*Schizaea pennula*		SE		E	P						2	2,5,							X					
Plant	Florida Keys nutrush	*Scleria lithosperma*		SE		P	P						2	2,5,												
Plant	Havana skullcap	*Scutellaria havanensis*		SE		P							2													
Plant	Eaton's Spike moss, Pygmy Spike moss	*Selaginella armata var. eatonii*		SE		P							2													
Plant	Chapman's senna	*Senna mexicana var. chapmanii*		ST		P							2													
Plant	Everglades bully	*Sideroxylon reclinatum subsp. austrofloridense*	C			P	P						22, 25	2,5,							X				2,5	
Plant	Everglades greenbrier	*Smilax havanensis*		ST		P		P					2		2											
Plant	Mullein nightshade	*Solanum verbascifolium*		ST		P	P						2	2,5,6												
Plant	Everglades Keys false buttonweed	*Spermacoce terminalis*		ST		P	P						2	2,5,												
Plant	Texas lady's-tresses	*Spiranthes brevilabris*		SE			H							2,							X					
Plant	Costa Rican lady's-tresses	*Spiranthes costaricensis*		SE		P							2								X					
Plant	Lacelip lady's-tresses	*Spiranthes laciniata*		ST		P	P						2	2												

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Plant	Longlip lady's-tresses	*Spiranthes longilabris*		ST			P							2,												
Plant	Florida Keys lady's-tresses	*Spiranthes polyantha*		SE				E							2							X				
Plant	Southern lady's-tresses	*Spiranthes torta*		SE		P	H						2	2						X	X					
Plant	Everglade Key lady's-tresses	*Stylosanthes calcicola pencilflower*		SE		P							2													
Plant	Bay cedar	*Suriana maritima*		SE				P							10											
Plant	West Indian mahogany	*Swietenia mahagoni*		ST		P	P	P					2	2	2, 10											
Plant	Least halberd-fern	*Tectaria fimbriata*		SE		P							2													
Plant	Broad halberd fern	*Tectaria heracleifolia*		ST		P	H						2	2,5												
Plant	Florida clover ash	*Tetrazygia bicolor*		ST		P							2													
Plant	Abruptip maiden fern	*Thelypteris augescens*		ST		P							2													
Plant	Creeping maiden fern	*Thelypteris reptans*		SE		P							2													
Plant	Lattice-vein fern	*Thelypteris reticulata*		SE		P	P						2	2							X					
Plant	Stiff star-hair fern	*Thelypteris sclerophylla*		SE		E							2								X					
Plant	Toothed lattice-vein fern	*Thelypteris serrata*		SE		P							2													
Plant	Aspidium fern	*Thelypterus kunthii*		ST				P							10											
Plant	Key thatch palm	*Thrinax morrisii*		SE		E		P					2		2											
Plant	Florida thatch palm	*Thrinax radiata*		SE		P		P					2		2											
Plant	Reflexed wild-pine, Northern needleleaf	*Tillandsia balbisiana*		ST		P	P	P					2	2,5,6	2											
Plant	Clubspike cardinal airplant	*Tillandsia fasciculata var. clavispica*		SE		H							2								X					
Plant	Stiff-leaved wild-pine, Cardinal airplant	*Tillandsia fasciculata var. densispica*		SE		P	P	P	P				2	2,5,6	2	2										
Plant	Banded wild-pine, Twisted airplant	*Tillandsia flexuosa*		ST		P	P	P					2	2,5,6	2, 10											
Plant	Hoary wild-pine, Fuzzywuzzy airplant	*Tillandsia pruinosa*		SE			P							2,5,6												
Plant	Giant wild-pine, Giant airplant	*Tillandsia utriculata*		ST		P	P	P					2	2,5,6	2, 10											
Plant	Soft-leaved wild-pine, Leatherleaf airplant	*Tillandsia variabilis*		ST		P	P						2	2,5,6												
Plant	Chiggery grapes	*Tournefortia hirsutissima*		SE		P	P						2	2,5,												
Plant	Florida Keys noseburn	*Tragia saxicola*		ST		P							2													
Plant	Lamarck's thema	*Trema lamarckianum*		SE		P		P					2		2											
Plant	Entire-winged bristle fern	*Trichomanes holopterum*		SE			P							2,5,							X					
Plant	Kraus' bristle fern	*Trichomanes krausii*		SE		E							2								X					
Plant	Florida bristle fern	*Trichomanes punctatum subsp. floridanum*		SE		E							2								X					
Plant	Florida gamagrass	*Tripsacum floridanum*		ST		P	P						2	2,5,6												
Plant	Pearlberry	*Vallesia antillana*		SE		E		P					2		2						X		X			
Plant	Wormvine orchid	*Vanilla barbellata*		SE		P							2													
Plant	Mrs. Lott's vanilla	*Vanilla dilloniana*		SE		H							2								X					
Plant	Leafy vanilla	*Vanilla phaeantha*		SE		E							2													
Plant	St. Thomas pricklyash	*Zanthoxylum thomasianum*	FE							P							1, 22, 25									
Plant	Rain-lily, Redmargin zephyrlily	*Zephyranthes simpsonii*		ST			H							2,6												

Federal Status Codes
- FE Federally Endangered
- FT Federally Threatened
- C Candidate
- SA Simularity of Appearance with federally listed species

Presence Status
- P Present
- H Historical Record
- E Presumed Extirpated or Extinct

State Listed Codes

Habitat Status

Appendix K. SFCN Federal, State, and Territorial Endangered Species, Threatened Species, and Species of Special Concern

Printed	9/17/2008		Legal Status			Presence Status							References							Habitats						
Taxa	Common name	Scientific name	Federal Status	Florida Status (19, 20)	VIIS Status (21)	EVER	BICY	BISC	DRTO	VIIS	BUIS	SARI	EVER	BICY	BISC	DRTO	VIIS	BUIS	SARI	Wet prairies & marshes	Forested uplands & wetlands	Island interior	Coastal Wetlands	Florida & Biscayne Bays	Coastal shelf/ Deep Oceanic	
SE	State Endangered		f	feeding habitat																						
ST	State Threatened		b	breeding/reproduction habitat																						
SSC	State Species of Special Concern		r	resting/roosting habitat																						
			X	presence																						

U.S. Virgin Islands Status Codes

VE U.S. Virgin Islands Territorially Endangered

References for Appendix K

Ref. #	Source
1	Source of Data: NPSpecies Database Date of Data Source: Queried on 4/29/2005 Location of Data Source: National Park Service Inventory and Monitoring Program database cataloging species within parks. Database maintained in Fort Collins, CO. http://science.nature.nps.gov/im/apps/npspp/ Other (Methodology, Preparer, etc.): NPS-South Florida Caribbean Network queries can be made by Brian Witcher (Database Manager, 305-252-0347, brian_witcher@nps.gov) Metadata Prepared by: Andrea J. Atkinson, NPS-SFCN
2	Source of Data: "Floristic Inventory of South Florida Database" Date of Data Source: 2005. Queried 6/13/2005 Location of Data Source: The Institute for Regional Conservation, 22601 S.W. 152 Ave., Miami, Florida 33170; URL: www.regionalconservation.org Other (Methodology, Preparer, etc.): Database preparers are George D. Gann, Keith A. Bradley, and Steven W. Woodmansee. Metadata Prepared by: Andrea J. Atkinson, NPS-SFCN
3	Source of Data: "Strategic Plan for Big Cypress National Preserve: Oct. 1, 2001 – Sept. 30, 2005" Date of Data Source: 10/23/2000 Location of Data Source: URL http://www.nps.gov/bicy/bicyclen2.htm#strat Other (Methodology, Preparer, etc.): Metadata Prepared by: Andrea J. Atkinson, NPS-SFCN
4	Source of Data: "Listed Wildlife Species in Big Cypress National Preserve", Date of Data Source: File date is 2/7/2002. Downloaded 6/13/2005 Location of Data Source: Big Cypress National Preserve web page http://www.nps.gov/bicy/tne.pdf Other (Methodology, Preparer, etc.): No author of the document is given Metadata Prepared by: Andrea J. Atkinson, NPS-SFCN
5	Source of Data: Floristic Inventory of Big Cypress National Preserve Vegetation Transects Database titled "BICYFloraEdited" Date of Data Source: 2005 Location of Data Source: NPS South Florida Caribbean Office, 18001 Old Cutler Rd., Suite 419, Village of Palmetto Bay, FL 33157. Phone: 305-252-0347 Other (Methodology, Preparer, etc.): Contains results from 600 vegetation transects plus supplemental data from a Floristic Inventory of Big Cypress National Preserve conducted by Institute for Regional Conservation from 2002-2004. Report is pending. Metadata Prepared by: Andrea J. Atkinson, NPS-SFCN

References for Appendix K

Ref. #	Source
6	Source of Data: "Scope of Work: Inventory of vascular plant species at selected sites within the Big Cypress National Preserve, Appendix A: Vascular plants in Big Cypress National Preserve (BICY) listed as endangered, threatened or commercially exploited. Big Cypress National Preserve, USGS, Biological Resources Division." Date of Data Source: 2001 Location of Data Source: NPS South Florida Caribbean Office, 18001 Old Cutler Rd., Suite 419, Village of Palmetto Bay, FL 33157. Phone: 305-252-0347 Other (Methodology, Preparer, etc.): The description for how Appendix A was compiled is as follows—"Status: State of Florida. Status of plants was determined from a listing by Coile (1998); presence of plant species was determined from a checklist produced by Black and Black (1980) with subsequent collections and annotations to that list. Status: Federal. No species noted here were indicated on a federal list of endangered or threatened plants. Taxonomy and common names follow Wunderlin (1998); names used by Black and Black (1980), if different, are indicated in
7	BUIS park web page http://www.nps.gov/buis/index.htm
8	EVER park web page http://www.nps.gov/ever/eco/toofew.htm
9	BISC park web page http://www.nps.gov/bisc/resource/endspc.htm
10	BISC park web page http://www.nps.gov/bisc/resource/florida.htm
11	Personal observation by DRTO park staff, Jan. 2005
12	Kendall, M.S., L. T. Takata, O. Jensen, Z. Hillis-Starr, and M.E. Monaco. 2005 DRAFT. An Ecological Characterization of the Salt River Bay National Historical Park and Ecological Preserve, U.S. Virgin Islands. NOAA Technical Memorandum NOS NCCOS 14. April 2005. 116 pages.
13	USFWS. 1993. Caribbean Roseate Tern Recovery Plan. USFWS Atlanta Georgia, 40 pp. URL: http://ecos.fws.gov/docs/recovery_plans/1983/830924.pdf
14	National Marine Fisheries Service and U.S. Fish and Wildlife Service.1 992. Recovery Plan for Leatherback Turtles in the U.S. Caribbean, Atlantic and Gulf of Mexico. National Marine Fisheries Service, Washington, D.C. URL: http://ecos.fws.gov/docs/recovery_plans/1992/920406.pdf
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16	EVER park web page http://www.nps.gov/ever/eco/birds.htm
17	EVER park web page http://www.nps.gov/ever/eco/mammals.htm
18	EVER park web page http://www.nps.gov/ever/eco/herps.htm
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20	Coile, N. C., and M. A. Garland. 2003. Notes on Florida's Endangered and Threatened Plants. Botany Contribution No. 38, 4th Edition. Prepared for Florida Department of Agriculture and Consumer Services, Div. Plant Industry, Gainesville. 122 pages. URL: http://www.doacs.state.fl.us/pi/enpp/botany/images/Notes2003.pdf

References for Appendix K

Ref. #	Source
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23	Source of Data: "Coral Database" & personal observation of Matt Patterson, William "Jeff" Miller Date of Data Source: 2005. Queried 7/25/2005 Location of Data Source: NPS, SFCN Other (Methodology, Preparer, etc.): Jeff Miller, Rob Waara, Brian Witcher Metadata Prepared by: Andrea J. Atkinson, NPS-SFCN
24	Adams, W. F., C. M. Bailey, S. Branstetter, G. H. Burgess, J. I. Castro, J. L. Lee, and J. A. Musick. December 2000. Status Review of Smalltooth Sawfish (Pristis pectinata). http://isurus.mote.org/~colins/Smalltooth_sawfish.pdf
25	Source of Data: NPS ESA database Date of Data Source: Queried 8/11/2005 Location of Data Source: NPS Other: Cherry Green Metadata Prepared by: Andrea J. Atkinson, NPS-SFCN
26	Watson, Keith. November 2003. DRAFT Avian Conservation Implementation Plan, Salt River Bay National Historic Park and Ecologica Preserve, National Park Service, Southeast Region. Technical Report Prepared for National Park Service South Florida / Caribbean Network. 41 Pages.
27	Watson, Keith. November 2003. DRAFT Avian Conservation Implementation, Plan Virgin Islands National Park, National Park Service, Southeast Region. Technical Report Prepared for National Park Service South Florida / Caribbean Network. 40 Pages.
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APPENDIX L

Avian Conservation Implementation Plans

L.1 Big Cypress National Preserve
L.2 Biscayne National Park
L.3 Buck Island Reef National Monument
L.4 Dry Tortugas National Park
L.5 Everglades National Park
L.6 Salt River Bay National Historical Park and Ecological Preserve
L.7 Virgin Islands National Park and Coral Reef National Monument

APPENDIX L.1

BIG CYPRESS NATIONAL PRESERVE

FINAL DRAFT

Avian Conservation Implementation Plan
Big Cypress National Preserve

National Park Service
Southeast Region



Compiled by J. Keith Watson
U.S. Fish and Wildlife Service
In cooperation with

BICY Resource Management Staff, National Park Service
And Bird Conservation Partners
January 2005

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- US Fish and Wildlife Service, Species of Conservation Concern 2002, Peninsular Florida (BCR 31)

Introduction

This Avian Conservation Implementation Plan (ACIP) is provided to the staff at Big Cypress National Preserve (BICY) to help identify and prioritize bird conservation opportunities, and to provide information and guidance for the successful implementation of needed conservation activities. This plan may identify goals, strategies, partnerships, and perhaps specific projects for the preserve to participate in existing bird conservation planning and implementation efforts associated with the North American Bird Conservation Initiative (NABCI). Under the auspice of NABCI, appropriate bird and habitat conservation goals may be recommended as identified in the appropriate existing national or regional bird conservation efforts aligned with this initiative: Partners In Flight (PIF), North American Waterfowl Management Plan (NAWMP), US Shorebird Conservation Plan (USSCP), and Waterbird Conservation for the Americas (WCA). For example, parks in the Appalachians and the Cumberland Plateau will have few if any high priority waterbird conservation issues at a regional landscape or greater scale. As such, little information regarding waterbird conservation will be presented in the ACIP, unless there is an identified park need for this species group, or other mandates, such as federal laws. Similarly, because BICY has a mix of habitat types, recommendations will be derived from the appropriate existing planning document priorities, with an emphasis on waterbirds, including marshbirds, and landbirds. However, all high priority bird conservation issues for BICY will be discussed and integrated as appropriate.

Information and data presented in the ACIP have been obtained from several sources: 1) interviews with BICY staff 2) BICY bird conservation partners 3) the PIF Subtropical Florida Bird Conservation Plan Executive Summary 4) NPS databases, 5) peer reviewed bird conservation and management literature, and 6) personal communications with bird conservation specialists throughout North America, especially in the southeastern United States. This plan has been reviewed by BICY resource management staff and managers, South Florida/Caribbean Inventory and Monitoring (AHN I&M) Network staff, and bird conservation partners and approved by BICY management. Optimally, this plan will be incorporated into the preserve's Resource Management Plan (RMP) and updated annually to reflect completed projects, newly identified needs, and shifts in bird conservation priorities in the region.

BICY is not obligated to undertake any of the proposed actions in this plan. The plan is provided to offer guidance to BICY to voluntarily support important preserve, regional, and perhaps national and international bird conservation projects for which BICY is a primary participant in the proposed actions.

Background

During the past thirty years, monitoring programs across North America have documented declines of certain bird species populations and their habitats, often severe (Sauer et al. 2000). The decline has caused great concern among scientists, biologists,

biodiversity proponents, ecologists, land managers, etc., and the bird conservation community in general. Birds are recognized as critical components of local and global genetic, species, and population diversity, providing important and often critical ecological, social, economic, and cultural values. Their overall decline has stimulated a worldwide focus on conservation efforts and North American interest in bird conservation is rapidly becoming a focus of government, non-government, industry, and private interests and expenditures.

Many state, federal, and non-governmental wildlife agencies and non-government organizations (NGO's) have recognized this alarming bird decline trend and have joined forces in several extensive partnerships to address the conservation needs of various bird groups and their habitats. The primary initiatives are:

- North American Waterfowl Management Plan
- Partners in Flight
- U.S. Shorebird Conservation Plan
- Waterbird Conservation for the Americas

The North American Bird Conservation Initiative: While efforts associated with these plans have generated some successes, it has been increasingly recognized that the overlapping conservation interests of these initiatives can be better served through more integrated planning and delivery of bird conservation. The *North American Bird Conservation Initiative (NABCI*; http://www.nabci-us.org/main2.html*)* arose out of this realization. The vision of NABCI is simply to see ***"populations and habitats of North America's birds protected, restored and enhanced through coordinated efforts at international, national, regional, state and local levels, guided by sound science and effective management."*** NABCI seeks to accomplish this vision through (1) broadening bird conservation partnerships, (2) working to increase the financial resources available for bird conservation in the U.S., and (3) enhancing the effectiveness of those resources and partnerships by facilitating integrated bird conservation (U.S. NABCI Committee 2000). Together, the four bird conservation initiatives mentioned above, as well as several other local and regional partnerships, work collectively to pursue this vision.

NABCI is guided by a set of principles that establish an operational framework within which the Initiative and its partners may conduct integrated bird conservation in the U.S. These will articulate a common understanding of the relationship between NABCI, the individual bird conservation initiatives, and all partner entities to ensure recognition of existing federal legislative and international treaty obligations, state authorities, and respect for the identity and autonomy of each initiative. The fundamental components of the conservation approach to be used by NABCI are expressed within its goal:

> ***To deliver the full spectrum of bird conservation through regionally-based, biologically-driven, landscape-oriented partnerships.***

The Southeastern Bird Conservation Initiative: National Park Service: In 1999, the Southeast Region of the National Park Service (NPS) recognized the importance of coordinating existing bird conservation goals into planning and operations of national park units in the southeast, that is, integration of NABCI. In support of this recognition, the Southeast Regional Office NPS approved and allocated eighty-eight thousand dollars, cost sharing 1:1 with the US Fish and Wildlife Service (FWS) Region 4 (Southeast) to hire a biologist to conduct this two-year project (Interagency Agreement FS028 01 0368). This project is unique in the NPS, and perhaps the nation, and represents a potential model for better coordinating regional bird conservation programs and activities within and outside the NPS. It further represents a progressive action toward institutionalizing bird conservation as a programmatic priority in the Southeast Region of NPS, and potentially the nation.

As envisioned, the integration of NABCI into the Southeastern NPS involves:

1) Development and delivery of Avian Conservation Implementation Plans
2) Coordination with NPS Inventory and Monitoring Program,
3) Development of a web based project site,
4) Establishment or enhancement of bird conservation partnerships,
5) Identification and exploration of potential funding opportunities, and
6) Technical guidance and assistance as needed or requested.

This ACIP fulfills one aspect of the plan outlined above, and serves as a basis for future bird conservation actions in BICY and with adjacent partners or landowners.

Concurrently, the development of a Memorandum of Understanding (MOU) between the FWS and the NPS (Appendix A) to implement Presidential Executive Order (EO) 13186, Responsibilities of Federal Agencies to Protect Migratory Birds (US Government 2000), calls for integration of programs and recommendations of existing bird conservation efforts into preserve planning and operations. Complementing each other, the MOU and the Southeastern Bird Conservation Initiative will advance bird conservation in the Southeast Region of the NPS beyond current regional NPS efforts.

Role of NPS in Avian Conservation

The interagency agreement that facilitates this partnership supports both FWS and NPS management policies. Specifically for the NPS, the agreement supports and advances the Strategy for Collaboration, a visionary document developed and signed by the Southeast Natural Resource Leaders Advisory Group (SENRLAG 2000), a consortium of 13 land and resource management agencies in the Southeastern United States whose vision is to encourage and support cooperation in planning and managing the region's natural resources. Furthermore, the agreement is aligned with and implements a variety of NPS Management Polices (2001) including, but not limited to, External Threats and Opportunities, Environmental Leadership, Cooperative Planning, Land Protection, and especially Natural Resource Management that details policy and management guidelines which apply to bird conservation. Important policies in the

Natural Resource Management chapter include:

- Planning for Natural Resource Management
- Partnerships
- Restoration of Natural Systems
- Studies and Collection
- General Principles for Managing Biological Resources
- Plant and Animal Population Management Principles
- Management of Native Plants and Animals
- Management of Endangered Plants and Animals
- Management of Natural Landscapes
- Management of Exotic Species
- Pest Management
- Fire Management and
- Water Resource Management

The NPS is the fourth largest landowner in the United States, consisting of over 380 national park units covering 83 million acres of land and water with associated biotic resources (www.nps.gov). The 64 units in the Southeast Region of the NPS represent 16% of the total number of park units in the national park system and cover approximately 5% of the total land base in the entire system. Park units in the Southeast Region include national seashores (Canaveral National Seashore, Cape Hatteras National Seashore), national parks (Great Smoky Mountains National Park, Everglades National Park), national recreation areas (Big South Fork National Recreation Area), national preserves (Big Cypress National Preserve), national battlefields (Cowpens National Battlefield, Fort Donelson National Battlefield), national monuments (Ocmulgee National Monument), and others such as the Blue Ridge Parkway, Obed Wild and Scenic River, and Timicuan Ecological and Historic Preserve.

Southeast NPS units provide habitat for over 400 species of migrating, breeding, and wintering birds and include a wide range of Federal and State listed threatened and endangered species. Likewise, these units also provide nest, migration, and winter habitat for most of the eastern species identified in the national bird conservation plans in need of conservation attention.

Additionally, the NPS attracts over 280 million visitors to the parks each year, 120 million of these in the Southeast Region, affording excellent recreational bird watching and opportunities to strengthen bird conservation interpretation, outreach, and education programs. These opportunities, the NPS mission, policies, and organization all lead to the conclusion that the NPS is an extremely valuable partner and contributor to bird conservation in the region.

Nationally, the status of birds in national parks is largely unknown, although many parks have adequate knowledge regarding bird occurrence in the parks (http://www.npwrc.usgs.gov/resource/othrdata/chekbird/chekbird.htm). Parks often

play a role in ongoing regional bird conservation efforts. Indeed many of these parks are often important to regional, national, or international bird conservation, and many have been designated as Important Bird Areas (IBA's) by the National Audubon Society. To date, there are approximately 64 NPS units that are designated IBA's, 35 of which are considered of global importance (http://abcbirds.org/iba/aboutiba.htm). In the Southeast Region, the NPS has 13 IBA's.

The NPS Inventory and Monitoring (I&M) Program has been developed to provide management driven scientific information to national park managers so that resources can be adequately protected within national parks. One of the first phases of this program is to inventory vertebrates, including birds, within the 260 national park units in the program. Once completed, data from the inventories will provide an account of the occurrence and abundance of birds in all the national parks in the program. These records will be stored in the NPS I&M NPSpecies database http://www.nature.nps.gov/im/apps/npspp/). Coordination with I&M network staff is important to developing long-term bird monitoring programs that fulfill both park and NABCI objectives.

Park Flight is a NPS international partnership initiative that directs funding toward a variety of NPS programs that involve conservation of neotropical migratory birds whose life history range covers a US national park and a Latin American protected area. A relatively new program, Park Flight offers parks the opportunity to partner with a Latin American national park or protected area to cooperate on developing bird conservation and education projects (NPS 2002).

Recent increases in NPS base funded programs such as inventory and monitoring, exotic species management, habitat restoration, and fire management all indicate that national park managers recognize that park lands are increasingly subject to a variety of threats and conditions that must be improved to provide the quality of national park experience articulated in the NPS Organic Act (1916). Programmatic funding in these areas will increase the ability of national parks to provide quality habitat and conditions for increased wildlife conservation, including birds. Furthermore, private interests and non-profit conservation organizations have initiated programs, including grant programs, to provide much needed funding to national parks to meet backlogs of identified yet unfunded needs.

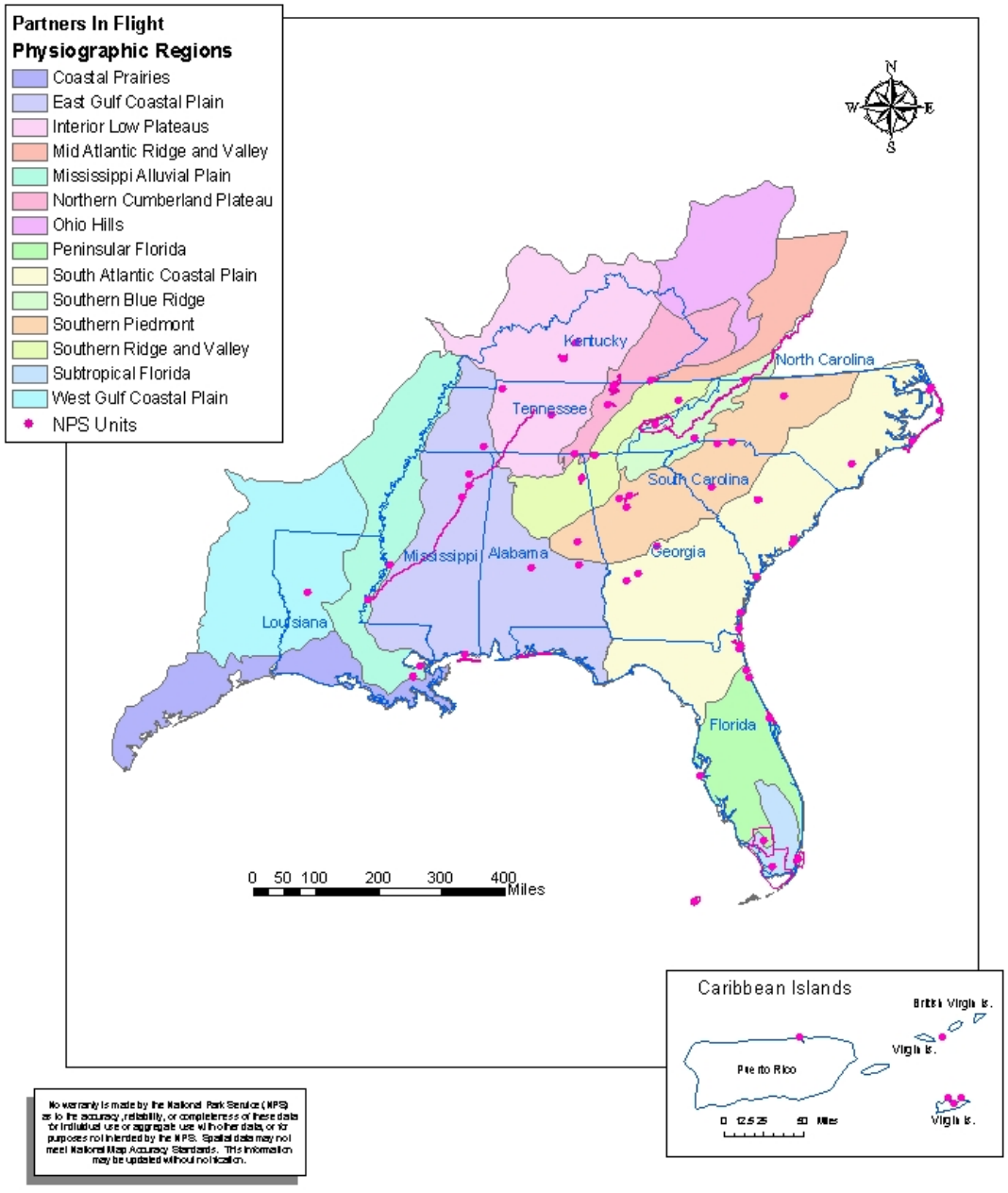
Preserve Description

Water is a principal natural resource of the entire south Florida region. Big Cypress National Preserve clearly illustrates this important resource with close to 90 percent of the preserve's area flooded seasonally. Because the 295,015 ha (729,000 acre) preserve is relatively undeveloped, it serves as a large natural reservoir and nutrient filter, permitting natural biological processes to nourish diverse ecological communities distinctive to south Florida (see PIF and NPS maps below). The preserve's ecology is finely tuned to seasonal water flow patterns, and any interference can alter this sensitive habitat. About 80 percent of the current Big Cypress land mass is wetland and

Partners in Flight (PIF) Regions

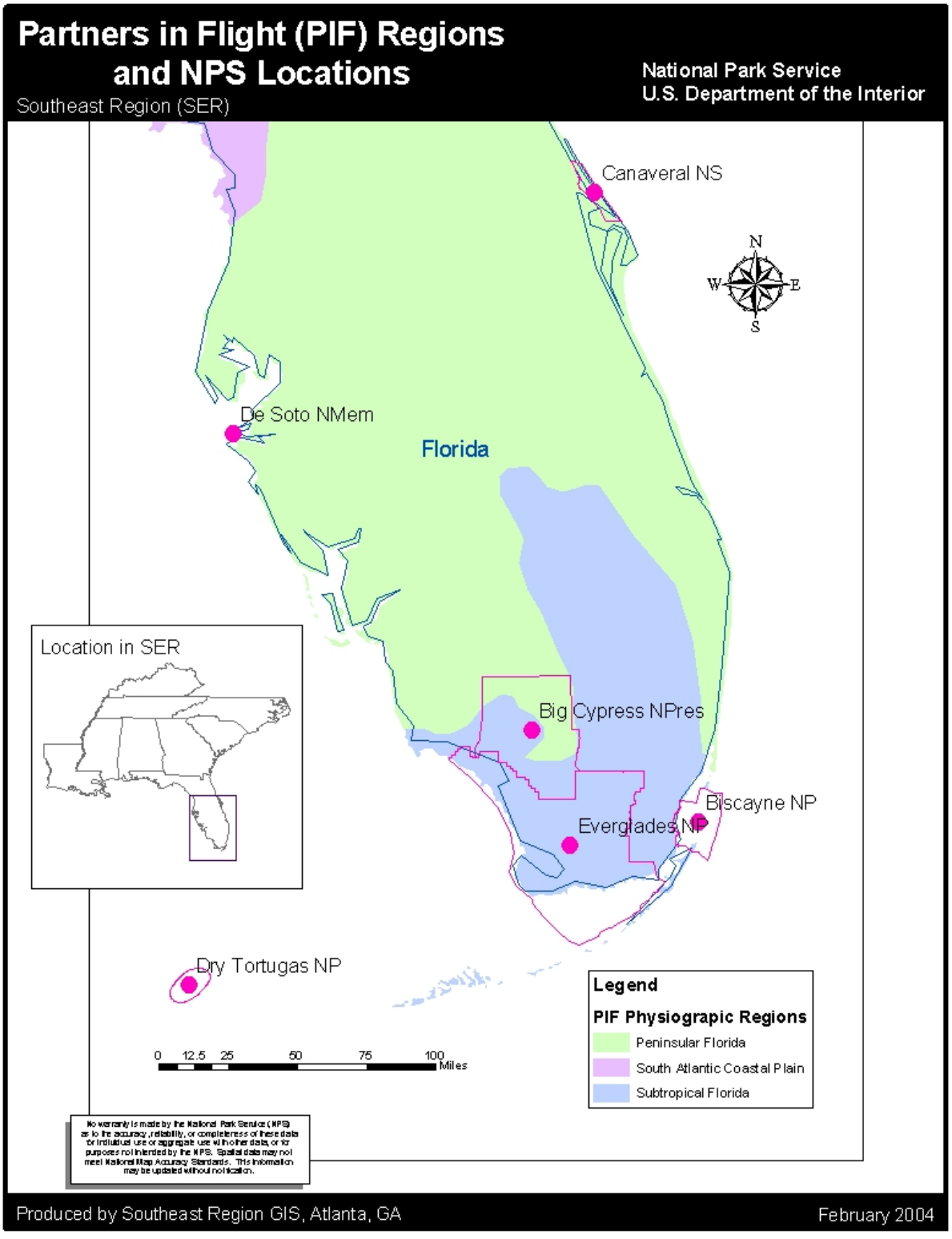
Southeast Region (SER)

National Park Service
U.S. Department of the Interior



Produced by Southeast Regional Office GIS, Atlanta, GA

March 2004


Partners in Flight (PIF) Regions
and NPS Locations
Southeast Region (SER)
National Park Service
U.S. Department of the Interior
Canaveral NS
N
W
E
S
De Soto NMem
Florida
Location in SER
Big Cypress NPres
Biscayne NP
Everglades NP
Dry Tortugas NP
Legend
PIF Physiograpic Regions
Peninsular Florida
South Atlantic Coastal Plain
Subtropical Florida
0 12.5 25 50 75 100
Miles
No warranty is made by the National Park Service (NPS) as to the accuracy, reliability, or completeness of these data for individual use or aggregate use with other data, or for purposes not intended by the NPS. Spatial data may not meet National Map Accuracy Standards. This information may be updated without notification.
Produced by Southeast Region GIS, Atlanta, GA
February 2004

is characterized by extensive prairies, freshwater marshes, forested swamps, and shallow sloughs. Most wildlife species native to south Florida occur within the Big Cypress watershed. Ten species are listed by the U.S. Fish and Wildlife Service as threatened or endangered, and 10 species are candidates for threatened or endangered status; an additional 14 species are listed by the state of Florida as threatened, endangered, or of special concern.

Avian Resources of Subtropical Florida

The physiographic area is entirely contained within Florida, and extends from the northern edge of Lake Okeechobee south through the Florida Keys. The region has very little topographic relief, but slight changes in elevation have important consequences for vegetation and the diversity of habitat types. The highest points of elevation are less than 2 meters and correspond with fairly recent shorelines (less than 5,000 years before present). Underlying sediments consist of freshwater marl, peat, freshwater lake and marine sediments, and to a lesser extent, sand deposited during the Pleistocene and Holocene. The subtropical Florida region can be divided into four smaller sub-regions: 1) the everglades, 2) Big Cypress, 3) Miami Ridge and Atlantic Coastal Strip, and 4) Southern Coasts and Islands. The Everglades is the most extensive of these areas, followed by the Big Cypress, Miami Ridge and Southern Coasts. Across all subregions, much of the physical and ecological characteristics of the region resemble tropical ecosystems where seasonal changes are reflected by changing rainfall patterns rather than by dramatic temperature changes. Distinctive dry (winter/spring) and wet (summer) seasons occur annually, and the nesting cycles of many birds are tied to these changes. At least two major forms of disturbance play key roles in the ecology of the region. Fire is an important feature in many pine dominated communities and many marsh and prairie communities. Frequent fires are essential in pine-dominated stands and prairies if understory conditions suitable to many nesting birds are to be maintained. However, the ideal fire frequency in some pine communities is not known. Hurricanes are a second form of disturbance that less frequently but predictably provide early successional habitats or open forest cover (Brawn et al. 2001).

Bird conservation priorities for Subtropical Florida have been stratified by habitat type. Recognized habitat types where high priority conservation actions are needed for both birds and habitats are pine forests (including pine rocklands, pine Flatwoods, sand pine scrub), grassland/grassland-scrub (including dry prairie and coastal strands), subtropical deciduous forest, everglades, brackish saltwater and freshwater marsh, and mangrove swamps. Species associated with each of these habitats and identified as high priority for conservation needs are given below.

Florida Scrub Jay, Red-cockaded Woodpecker, Southeastern American Kestrel, Brown-headed Nuthatch, Bachman's Sparrow, Palm Warbler and Sedge Wren are associated with the pine forests. Both Florida Scrub Jay and Southeastern American Kestrel have been extirpated in Subtropical Florida and the Brown-headed Nuthatch and Bachman's

Sparrow are nearly extirpated here. Both Palm Warbler and Sedge Wren are present only in the non-breeding seasons.

Grasshopper Sparrow, Crested Caracara, Burrowing Owl, Sandhill Crane and Mottled Duck are all species associated with grassland to grassland scrub habitats. Grasshopper Sparrow has been extirpated in South Florida.

In the subtropical deciduous forest, Short-tailed Hawk, Swallow-tailed Kite, White-crowned Pigeon and Gray Kingbird are high priorities for conservation.

In the Everglades, brackish saltwater and freshwater marshes, Snail Kite, Cape Sable Seaside Sparrow, Wood Stork, Black Rail, Reddish Egret, Yellow Rail, White Ibis, and Clapper Rail are species in need of conservation attention.

Prairie Warbler, Yellow Warbler, Black-whiskered Vireo, and Mangrove Cuckoo, species associated with Mangrove swamps and forests, and are of high priority conservation concern.

Human population growth has been phenomenal in subtropical Florida for the last 40 years. The impacts of such tremendous growth include increased infrastructure that directly reduces habitat availability, but also secondary impacts to bird habitats, such as pollution. Other land uses include production of sugarcane, winter vegetables, and citrus. Drastic changes in hydroperiod and natural water cycles are secondary impacts of increasingly intensive agriculture. However, among the best opportunities in the Southeast to work with existing public lands occur in Subtropical Florida, where over 54% of the area is publicly owned. Therefore, primary conservation programs include efforts to reduce impacts from adjacent or nearby lands on management of existing public lands. Many programs have been developed and are in various phases of implementation. These include the Save our Everglades program, the Surface Water Improvement and Management Act, Florida's Everglades Forever Act and the development of the South Florida Ecosystem Restoration Task Force as well as aggressive acquisition programs. These and other programs serve the basis for bird conservation efforts in the region (PIF 2000).

Avian Conservation in BICY

Avian Biodiversity: BICY has a complete avian inventory and a checklist of birds that is available for the public. Preserve staff are in the process of updating the checklist. Over 175 birds have been observed in BICY.

Verified records of birds in BICY have been entered into the NPS I&M program's database, NPSpecies, and may be viewed via the internet at http://www.nature.nps.gov/im/app/npspp with a user identification and password combination authorized by the NPS for NPS personnel and NPS cooperators. Many other avian observational data need to be verified and entered into the database.

Preserve Priorities: Preserve staff and consultants have not identified any particular species that is a preserve management concern or high priority for conservation. However, the presence of 5 Federally listed bird species requires compliance with the Endangered Species Act and a large amount of staff time is given to managing these species. Additionally, preserve staff are concerned about conserving all birds and their habitats in BICY. However, several species that occur in BICY are high priority in Subtropical Florida and conservation efforts in the preserve could focus on these species or groups of species.

Inventory: A complete inventory has been recognized as important information for park managers and the BICY inventory is considered complete. However, BICY has identified additional funding needs to document distribution and abundance of the preserve's avifauna.

Threatened and Endangered Species: Five Federally listed threatened or endangered species nest in BICY. These are Red-cockaded Woodpecker, Wood Stork, Bald Eagle, Snail Kite, and Cape Sable Seaside Sparrow. The recently delisted American Peregrine Falcon is a rare but regular fall transient and winter visitor.

Several Florida listed species occur in BICY as well. Prominent among these are: Florida Grasshopper Sparrow, White-crowned Pigeon, Arctic Peregrine Falcon, Florida Sandhill Crane, and Least Tern.

Partners In Flight (PIF) has also listed Brown-headed Nuthatch, Bachman's Sparrow, Grasshopper Sparrow, Sandhill Crane, Mottled Duck, Short-tailed Hawk, Swallow-tailed Kite, White-crowned Pigeon, Black Rail, Reddish Egret, White Ibis, Florida Prairie Warbler, Yellow Warbler, Mangrove Cuckoo, Black-whiskered Vireo and non-breeding populations of Palm Warbler and Sedge Wren as species of high conservation concern in Subtropical Florida (PIF 2000).

Monitoring: Currently, several avian monitoring projects are being conducted at BICY. These are:

- Cape Sable Seaside Sparrow population monitoring (Population A) conducted by Everglades National Park personnel
- Red-cockaded Woodpecker nest monitoring on 45 clusters of woodpeckers
- Red-cockaded Woodpecker nestling banding
- Wood Stork colony monitoring by helicopter
- Snail Kite Monitoring
- Bald Eagle nest surveys conducted by State of Florida
- Waterbird colony monitoring conducted by Everglades National Park and State of Florida
- Osprey nest monitoring conducted by State of Florida
- Brown-headed Nuthatch and Eastern Bluebird monitoring following translocations
- Three mini-Breeding Bird Survey routes conducted during May

- Regular Breeding Bird Survey route conducted by US Fish and Wildlife Service
- Randomized recreational birding

Research: Scientific research is permitted within the preserve, and several recent projects have been concluded, focusing on several of the listed species that occur in the preserve. The only active current active avian research involves work on the endangered Snail Kite.

Outreach: No specific educational and outreach programs related to birds are undertaken in the preserve, but birds are included in the more generic wildlife programs.

Preserve Identified Needs for Avian Conservation

BICY has identified on high priority projects that would increase the avian knowledge of the preserve and would assist preserve managers in better decision making.

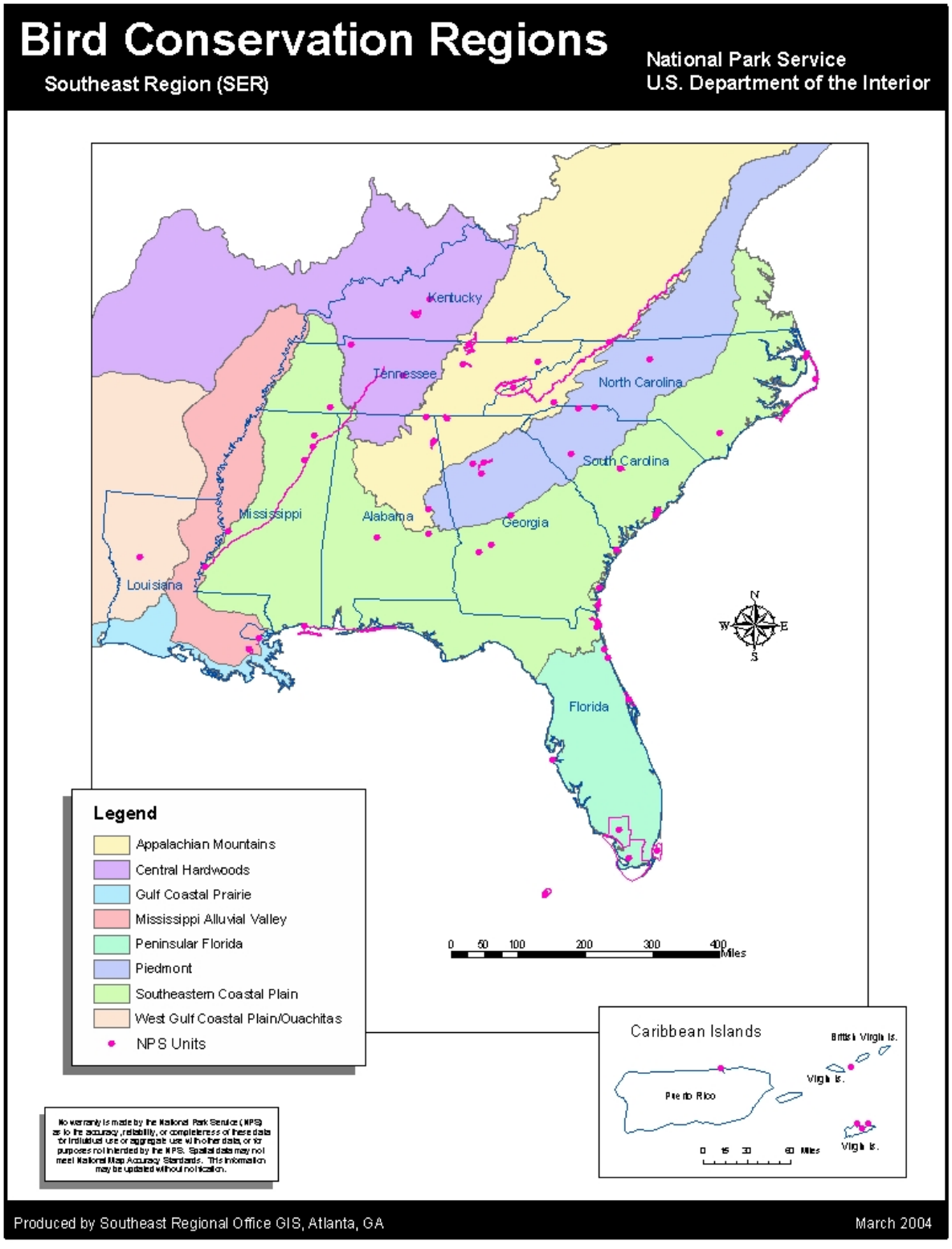
Research*:* The preserve would like to assess the impacts that Off Road Vehicles (ORV's) have on the bird populations, especially birds that nest on the ground or in the herb/shrub layer of the forests.

Coordination with Regional Conservation Initiatives

North American Bird Conservation Initiative: NABCI bird conservation planning units, referred to as Bird Conservation Regions (BCR), are often larger than other planning units associated with other plans, such as Partners In Flight. For example, BICY is within the NABCI Peninsular Florida BCR located entirely within Florida (see BCR map) and encompasses two PIF physiographic areas (the planning unit for PIF)(compare to NPS and PIF maps).

Several NABCI BCR's have coordinators whose primary responsibility is to coordinate all bird conservation planning in the BCR, across all agencies and organizations. Currently, Peninsular Florida does not have a designated coordinator; however, a large portion of the BCR lies within the Atlantic Coast Joint Venture area (Maine to Florida and includes Puerto Rico) and the ACJV has several professional bird conservationists base throughout the region to assist partners in bird conservation efforts (see contacts below). This staff can provide valuable assistance to BICY with implementation of aspects of this ACIP.

North American Waterfowl Management Plan (NAWMP): The NAWMP (http://northamerican.fws.gov/NAWMP/nawmphp.htm) is completed and has been revised several times, incorporating updated goals and strategies based on new information. This plan is one of the most successful bird conservation delivery


Bird Conservation Regions
Southeast Region (SER)
National Park Service
U.S. Department of the Interior
Kentucky
Tennessee
North Carolina
South Carolina
Mississippi
Alabama
Georgia
Louisiana
Florida
N
W
E
S
0 50 100 200 300 400 Miles
Legend
Appalachian Mountains
Central Hardwoods
Gulf Coastal Prairie
Mississippi Alluvial Valley
Peninsular Florida
Piedmont
Southeastern Coastal Plain
West Gulf Coastal Plain/Ouachitas
NPS Units
No warranty is made by the National Park Service (NPS) as to the accuracy, reliability, or completeness of these data for individual use or aggregate use with other data, or for purposes not intended by the NPS. Spatial data may not meet National Map Accuracy Standards. This information may be updated without notification.
Caribbean Islands
British Virgin Is.
Virgin Is.
Puerto Rico
Virgin Is.
0 15 30 60 Miles
Produced by Southeast Regional Office GIS, Atlanta, GA
March 2004

programs in the United States, being monetarily supported by the North American Wetlands Conservation Act (NAWCA).

Partners In Flight: Goals and strategies for Subtropical Florida have yet to be fully identified and organized into a bird conservation plan. Personnel from the Florida Fish and Wildlife Conservation Commission are currently working on completing the Partners in Flight bird conservation plan for South Florida. In the meantime, Florida's avian priorities and conservation needs are identified in Millsap et al. (1990).

Similar to NABCI BCR's, PIF physiographic areas often do not have designated coordinators. However, state level non-game agencies with investment in PIF will establish key personnel to develop partnerships among cooperators in the physiographic area. The State of Florida has a non-game bird conservation coordinator and can be instrumental in assisting BICY to implement recommendations identified in this ACIP and projects important to bird conservation relative to Florida's role in implementation of the bird conservation goals in Subtropical Florida.

United States Shorebird Conservation Plan (USSCP): The USSCP has been completed and is available on the World Wide Web (http://shorebirdplan.fws.gov/). A regional step down plan is in preparation by FWS personnel and should be available in 2004.

Waterbird Conservation for the Americas (WCA): The WCA plan has been completed and is available on the World Wide Web or can be ordered from the US Fish and Wildlife Service National Conservation Training Center (http://www.waterbirdconservation.org/). BICY will utilize this regional plan when completed.

Integration of NABCI Goals and Objectives into Preserve Planning and Operations: NABCI Implementation Recommendations

To successfully achieve preserve-established goals and actively participate in NABCI, the preserve could implement a variety of projects in different NPS programs. Most of these projects would require some level of participation by many existing preserve programs and could either be achieved through NPS funding, or more likely, through establishing or improving partnerships with agencies and organizations that already have the necessary expertise to provide guidance, funding, and execution of these programs. Programmatic areas where bird conservation actions are likely to be focused are:

- Inventory
- Monitoring
- Habitat Restoration
- Threat Management (includes exotic species, air quality, water quality, etc.)
- Research

- Compliance
- Outreach
- Partnerships

To the extent appropriate, each of these program areas will be discussed separately and within each, specific opportunities identified that, when implemented, will enable the preserve to meet its mandates (current and expected) as well as integrate NABCI into its planning and operations. With emphasis added, the preserve is not expected to implement any of these recommendations or be obligated to pursue any opportunity other than those the preserve is required to do by law or NPS program or policy. In other words, participation in this effort is currently voluntary. However, participation in these efforts at some level could become mandatory with the completion of an MOU with the FWS regarding EO 13186 (US Government 2000). The MOU will establish a formal agreement between the FWS and the NPS to promote bird conservation within the agency by incorporating goals and strategies of existing bird conservation initiatives, plans, and goals into park planning and operations.

Should the preserve decide to implement any of these projects, further consultation with bird conservation contacts is encouraged to obtain updated information on the relevance of these opportunities in regional bird conservation.

High priority projects are identified in **bold** print. Priorities that the preserve is encouraged to seek NPS funding for are marked with and asterisk (*****). These projects are those that are critical to the stabilization or improvement of a bird population in the planning region.

Inventory: The preserve has inventoried its bird fauna exceptionally well. Although the avifauna of BICY is well documented, distribution and abundance data are desired to fully understand the status of birds in the preserve so that conservation actions for birds can be implemented. Status of high priority species is needed to effectively structure preserve management for the continued preservation and enhancement of the preserve's avifauna.

Additional abundance and distribution data is needed for

- **Marshbirds**
- **Wet and Dry Prairie birds**
- **Mangrove birds**
- **Pine Hammock birds**
- **Cypress Strands and Domes**

Additionally, BICY is encouraged to

- **partner with Everglades National Park (EVER), Ten Thousand Island National Wildlife Refuge (TTINWR), Florida Panther National Wildlife Refuge**

(FPNWR), Fakahatchee , Big Cypress Seminole Indians, Miccosukee Indians, and South Florida Water Management District (SFWMD) to coordinate area inventory efforts

- **verify other avian observational data collected in the preserve and enter into the appropriate database (NPSpecies, eBird, etc.)**

- **standardize inventory and monitoring methodology to conform to NPS and/or FWS recommended standards (Fancy and Sauer 2000, Hunter 2000).**

Monitoring: The preserve has an active bird monitoring program resulting in documentation of many high priority species identified for conservation effort occur in the Subtropical Florida and the preserve. Efforts should be made to continue existing monitoring programs, striving to conform to established NPS or FWS surveys protocols. Close coordination with State of Florida biologists, researchers, and local federal land managers is needed to identify and implement high priority projects on preserve lands and to ensure that preserve efforts contribute to preserve or regional bird conservation rather than undertake an action or actions that are not needed or are better conducted in other areas. Specific recommendations are to:

- **continue to conduct existing monitoring programs and enter data into the appropriate database (NPSpecies, eBird, etc.) and provide data to cooperators**

- **conduct follow up monitoring on translocations of Brown-headed Nuthatch and Eastern Bluebird to Everglades National Park***

- **conduct follow up monitoring to determine success of translocation of Red-cockaded Woodpeckers to Dupuis Wildlife and Environmental Area (DWEA)***

- **establish an avian monitoring program based on distribution and abundance surveys that focus on regionally identified high priority species***

- **establish a pre and post fire inventory program to document response of birds to prescribed fire**

- **standardize inventory and monitoring methodology to conform to NPS and/or FWS recommended standards (Fancy and Sauer 2000, Hunter 2000).**

- **partner with Everglades National Park (EVER), Ten Thousand Island National Wildlife Refuge (TTINWR), Big Cypress Seminole Indians,**

- **Miccosukee Indians, and South Florida Water Management District (SFWMD) to coordinate area monitoring efforts**

Habitat Restoration: Historical landscape conditions in the Southeastern US have changed dramatically since early European explorers began documenting the area, its habitats, and its inhabitants. Historic landscape alternation by Native Americans for a variety of uses (Williams 2002), wildfire, Bison (*Bison bison*), beaver (*Castor Canadensis*) and elk (*Cervus elaphus*) effects, weather, and beaver, etc. (Hunter et al. 2001) resulted in a landscape mosaic that supported a rich and diverse bird fauna in the Southeast (Barden 1997, Brawn et al. 2001). The arrival of Europeans and the subsequent change in landscape has dramatically effected bird habitat and bird populations. Bird conservationists have recognized for a long time that habitat restoration is critical to restoration of bird populations, stabilizing or reversing bird declines, and removing birds from both State and Federal Threatened and Endangered Species lists. Recently, habitat restoration efforts have increased nationwide, and on NPS lands; NPS receiving restoration emphasis and guidance in the 2001 Management Policies (NPS 2001). Habitat restoration efforts that parks may undertake are wetland restoration, grassland restoration, woodland restoration, etc. utilizing a wide range of tools to accomplish the restoration. Some of these tools may be but not limited to forest management practices, exotic species management, public use and recreation management, infrastructure development management, and prescribed fire.

Due to the protected nature of BICY lands, and generally those in the national park system, the condition of habitats for bird use may be of higher quality than other natural, developed, agricultural, or forest lands under other management regimes. However, national park lands can be greatly improved for wildlife, and particularly bird use, by restoring processes important for habitat formation, succession, and structural development. Largely, these processes have not been managed historically in the national park system but current policy allows for active management of species, populations, and lands to provide for long-term conservation of park resources. Protection, restoration, and enhancement of habitats in BICY can greatly contribute to established habitat goals identified in the Subtropical Florida bird conservation plan.

BICY is primarily a large wetland that cover a variety of habitats, including freshwater marsh, wet and dry prairies, forested wetlands, mangrove forest, and shallow sloughs. Preservation of these habitats and many species have evolved through a dependence on wildfire. Indeed, BICY is one of the most fire dependant landscapes in Florida and currently conducts the largest prescribed fire program in the NPS. Specific habitat recommendations are to:

- **increase the amount of prescribed fire from current average to approximately 40,000 ha (100,000 acres) to improve habitat conditions in pinelands and prairies for high priority birds**

- **restore previously disturbed lands due to agriculture, ORV's, and developments to natural vegetation**

- **protect existing snag trees, where not identified as a safety hazard, as important to cavity nesting birds**

- **enhance or maintain water quality to support aquatic biota necessary to support existing waterbirds, marshbirds, and other birds that use water for nesting and foraging**

- assess historic landscape cover and determine feasibility of restoring landscape within the context of the preserve's enabling legislation.

Threat Management: Potentially the greatest impact to birds at BICY is the use of ORV's. The preserve has completed and ORV Management Plan. Implementation of the ORV Management Plan should allow the preserve to demonstrate that the preserve's bird populations will improve. However, because ORV's will still impact preserve habitats and vegetation, the preserve is encouraged to:

- **fund and conduct the Project Management Information System (PMIS) project to assess the impacts of ORV's to the preserve's bird populations and at the conclusion of the research implement needed changes in the plan to further protect the preserve's avifauna***

Impact of exotic species on birds at BICY is largely unquantified but feral hogs do occur in the preserve. However, feral hogs are a prey item of the Florida Panther and are not considered a resources threat, but a regulated resource.

Significant exotic plants species are negatively impacting habitat at BICY, particularly Melaleuca. Brazilian Pepper, Australian Pine, and Old World Climbing Fern are present and potentially a threat to habitat at BICY. It is important to establish and continue inventory and monitoring for exotic plant species and implement aggressive removal/reduction projects for these species. The South Florida Exotic Plant Management Team can assist in coordination and implementation of exotic plant management. BICY is encouraged to:

- **implement an aggressive exotic plant reduction program to restore and improve habitat quality**

Research: Several research projects have been identified that would provide additional information to BICY managers for bird conservation purposes.

- **assess ORV impacts on the bird populations throughout the preserve***

- **determine the response of Cape Sable Seaside Sparrow to airboat use***

- **determine the effects of wildfire and fuel treatments on the avifauna of the pine rockland ecosystem in southern Florida***

- determine demographics of Limpkin

- determine winter and Neotropical and temperate migrants use of preserve

- assess the effects of prescribed burning on wintering and breeding birds of wet prairie habitats

Additionally, the preserve is encouraged to:

- **list preserve needs and projects on Research Permit and Reporting System web site (RPRS)**

- develop contact with South Florida/Caribbean Cooperative Ecosystem Studies Unit at the University of Miami, Miami, Fl

Compliance: Preserve compliance with the Migratory Bird Treaty Act EO 13186 (US Government 2000) is necessary to assure that preserve activities incorporate bird conservation into preserve planning and operations. Further, to ensure that migratory birds are considered in all phases of preserve planning processes, especially during the National Environmental Policy Act (NEPA) and the Director's Order #12 Compliance processes, the preserve should consider adding specific language in project evaluations that requires consideration and implications of preserve projects on migratory birds. The MOU being developed between the NPS and the FWS will likely contain specific language requiring a preserve to consider implications of preserve projects on migratory birds, particularly those species identified in the USFWS Species of Conservation Concern 2002 (Appendix C). Additional considerations are to encourage:

- **preserve staff to begin specific consideration of migratory birds during preserve planning processes**

- preserve staff to attend USFWS training on implementation of EO 13186 (US Government 2000) at the National Conservation Training Center (NCTC) (when available) or other training on migratory bird conservation in North America. NCTC has several courses and training related to conservation of migratory birds (http://training.fws.gov/courses.html).

The USFWS NCTC offers and reserves two tuition free slots for National Park Service employees wishing to attend NCTC courses on a first come, first served basis. Additionally, discount lodging is also available while attending a NCTC course.

Outreach:

- **update the bird checklist for public availability**

- **participate in International Migratory Bird Day (IMBD) events with a local partner (http://birds.fws.gov/imbd.html), such as TTINWR or Collier-Seminole State Park**

- **continue to develop and foster relationship with local area bird clubs, such as Naples Bird Club and Collier County Audubon**

- **encourage development of outreach and educational programs to enhance visibility of bird conservation issues, which may include organized bird walks, owl prowls, and raptor surveys with the public**

- **encourage accurate documentation and reporting from these and random outings by visitors (see Cornell University's eBird monitoring program (Cornell Lab. Ornith. 2002 (http://www.ebird.org/about/index.jsp)**

- **develop relationship with Big Cypress Seminole Indian Reservation and Miccosukee Indian Reservation personnel to cooperate on a joint bird conservation project**

- preserve interpretation/education staff are encouraged to attend USFWS training on Migratory Bird Education at NCTC

- consider adding links to bird conservation information, data, etc. to the preserve's web site home page

- support bird conservation by serving shade-grown coffees at meetings, events, and the office buildings in the preserve (http://www.americanbirding.org/programs/conssbcof3.htm)

- subscribe to Florida Birds, an electronic forum for listing bird sightings and publications in Florida

- explore cultural affiliation of landscape to inhabitants, both historical and contemporary. Cultures are strongly tied to the landscape they inhabit and birds often play a role in a cultural tie to the landscape. When these connections are discovered and preserved, a greater appreciation for the landscape and it's value to the culture can be achieved.

Partners and Partnerships: Partnerships for land conservation and protection will perhaps have the greatest positive influence on bird conservation above all other landscape scale planning. Specific recommendations are to:

- **keep abreast of Collier, Broward, and Hendry Counties initiatives or programs that could impact preserve resources***

- **develop relationship with Big Cypress Seminole Indian Reservation and Miccosukee Indian Reservation personnel***

- **contact US Fish and Wildlife Service private lands biologists to discuss private landowner initiatives applicable to the area***

Several private landowner programs could be implemented that would serve to protect areas adjacent to BICY and potentially improve water and habitat quality in the vicinity

- **develop partnership with Florida Wildlife and Conservation Commission, SFWMD, TTINWR, Collier-Seminole State Park and EVER to coordinate and implement various aspects of this ACIP***

- **contact the nearest Joint Venture office (see Funding section for explanation of Joint Ventures) or BCR coordinator to develop partnerships and funding proposals tiered to priorities established by the preserve, this ACIP, and the Subtropical Florida bird conservation plan***

- partner with and engage the local bird clubs, including Naples Bird Club, and Collier County Audubon as active partners in BICY's bird conservation program

- develop land use agreements with local landowners through state, FWS programs to protect important habitats and landscapes adjacent to BICY

Funding Opportunities: Internal NPS funding is often an effective source to obtain funding; however, the project will have to be a fairly high priority among the preserve's natural resource program to successfully compete for the limited funding available in the NPS. Therefore, partnerships and outside funding programs are often more productive for securing bird conservation funding. BICY is encouraged to enter all high priority projects into the NPS Performance Management Information System (PMIS) database. Funding for conservation projects for neotropical migrants is also available through the Park Flight program.

With the exception of the North American Waterfowl Management Plan (NAWMP and its associated funding legislation, the North American Wetland Conservation Act), funding opportunities for bird conservation programs, plans, and initiatives have been lacking. Only within the last decade have other appropriate and specific sources for bird conservation funding been created and used. The NAWMP has been supported for approximately 14 years by the North American Wetlands Conservation Act (NAWCA 1989). This program has provided $487 million in appropriated funds matched with $1.7 billion for wetland and bird conservation projects since its inception. In 2002 alone,

over $70 million US dollars were awarded to US and Canadian agencies and organizations to enhance waterfowl populations by improving, restoring, or protecting wetland habitats. To adequately evaluate projects and distribute these funds, partnerships called Joint Ventures were established. Nationally, 14 (11 US, 3 Canada) Joint Ventures have been established, several which are funded and staffed. Internet links to Joint Ventures are: (http://southwest.fws.gov/gulfcoastjv/ojvcontact.html) and (http://northamerican.fws.gov/NAWMP/jv.htm).

Funding through NAWCA is highly underutilized by the NPS and any park unit that has wetland, water, or bird conservation needs associated with wetland are encouraged to investigate using this funding source. Naturally, there are certain requirements to be eligible for all grants and preserve managers are encouraged to consult with the nearest Joint Venture, BCR, PIF Coordinator, to learn how this program might be applicable to implementation of this plan, and other preserve wetland issues. BICY is not within a region which has an operational Joint Venture, but contact with the Atlantic Coast Joint Venture, Central Hardwoods BCR, and Tennessee PIF coordinators will provide opportunity to investigate use of this funding source and developing proposals. Internal FWS funding programs may be used to support projects, but no effective method of project proposal delivery to these sources is currently in place for the NPS. Current funding in these programs may result from FWS familiarity with NPS needs, or NPS participation in one of the area FWS Ecosystem Teams, where a project has been identified and proposed to be funded through the Ecosystem Team.

One unexplored yet potentially fruitful funding source for national parks is the myriad of grants through the FWS State Programs, where grants are awarded to private individuals engaged in habitat conservation projects. No funding is directly available to national parks, but identified projects with important or critical adjacent landowners can sometimes be funded through these sources. Similar programs are available if the adjacent landowner is a federally recognized American Indian tribe.

Specific congressional appropriations to protect migratory birds has recently been authorized under the Neotropical Migratory Bird Conservation Act (2000) (http://www.nfwf.org/programs/nmbcapp.htm). Appropriations through this Act are authorized up to $5 million per year. However, in 2000, appropriation was approximately $3.75 million and a majority of this funding was directed toward projects in Central and South America.

Many of the identified projects are eligible for funding under various grant programs of the National Fish and Wildlife Foundation http://www.nfwf.org/programs/programs.htm).

Other prominent funding sources available to NPS managers for bird conservation are listed on this projects web site at: http://southeast.fws.gov/birds/NPSHighlits.htm.

Funding opportunities for migratory bird conservation are available yet most natural resource agencies are not fully aware of and/or understanding of how to use these sources. Perhaps a consolidated migratory bird funding source catalog will become

available to managers in the future; this is needed.

Contacts: Primary contacts within the region can be obtained by viewing the web site for the Southeastern Bird Conservation Initiative, National Park Service at http://southeast.fws.gov/birds/npsbirds.htm. This web site will provide contact information of the appropriate bird conservation coordinator in the region for preserve personnel. Preserve staff are encouraged to view the web site and obtain contact information. Primary contacts for BICY are:

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APPENDIX A

HIGH PRIORITY SPECIES IN PENINSULAR FLORIDA BIRD CONSERVATION REGION (from Table 1, Peninsular Florida Priority Bird Species)

Table 1. Priority bird species for Peninsular Florida: Entry criteria and selection rationale

Priority Entry Criteria[1]	Species	Total PIF Priority Species Score	Conservation Score		Percent of BBS Population	Migratory Status[2]	Local Geographical or Historical Notes
			Area Importance	Population Trend			
Ia.	Florida Scrub-Jay[5]	35	5[4]	5[4]	100	R	
	Grasshopper Sparrow[5] (Florida)	35	5[4]	5[4]	100	R	
	Snail Kite[5] (Everglade)	34	5	4[4]	100?	D	
	Crested Caracara[5] (Florida pop.)	34	5[4]	4[4]		D	
	Snowy Plover (SE US)	34	5	5		D	Gulf side only
	Red Knot (SE US)	32	5	5		C	
	Piping Plover[5]	31	4	5		C	
	Prairie Warbler (Florida)	31	5[4]	5[4]		D	
	Wood Stork[5] (SE US pop.)	30	5	4		D	
	Short-tailed Hawk (Florida pop.)	30	5[4]	3		D	
	Swallow-tailed Kite (SE US)	29	5	3	61.7	B	
	Red-cockaded Woodpecker[5]	29	3[4]	3		R	

Table 1 (cont.).

Priority Entry Criteria[1]	Species	Total PIF Priority Species Score	Conservation Score: Area Importance	Conservation Score: Population Trend	Percent of BBS Population	Migratory Status[2]	Local Geographical or Historical Notes
	Mottled Duck	29	5	4[4]	11.3?	D	
	American Kestrel (SE US)	28	5[4]	4[4]		R	
	Burrowing Owl (Florida)	28	5[4]	3		D	
	Bachman's Sparrow	28	5	3	18.9	D	
	Saltmarsh Sharp-tailed Sparrow	28	3	3		C	
	Painted Bunting (Eastern)		28	3[4]	3		D
	American Oystercatcher (Eastern NA pops.)	28	5	3		D	
Ib.	Wilson's Plover	27	4	3		D	
	Nelson's Sharp-tailed Sparrow	27	3	3		C	
	Henslow's Sparrow	27	3	4		C	
	Black Rail	27	4	3		D	
	Sandhill Crane (Florida)	26	5[4]	1		R	
	Audubon's Shearwater (Caribbean)	26	5	3		P	
	Reddish Egret	26	4	3		D	
	Least Tern	26	5	4[4]	4.6?	B	
	Black Skimmer	26	5	5		D	
	Bicknell's Thrush	26	5	3		A	

Table 1 (cont.).

Priority Entry Criteria[1]	Species	Total PIF Priority Species Score	Conservation Score: Area Importance	Conservation Score: Population Trend	Percent of BBS Population	Migratory Status[2]	Local Geographical or Historical Notes
	Yellow Rail	26	4	3		C	
	Buff-breasted Sandpiper	25	3	4		A	Most southbound migration
	Black-throated Blue Warbler	25	5	3		A	
	Seaside Sparrow	25	4[4]	3		D	Gulf populations
	Brown Pelican (SE US)	24	5	1[4]		D	
	Marbled Godwit	24	3	4		C	
	Bobolink	24	5	5		A	
	Tricolored Heron	23	4	3	17.3?	D	
	White Ibis	23	4	4		D	
	King Rail	23	4	3		D	
	Sandhill Crane (Greater)	23	5	3		C	
	Solitary Sandpiper	23	5	3		A	
	Whimbrel	23	3	5		A	
	Stilt Sandpiper	23	4	3		A	
	Brown-headed Nuthatch	23	3	3		R	
	Cape May Warbler	23	5	3		A	
	Connecticut Warbler	23	5	3		A	
	Cory=s Shearwater	22	5	3		P	
	Clapper Rail	22	3	3		R	
	Limpkin	22	3[4]	4[4]	33.2?	R	
	Semipalmated Sandpiper	22	5	5		A	
	Short-billed Dowitcher	22	5	5		C	
	Gull-billed Tern	22	3	4		D	
	Royal Tern	22	4	3		D	
	Sandwich Tern	22	5	3		D	
	Black Tern	22	5	5		A	
	Mangrove Cuckoo	22	3[4]	3		E	

Table 1 (cont.).

Priority Entry Criteria[1]	Species	Total PIF Priority Species Score	Conservation Score		Percent of BBS Population	Migratory Status[2]	Local Geographical or Historical Notes
			Area Importance	Population Trend			
	Gray Kingbird	22	3[4]	3	4.5?	B	
	Black-whiskered Vireo	22	3[4]	3		B	
	Loggerhead Shrike	22	5	5	4.1	D	
	Sedge Wren	22	4	2		C	
	Palm Warbler	22	5	5		C	
II a.	Anhinga	21	5	3		D	
	American Bittern	21	4	5		C	
	Northern Bobwhite	21	4	5		R	
	Black-bellied Plover	21	4	5		D	
	Willet	21	5	3		D	
	Western Sandpiper	21	5	3		C	
	Common Ground-Dove	21	5	5	23.8?	R	
	Red-headed Woodpecker	21	3	5	1.0	D	
	Veery	21	4	5		A	
	Pine Warbler	21	4	5		D	
	Grasshopper Sparrow (Eastern)	21	5	5		C	
	Green Heron	20	5	3		D	
	Northern Harrier20	4	4		C		
	Ruddy Turnstone	20	3	4		D	
	Least Sandpiper	20	5	5		C	
	Dunlin	20	4	5		C	
	Yellow-billed Cuckoo	20	3	5		B	
	Gray Catbird	20	5	5		C	
	Eastern Towhee	20	5	5	7.9	D	
	American Avocet	19	3	3		C	

Table 1 (cont.).

Priority Entry Criteria[1]	Species	Total PIF Priority Species Score	Conservation Score		Percent of BBS Population	Migratory Status[2]	Local Geographical or Historical Notes
			Area Importance	Population Trend			
	Greater Yellowlegs	19	5	3		C	
	Sanderling	19	3	5		C	
	Pectoral Sandpiper	19	5	3		A	
	Common Nighthawk	19	5	5	3.6	B	
II b.	Chuck-will=s-widow	21	5	3	7.0	B	
	White-eyed Vireo	20	5	2	5.4	D	
II c.	Snowy Egret	19	4	3		D	
	Little Blue Heron	20	3	4	5.1	D	
Local or Regional Interest	Prothonotary Warbler	21	2	3		B	(AA@ Merritt Island)
	American White Pelican	20	4	1		C	
	Redhead	20	2	4		C	
	American Woodcock	20	2	4		D	
	Acadian Flycatcher	20	2	3		B	(AA@ Merritt Island)
	Yellow-throated Vireo	20	3	3		B	(AA@ Merritt Island)
	Yellow-throated Warbler	20	3	3		C	
	Hooded Warbler	20	2	3		B	(AA@ Merritt Island)
	Peregrine Falcon	19	5	1		A	Winters in small numbers
	Northern Parula	19	5	2		C	
	Common Loon	18	4	3		C	
	Least Bittern	18	2	3	7.0?	D	
	Wood Duck	18	4	2		D	
	Ring-necked Duck	18	3	2		C	
	Lesser Scaup	18	3	5		C	

Table 1 (cont.).

Priority Entry Criteria[1]	Species	Total PIF Priority Species Score	Conservation Score		Percent of BBS Population	Migratory Status[2]	Local Geographical or Historical Notes
			Area Importance	Population Trend			
	Red-shouldered Hawk	18	5	2		D	
	Eastern Kingbird	18	3	5		B	
	Summer Tanager	18	3	3		B	
	Eastern Meadowlark	18	4	5		D	
	Rusty Blackbird	18	2	5		C	
	Bald Eagle[5]	17	4[4]	1		D	
	Blue-winged Teal	17	5	3		A	
	Barn Owl	17	3	3		D	
	Northern Flicker	17	4	5		D	
	Eastern Wood-Pewee	17	2	3		B	(AA@ Merritt Island)
	Yellow-crowned Night-Heron	16	2	3		D	
	Roseate Spoonbill	16	2	3		D	
	Northern Pintail	16	3	5		C	
	Brown Thrasher	16	2	3		D	
	Black-and-white Warbler	17	3	3		C	
	Smooth-billed Ani	15	2	3		R	
	Blue-gray Gnatcatcher	14	3	2		C	

[1]Entry criteria (Area Importance [AI] scores roughly mean A1" irregular and unpredictable occurrence, A2" rare to uncommon but regular occurrence, A3" low relative abundance, A4" moderate to high relative abundance, A5" highest relative abundance; Population Trend [PT] scores roughly mean A1" definite increase, A2" stable or possible increase, A3" trend unknown, A4" possible decrease, A5" definite decrease):

Ia. <u>Overall Highest Priority Species.</u> Species with total score 28-35. Ordered by total score. Consider deleting species with AI <u>≤</u> 2 confirmed to be of peripheral occurrence and not of local conservation interest, but retain species

potentially undersampled by BBS or known to have greatly declined during this century.

Ib. **<u>Overall High Priority Species.</u> Species with total score 22-27. Ordered by total score. Consider deleting species with AI <u>≤</u> 2 confirmed to be of peripheral occurrence and not of local conservation interest, but retain species potentially undersampled by BBS or known to have greatly declined during this century.**

II. **<u>Area Priority Species.</u> Species with slightly lower score total 19-21 with PT+AI=8+(a), with high percent BBS population (b), or high level of threats identified (TB+TN=7+, TB or TN=5). Ordered by total score. These are <u>overall moderate priority species</u>.**

III. **<u>Additional Species of Global Priority.</u> Add WatchList species (Partners in Flight-National Audubon Society priority species at national level), not already listed in either I or II, with AI=2+. Order by total score. Consider deleting species with AI=2 if confirmed to be of peripheral occurrence and not of local conservation interest, but retain if a local population is viable and/or manageable. These are also <u>overall moderate priority species</u>.**

LORI **<u>Local or Regional Interest Species.</u> Includes game or nongame species identified by State Working Groups. Also, may include species often meeting criteria for I or II within other physiographic areas and therefore of regional interest for monitoring throughout the Southeast. These are <u>overall low priority species</u> within physiographic area, but may be more important within one or more States (especially where multiple states have designated some special protective status on the species).**

[2] Local Migratory Status, codes adapted from Texas Partners in Flight as follows:

A = Breeds in temperate or tropical areas outside of region, and winters in temperate or tropics outside of region (*i.e.*, passage migrant).

B = Breeds in temperate or tropical areas including the region, and winters exclusively in temperate or tropics outside the region (*i.e.*, includes both breeding and transient populations).

C = Breeds in temperate or tropical areas outside of region, and winters in both the region and in temperate or tropical areas beyond area (*i.e.*, includes both transient and wintering populations).

D = Breeds and winters in the region, with perhaps different populations involved, including populations moving through to winter beyond the region in temperate or tropical areas (*i.e.*, populations may be present throughout year, but may include a large number of passage migrants).

E = Species reaching distributional limits within the region, either as short-distance or long-distance breeding migrants, but at population levels above peripheral status.

F = Same as E except for wintering (non-breeding) migrants.

R = Resident, generally non-migratory species (though there may be local movements).

RP= Resident, non-migratory species, reaching distributional limits within the region, but at population levels above peripheral status.

P = Pelagic, breeding grounds outside of region, but can occur during breeding season.

PB = Post-breeding dispersal or non-breeding resident; species present during breeding season, but not known to be breeding in the region proper.

[3]Highest percent of breeding population recorded in temperate North America; numbers in A @ are likely projections; ? indicates species widespread outside of temperate North America and/or waterbirds poorly sampled by Breeding Bird Survey within physio. area.

[4]AI or PT score revised from what was derived by BBS data, or lack thereof, based on better local information.

[5]Species listed as either Federal Endangered or Threatened.

APPENDIX B

Wildlife Conservation Commission

FLORIDA'S ENDANGERED SPECIES, THREATENED SPECIES AND SPECIES OF SPECIAL CONCERN

Official Lists

Publication Date: 1 August 1997

This document consolidates the state and federal official lists of endangered species, threatened species, and other species categorized in some way by the respective jurisdictional agencies as meriting special protection or consideration. The state lists of animals are maintained by the Florida Game and Fresh Water Fish Commission and categorized as endangered, threatened and of special concern, and constitute Rules 39-27.003, 39-27.004 and 39-27.005, respectively, Florida Administrative Code (F.A.C.). The state lists of plants are categorized into endangered, threatened and commercially exploited, and are administered and maintained by the Florida Department of Agriculture and Consumer Services via Chapter 5B-40, F.A.C. The federal lists of animals and plants are administered by the U.S. Fish and Wildlife Service and categorized into endangered and threatened, and are published in 50 CFR 17 (animals) and 50 CFR 23 (plants). The abbreviations used in part one are:

GFC = Florida Fish and Wildlife Conservation Commission

FDA = Florida Department of Agriculture and Consumer Services

FWS = United States Fish and Wildlife Service

E = Endangered

T = Threatened

T(S/A) = Threatened/Similarity of Appearance

T(E/P) = Threatened/Experimental Population

SSC = Species of Special Concern

C = Commercially Exploited

		Designated Status	
Scientific Name	**Common Name(s)**	**GFC**	**FWS**
Birds			
Ajaia ajaja	Roseate spoonbill	SSC	
Ammodramus maritimus juncicolus	Wakulla seaside sparrow	SSC	

		Designated Status	
Scientific Name	**Common Name(s)**	**GFC**	**FWS**
Ammodramus maritimus mirabilis	Cape Sable seaside sparrow	E	E
Ammodramus maritimus peninsulae	Scott's seaside sparrow	SSC	
Ammodramus savannarum floridanus	Florida grasshopper sparrow	E	
Aphelocoma coerulescens	Florida scrub-jay	T	T
Aramus guarauna	Limpkin	SSC	
Campephilus principalis	Ivory-billed woodpecker	E	E
Charadrius alexandrinus tenuirostris	Southeastern snowy plover	T	
Charadrius melodus	Piping plover	T	T
Cistothorus palustris griseus	Worthington's marsh wren	SSC	
Cistothorus palustris marianae	Marian's marsh wren	SSC	
Columba leucocephala	White-crowned pigeon	T	
Dendroica kirtlandii	Kirtland's warbler	E	E
Egretta caerulea	Little blue heron	SSC	
Egretta rufescens	Reddish egret	SSC	
Egretta thula	Snowy egret	SSC	
Egretta tricolor	Tricolored (=Louisiana) heron	SSC	
Eudocimus albus	White ibis	SSC	
Falco peregrinus tundrius	Arctic peregrine falcon	E	
Falco sparverius paulus	Southeastern American kestrel	T	
Grus americana	Whooping crane	SSC	T(E/P)
Grus canadensis pratensis	Florida Sandhill crane	T	
Haematopus palliatus	American oystercatcher	SSC	
Haliaeetus leucocephalus	Bald eagle	T	T
Mycteria americana	Wood stork	E	E

		Designated Status	
Scientific Name	**Common Name(s)**	**GFC**	**FWS**
Pandion haliaetus	Osprey	SSC*	
Pelecanus occidentalis	Brown pelican	SSC	
Picoides borealis	Red-cockaded woodpecker	T	E
Polyborus plancus audubonii	Audubon's crested caracara	T	T
Rostrhamus sociabilis	Snail kite	E	E
Rynchops niger	Black skimmer	SSC	
Speotyto cunicularia	Burrowing owl	SSC	
Sterna antillarum	Least tern	T	
Sterna dougallii	Roseate tern	T	T
Vermivora bachmanii	Bachman's warbler	E	E
*Applicable in Monroe County only			

APPENDIX C

US FISH AND WILDLIFE SERVICE, SPECIES OF CONSERVATION CONCERN IN PENINSULAR FLORIDA (BCR 31)

Black-capped Petrel
Audubon's Shearwater
Magnificent Frigatebird
American Bittern
Little Blue Heron
Reddish Egret
White Ibis
Swallow-tailed Kite
Short-tailed Hawk
American Kestrel (resident *paulus* ssp. only)
Peregrine Falcon
Yellow Rail
Black Rail
Limpkin
Snowy Plover
Wilson's Plover
American Oystercatcher
Whimbrel
Marbled Godwit
Red Knot
Semipalmated Sandpiper
Stilt Sandpiper
Buff-breasted Sandpiper
Short-billed Dowitcher
Gull-billed Tern
Common Tern
Least Tern
Black Tern
Black Skimmer
White-crowned Pigeon
Common Ground-Dove
Mangrove Cuckoo
Smooth-billed Ani
Burrowing Owl
Chuck-will's-widow
Red-headed Woodpecker
Loggerhead Shrike
Black-whiskered Vireo
Brown-headed Nuthatch
Yellow Warbler (resident *gundlachi* ssp. only)
Yellow-throated Warbler
Prairie Warbler
Bachman's Sparrow
Henslow's Sparrow
Nelson's Sharp-tailed Sparrow
Saltmarsh Sharp-tailed Sparrow
Seaside Sparrow
Painted Bunting

APPENDIX L.2

BISCAYNE NATIONAL PARK

FINAL DRAFT

Avian Conservation Implementation Plan
Biscayne National Park

National Park Service
Southeast Region



Compiled by J. Keith Watson
U.S. Fish and Wildlife Service
In cooperation with

BISC Resource Management Staff, National Park Service
And Bird Conservation Partners
December 2003

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Introduction

This Avian Conservation Implementation Plan (ACIP) is provided to the staff at Biscayne National Park (BISC) to serve as guidance to identify, document, and undertake bird conservation activities in the park and with neighboring communities, organizations, and adjacent landowners. This plan may identify goals, strategies, partnerships, and perhaps specific projects for the park to participate in existing bird conservation planning and implementation efforts associated with the North American Bird Conservation Initiative (NABCI). Under the auspice of NABCI, appropriate bird and habitat conservation goals may be recommended as identified in the appropriate existing national or regional bird conservation efforts aligned with this initiative: Partners In Flight (PIF), North American Waterfowl Management Plan (NAWMP), US Shorebird Conservation Plan (USSCP), and Waterbird Conservation for the Americas (WCA). For example, parks in the Appalachians and the Cumberland Plateau will have few if any high priority waterbird conservation issues at a regional landscape or greater scale. As such, little information regarding waterbird conservation will be presented in the ACIP, unless there is an identified park need for this species group, or other mandates, such as federal laws. Similarly, because BISC is primarily a marine/estuarine/barrier island park with coastal hammock and mangrove forests recommendations will be provided in the ACIP for landbirds and coastal birds and their habitats. However, all high priority bird conservation issues for BISC will be discussed and integrated as appropriate.

Information and data presented in the ACIP have been obtained from several sources: 1) interviews with BISC staff 2) BISC bird conservation partners 3) the PIF Subtropical Florida Bird Conservation Plan Executive Summary (Partners In Flight 2000?) 4) NPS databases, and 5) personal communications with bird conservation specialists throughout North America, especially in the southeastern United States. This plan has been reviewed by BISC resource management staff and managers, South Florida/Caribbean Inventory and Monitoring (SFC I&M) staff, and bird conservation partners and approved by BISC management. Optimally, this plan will be incorporated into the park's Resource Management Plan (USDI NPS 1995) and updated annually to reflect completed projects, newly identified needs, and shifts in bird conservation priorities in the region.

BISC is not obligated to undertake any of the proposed actions in this plan. The plan is provided to offer guidance to BISC to voluntarily support important park, regional, and perhaps national and international bird conservation projects for which BISC is a primary participant in the proposed actions.

Background

During the past thirty years, monitoring programs across North America have documented declines of certain bird species populations and their habitats, often severe (Sauer et al. 2000). The decline has caused great concern among scientists, biologists,

biodiversity proponents, ecologists, land managers, etc., and the bird conservation community in general. Birds are recognized as critical components of local and global genetic, species, and population diversity, providing important and often critical ecological, social, and cultural values. Their overall decline has stimulated a worldwide focus on conservation efforts and North American interest in bird conservation is rapidly becoming a focus of government, non-government, industry, and private interests and expenditures.

Many state, federal, and non-governmental wildlife agencies and organizations (NGO's) have recognized this alarming bird decline trend and have joined forces in several extensive partnerships to address the conservation needs of various bird groups and their habitats. The primary initiatives are:

- North American Waterfowl Management Plan
- Partners in Flight
- U.S. Shorebird Conservation Plan
- Waterbird Conservation for the Americas

While efforts associated with these plans have generated some successes, it has been increasingly recognized that the overlapping conservation interests of the; se initiatives can be better served through more integrated planning and delivery of bird conservation. The *North American Bird Conservation Initiative (NABCI* ;http://www.nabci-us.org/main2.html*)* arose out of this realization. The vision of NABCI is simply to see ***"populations and habitats of North America's birds protected, restored and enhanced through coordinated efforts at international, national, regional, state and local levels, guided by sound science and effective management."*** NABCI seeks to accomplish this vision through (1) broadening bird conservation partnerships, (2) working to increase the financial resources available for bird conservation in the U.S., and (3) enhancing the effectiveness of those resources and partnerships by facilitating integrated bird conservation (U.S. NABCI Committee 2000). Together, the four bird conservation initiatives mentioned above, as well as several other local and regional partnerships, work collectively to pursue this vision.

NABCI is guided by a set of principles that establish an operational framework within which the Initiative and its partners may conduct integrated bird conservation in the U.S. These will articulate a common understanding of the relationship between NABCI, the individual bird conservation initiatives, and all partner entities to ensure recognition of existing federal legislative and international treaty obligations, state authorities, and respect for the identity and autonomy of each initiative. The fundamental components of the conservation approach to be used by NABCI are expressed within its goal:

> ***To deliver the full spectrum of bird conservation through regionally-based, biologically-driven, landscape-oriented partnerships.***

The Southeastern Bird Conservation Initiative: National Park Service: In 2000, the Southeast Region of the National Park Service (NPS) recognized the importance of coordinating existing bird conservation goals into planning and operations of national park units in the southeast, that is, integration of NABCI. In support of this recognition, the Southeast Regional Office NPS approved and allocated eighty-eight thousand dollars, cost sharing 1:1 with the US Fish and Wildlife Service (FWS) Region 4 (Southeast) to hire a biologist to conduct this two-year project (Interagency Agreement FS028 01 0368). This project is unique in the NPS, and perhaps the nation, and represents a potential model for better coordinating regional bird conservation programs and activities within and outside the NPS. It further represents a progressive action toward institutionalizing bird conservation as a programmatic priority in the Southeast Region of NPS, and potentially the nation.

As envisioned, the integration of NABCI into the Southeastern NPS involves:

1) Development and delivery of Avian Conservation Implementation Plans (ACIP),
2) Coordination with NPS Inventory and Monitoring Program,
3) Development of a web based project site,
4) Establishment or enhancement of bird conservation partnerships,
5) Identification and exploration of potential funding opportunities, and
6) Technical guidance and assistance as needed or requested.

This ACIP fulfills one aspect of the plan outlined above, and serves as a basis for future bird conservation actions in BISC and with adjacent partners or landowners. Concurrently, the development of a Memorandum of Understanding (MOU) between the FWS and the NPS to implement Presidential Executive Order (EO) 13186, **Responsibilities of Federal Agencies to Protect Migratory Birds**, calls for integration of programs and recommendations of existing bird conservation efforts into park planning and operations. Complementing each other, the MOU and the Southeastern Bird Conservation Initiative will advance bird conservation in the Southeast Region of the NPS beyond current regional NPS efforts.

Role of NPS in Avian Conservation

The interagency agreement that facilitates this partnership supports both FWS and NPS management policies. Specifically for the NPS, the agreement supports and advances the **Strategy for Collaboration** (March 2000), a visionary document developed and signed by the Southeast Natural Resource Leaders Advisory Group (SENRLAG), a consortium of 13 land and resource management agencies in the Southeastern United States whose vision is to encourage and support cooperation in planning and managing the region's natural resources. Furthermore, the agreement is aligned with and implements a variety of NPS Management Polices (2001) including but not limited to External Threats and Opportunities (Chapter 1.5), Environmental Leadership (Chapter 1.6), Cooperative Planning (Chapter 2.3.1.9), Land Protection (Chapter 3), and especially Natural Resource Management (Chapter 4) that details policy and

management guidelines which apply to bird conservation. Important policies in this chapter include:

- Planning for Natural Resource Management (4.1.1)
- Partnerships (4.1.4)
- Restoration of Natural Systems (4.1.5)
- Studies and Collection (4.2)
- General Principles for Managing Biological Resources (4.4.1)
- Plant and Animal Population Management Principles (4.4.1.1)
- Management of Native Plants and Animals (4.4.2)
- Management of Endangered Plants and Animals (4.4.2.3)
- Management of Natural Landscapes (4.4.2.4)
- Management of Exotic Species (4.4.4)
- Pest Management (4.4.5)
- Fire Management (4.5) and
- Water Resource Management (4.6)

The NPS is the fourth largest landowner in the United States, consisting of over 380 national park units covering 83 million acres of land and water with associated biotic resources (www.nps.gov). The 64 units in the Southeast Region of the NPS represent 16% of the total number of park units in the national park system and cover approximately 5% of the total land base in the entire system. Park units in the Southeast Region include national seashores (Canaveral National Seashore, Cape Hatteras National Seashore), national parks (Great Smoky Mountains National Park, Everglades National Park), national recreation areas (Big South Fork National River and Recreation Area), national preserves (Big Cypress National Preserve), national battlefields (Cowpens National Battlefield, Fort Donelson National Battlefield), national monuments (Ocmulgee National Monument), and others such as the Blue Ridge Parkway, Obed Wild and Scenic River, and Timicuan Ecological and Historic Preserve.

Southeast NPS units provide habitat for over 400 species of migrating, breeding, and wintering birds and include a wide range of Federal and State listed threatened and endangered species. Likewise, these units also provide nest, migration, and winter habitat for most of the eastern species identified in the national bird conservation plans in need of conservation attention.

Additionally, the NPS attracts over 280 million visitors to the parks each year, 120 million of these in the Southeast Region, affording excellent recreational bird watching and opportunities to strengthen bird conservation interpretation, outreach, and education programs. These opportunities, the NPS mission, policies, and organization all lead to the conclusion that the NPS is an extremely valuable partner and contributor to bird conservation in the region.

Nationally, the status of birds in national parks is largely unknown, although many parks have adequate knowledge regarding bird occurrence in the parks

(http://www.npwrc.usgs.gov/resource/othrdata/chekbird/chekbird.htm). Parks often play a role in ongoing regional bird conservation efforts. Indeed many of these parks are often important to regional, national, or international bird conservation, and many have been designated as Important Bird Areas (IBA's) by the National Audubon Society. To date, there are approximately 64 NPS units that are designated IBA's, 35 of which are considered of global importance (http://abcbirds.org/iba/aboutiba.htm). In the Southeast Region, the NPS has 13 global IBA's.

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The **NPS Inventory and Monitoring (I&M) Program** has been developed to provide management driven scientific information to national park managers so that resources can be adequately protected within national parks. One of the first phases of this program is to inventory vertebrates, including birds, within the 260 national park units in the program. Once completed, data from the inventories will provide an account of the occurrence and abundance of birds in all the national parks in the program. These records will be stored in the NPS I&M NPSpecies database http://www.nature.nps.gov/im/apps/npspp/). Coordination with I&M network staff is important to developing long-term bird monitoring programs that fulfill both park and NABCI objectives.

Park Flight is a NPS international partnership initiative that directs funding toward a variety of NPS programs that involve conservation of neotropical migratory birds whose life history range covers a US national park and a Latin American protected area. A relatively new program, Park Flight offers parks the opportunity to partner with a Latin American national park or protected area to cooperate on developing bird conservation and education projects (NPS 2002).

Recent increases in NPS base funded programs such as inventory and monitoring, exotic species management, habitat restoration, and fire management all indicate that national park managers recognize that park lands are increasingly subject to a variety of threats and conditions that must be improved to provide the quality of national park experience articulated in the NPS Organic Act (1916). Programmatic funding in these areas will increase the ability of national parks to provide quality habitat and conditions for increased wildlife conservation, including birds. Furthermore, private interests and non-profit conservation organizations have initiated programs, including grant programs, to provide much needed funding to national parks to meet backlogs of identified yet unfunded needs.

Park Description

Biscayne National Park was established in 1969 as Biscayne National Monument with expansions in 1974 and 1980 when it was re-designated Biscayne National Park. The park is located in southeast Florida, within sight of a major metropolitan area, the City of Miami, and heavily influenced by growth within metro Miami-Dade County. The Park is comprised of 70,000 total ha (172,924 acres) of which 63,000 ha (155,631 acres) are submerged. Biscayne National Park's enabling legislation charges the National Park Service to keep a rare combination of terrestrial, marine, and amphibious life for the

inspiration and enjoyment of present and future generations. The park preserves an entire coastal island ecosystem (upland to oceanic), and is home to over eleven federally threatened and endangered species, and over 28 state listed plants and animals in addition to the federally listed species (Sasso and Patterson 2000).

Avian Resources of Subtropical Florida

The physiographic area is entirely contained within Florida, and extends from the northern edge of Lake Okeechobee south through the Florida Keys (see PIF and NPS location maps below). The region has very little topographic relief, but slight changes in elevation have important consequences for vegetation and the diversity of habitat types. The highest points of elevation are less than 2 meters and correspond with fairly recent shorelines (less than 5,000 years before present). Underlying sediments consist of freshwater marl, peat, freshwater lake and marine sediments, and to a lesser extent, sand deposited during the Pleistocene and Holocene. The subtropical Florida region can be divided into four smaller sub-regions: 1) the everglades, 2) Big Cypress, 3) Miami Ridge and Atlantic Coastal Strip, and 4) Southern Coasts and Islands. The Everglades is the most extensive of these areas, followed by the Big Cypress, Miami Ridge and Southern Coasts. Across all subregions, much of the physical and ecological characteristics of the region resemble tropical ecosystems where seasonal changes are reflected by changing rainfall patterns rather than by dramatic temperature changes. Distinctive dry (winter/spring) and wet (summer) seasons occur annually, and the nesting cycles of many birds are tied to these changes. At least two major forms of disturbance play key roles in the ecology of the region. Fire is an important feature in many pine dominated communities and many marsh and prairie communities. Frequent fires are essential in pine-dominated stands and prairies if understory conditions suitable to many nesting birds are to be maintained. However, the ideal fire frequency in some pine communities is not known. Hurricanes are a second form of disturbance that less frequently but predictably provide early successional habitats or open forest cover (Partners in Flight 2000?).

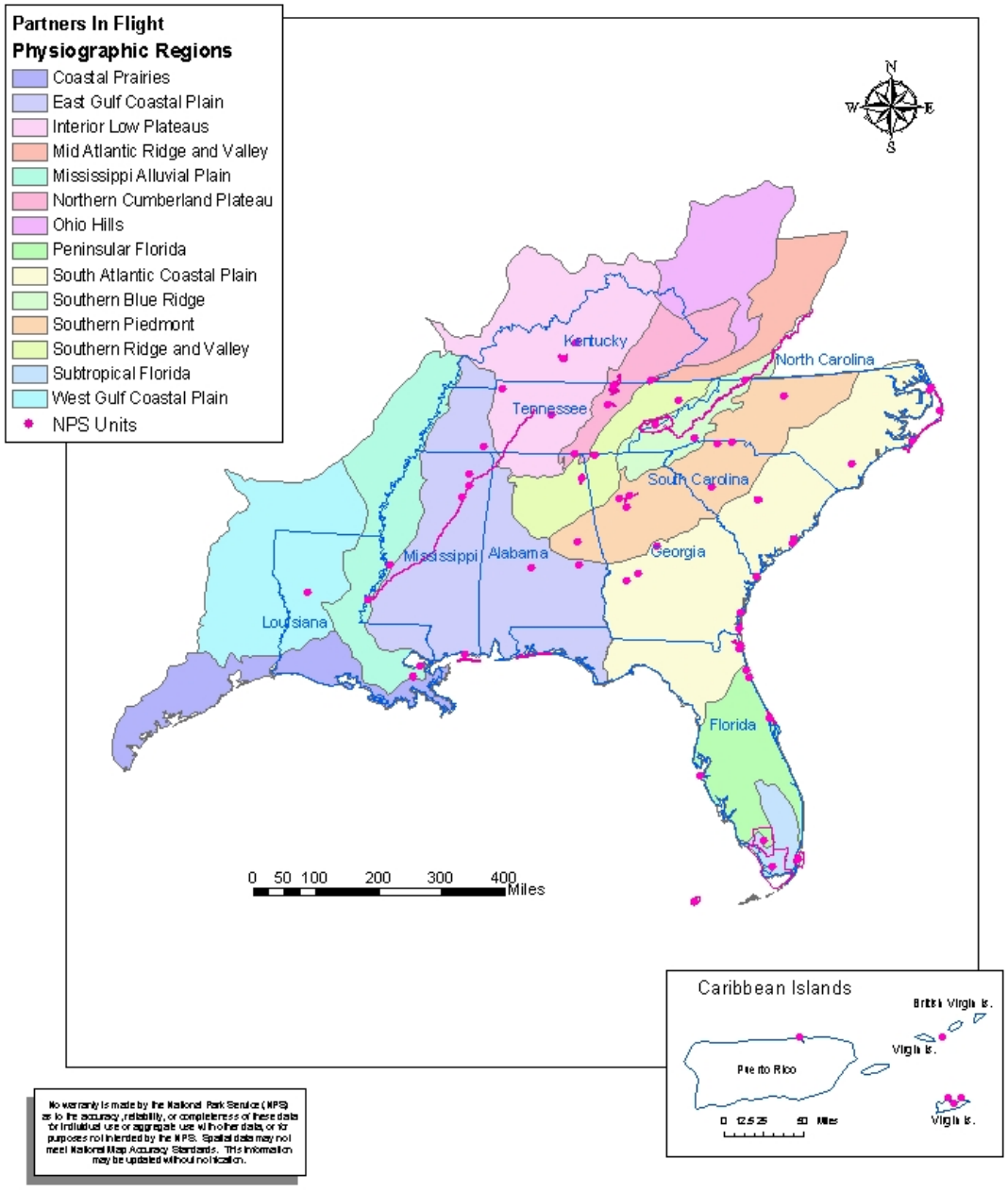
Bird conservation priorities for Subtropical Florida have been stratified by habitat type. Recognized habitat types where high priority conservation actions are needed for both birds and habitats are pine forests (including pine rocklands, pine Flatwoods, sand pine scrub), grassland/grassland-scrub (including dry prairie and coastal strands), subtropical deciduous forest, everglades, brackish saltwater and freshwater marsh, and mangrove swamps. Species associated with each of these habitats and identified as high priority for conservation needs are given below.

Florida Scrub Jay, Red-cockaded Woodpecker, Southeastern American Kestrel, Brown-headed Nuthatch, Bachman's Sparrow, Palm Warbler and Sedge Wren are associated with the pine forests. Both Florida Scrub Jay and Southeastern American Kestrel have been extirpated in Subtropical Florida and the Brown-headed Nuthatch and Bachman's

Partners in Flight (PIF) Regions

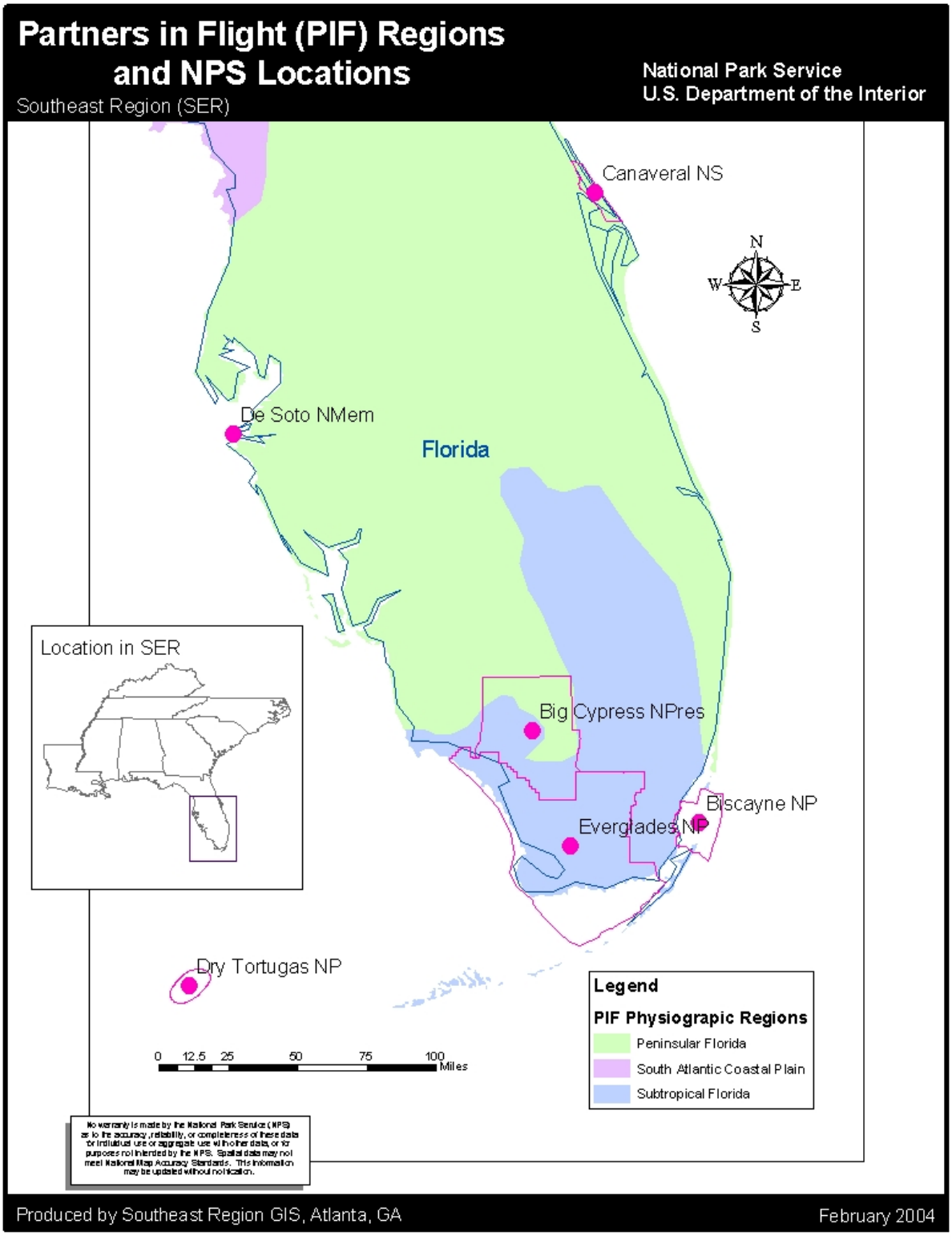
Southeast Region (SER)

National Park Service
U.S. Department of the Interior



Produced by Southeast Regional Office GIS, Atlanta, GA

March 2004


Partners in Flight (PIF) Regions
and NPS Locations
Southeast Region (SER)
National Park Service
U.S. Department of the Interior
Canaveral NS
N
W
E
S
De Soto NMem
Florida
Location in SER
Big Cypress NPres
Biscayne NP
Everglades NP
Dry Tortugas NP
Legend
PIF Physiograpic Regions
Peninsular Florida
South Atlantic Coastal Plain
Subtropical Florida
0 12.5 25 50 75 100
Miles
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February 2004

Sparrow are nearly extirpated here. Both Palm Warbler and Sedge Wren are present only in the non-breeding seasons.

Grasshopper Sparrow, Crested Caracara, Burrowing Owl, Sandhill Crane and Mottled Duck are all species associated with grassland to grassland scrub habitats. Grasshopper Sparrow has been extirpated in South Florida.

In the subtropical deciduous forest, Short-tailed Hawk, Swallow-tailed Kite, White-crowned Pigeon and Gray Kingbird are high priorities for conservation.

In the Everglades, brackish saltwater and freshwater marshes, Snail Kite, Cape Sable Seaside Sparrow, Wood Stork, Black Rail, Reddish Egret, Yellow Rail, White Ibis, and Clapper Rail are species in of conservation attention.

Prairie Warbler, Yellow Warbler, Black-whiskered Vireo, and Mangrove Cuckoo, species associated with Mangrove swamps and forests, and are of high priority conservation concern.

Human population growth has been phenomenal in subtropical Florida for the last 40 years. The impacts of such tremendous growth include increased infrastructure that directly reduces habitat availability, but also secondary impacts to bird habitats, such as pollution. Other land uses include production of sugarcane, winter vegetables, and citrus. Drastic changes in hydroperiod and natural water cycles are secondary impacts of increasingly intensive agriculture. However, among the best opportunities in the Southeast to work with existing public lands occur in Subtropical Florida, where over 54% of the area is publicly owned. Therefore, primary conservation programs include efforts to reduce impacts from adjacent or nearby lands on management of existing public lands. Many programs have been developed and are in various phases of implementation. These include the Save our Everglades program, the Surface Water Improvement and Management Act, Florida's Everglades Forever Act and the development of the South Florida Ecosystem Restoration Task Force as well as aggressive acquisition programs. These and other programs serve the basis for bird conservation efforts in the region.

Avian Conservation in BISC

Avian Biodiversity: BISC has a complete avian inventory (> 90% avifauna known) but has not developed a checklist of birds that is available for the public. Managers recognize the need to update the inventory and checklist. BISC has recorded over 215 species in the park, including many rare vagrants that often show up on the barrier islands of the park, attracting many birding enthusiasts.

Verified records of birds in BISC have been entered into the NPS I&M program's database, NPSpecies, and may be viewed via the internet at http://www.nature.nps.gov/im/app/npspp with a user identification and password

combination authorized by the NPS for NPS personnel and NPS cooperators. Many other avian observational data need to be verified and entered into the database.

Threatened and Endangered Species: Several federally listed threatened species occur in BISC, Bald Eagle, Wood Stork, Roseate Tern, and the Piping Plover. Only the Bald Eagle and Wood Stork are known to breed in BISC. The Roseate Tern is a migrant, and the Piping Plover is a winter resident. Critical habitat for Piping Plover has been established at BISC.

Several species in BISC are listed on the Florida Fish and Wildlife Conservation Commission (FFWCC) list of Endangered Species, Threatened Species, and Species of Special Concern. Prominent among these are Osprey, White-crowned Pigeon, Least Tern, Black Skimmer, Snowy Plover, and Peregrine Falcon (Arctic subspecies).

Additionally, BISC has several species that have been identified as high priority for conservation by Partners In Flight. These are Cuban Yellow Warbler, Black-whiskered Vireo, Mangrove Cuckoo, Florida Prairie Warbler, Gray Kingbird, Reddish Egret and White Ibis.

Park Priorities: Park staff and consultants have identified the Brown Pelican, Least Tern, and Piping Plover as species of significant management concern and high priority for conservation.

Inventory: The park's avian inventory has been recognized as important information for park managers and is considered complete within the framework of the NPS I&M Program. BISC is one of seven parks in the NPS South Florida/Caribbean I&M Network for which a plan to conduct high priority inventory projects has been prepared (Sasso and Patterson 2000). At this time, no inventory efforts are planned for BISC.

Monitoring: Currently, several avian monitoring projects are being conducted at BISC. These are:

- Breeding surveys are conducted for Least Tern, Wilson's Plover, and Killdeer
- Christmas Bird Count have been reinstated after a lapse in the late 1980's and 1990's
- Bald Eagle and Osprey nest monitoring
- Migration monitoring is occasionally conducted
- Colonial Waterbird surveys on Arsenicker Keys (all egrets and herons; including Reddish Egret)
- Randomized recreational birding

Research: Scientific research is permitted within the park, and currently no research other than existing avian monitoring is ongoing.

Outreach: Some educational information related to birds is conveyed to visitors to BISC.

- A Birdwatching for Beginners program is offered by Tropical Audubon Society

Park Identified Needs for Avian Conservation

BISC has identified several projects that would increase the avian knowledge of the park. They are:

Inventory:

- Better knowledge of nesting birds, and relative abundance of all species, especially high priority species

*Monitoring**:***

- Better information on value of park for migration

Data Management:

- Verify and enter avian observational data into NPSpecies, eBird, or another appropriate database (BISC data is stored in Everglades National Park databases)

Coordination with Regional Conservation Initiatives

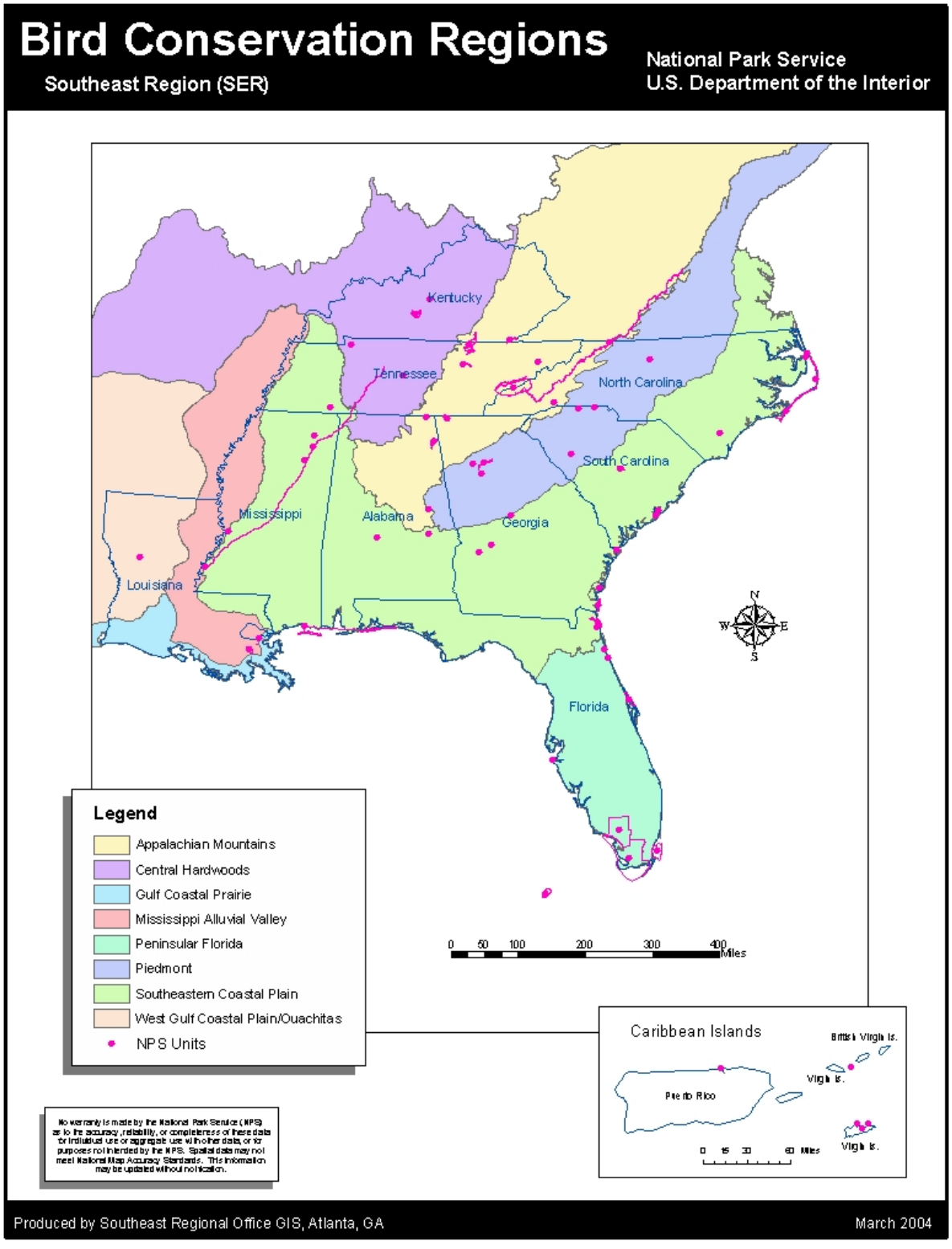
North American Bird Conservation Initiative

NABCI bird conservation planning units, referred to as Bird Conservation Regions (BCR), are often larger than other planning units associated with other plans, such as Partners In Flight. For example, BISC is within the NABCI Peninsular Florida BCR that covers all of Southern Florida south of approximately Jacksonville (see NABCI BCR map below) and encompasses two PIF physiographic areas (the planning unit for PIF)(compare to PIF map).

Several NABCI BCR's have coordinators whose primary responsibility is to coordinate all bird conservation planning in the BCR, across all agencies and organizations. Currently, the Peninsular Florida BCR does not have a designated coordinator; however, the Atlantic Coast Joint Venture (ACJV) has staff that with responsibility to provide bird conservation assistance to agencies and organizations in the area. This staff can provide valuable assistance to BISC with implementation of aspects of this ACIP.

North American Waterfowl Management Plan (NAWMP)

The NAWMP (http://northamerican.fws.gov/NAWMP/nawmphp.htm) is completed and has been revised several times, incorporating updated goals and strategies based on new information. This plan is one of the most successful bird conservation delivery


Bird Conservation Regions
Southeast Region (SER)
National Park Service
U.S. Department of the Interior
Kentucky
Tennessee
North Carolina
South Carolina
Mississippi
Alabama
Georgia
Louisiana
Florida
N
W
E
S
0 50 100 200 300 400 Miles
Legend
Appalachian Mountains
Central Hardwoods
Gulf Coastal Prairie
Mississippi Alluvial Valley
Peninsular Florida
Piedmont
Southeastern Coastal Plain
West Gulf Coastal Plain/Ouachitas
NPS Units
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Caribbean Islands
British Virgin Is.
Virgin Is.
Puerto Rico
Virgin Is.
0 15 30 60 Miles
Produced by Southeast Regional Office GIS, Atlanta, GA
March 2004

programs in the United States, being monetarily supported by the North American Wetlands Conservation Act (NAWCA). The ACJV coordinators are responsible for coordination and implementation of this program.

Partners In Flight

Goals and strategies for the Subtropical Florida are not yet fully developed into a draft bird conservation plan. However, as previously noted, bird conservation priorities for BISC are better aligned with Puerto Rico and the US Virgin Islands goals, yet are largely the responsibility of the NPS and the State of Florida, an arrangement that can make bird conservation at BISC challenging.

Similar to NABCI BCR's, PIF physiographic areas often do not have designated coordinators. However, state level non-game agencies with investment in PIF will establish key personnel to develop partnerships among cooperators in the physiographic area. The State of Florida has a non-game bird coordinator who can be instrumental in assisting BISC to implement recommendations identified in this ACIP and projects important to bird conservation relative to Florida's role in implementation of the respective geographical plans.

United States Shorebird Conservation Plan (USSCP)

The USSCP has been completed and is available on the world wide web (http://shorebirdplan.fws.gov/). A regional step down plan is in preparation by FWS personnel and should be available in 2003.

Waterbird Conservation for the Americas (WCA)

The WCA plan has been completed and is available on the World Wide Web or can be ordered from the US Fish and Wildlife Service National Conservation Training Center (http://www.waterbirdconservation.org/).

Integration of NABCI Goals and Objectives into Park Planning and Operations

NABCI Implementation Recommendations

To successfully achieve park-established goals and actively participate in NABCI, the park could implement a variety of projects in different NPS programs. Most of these projects would require some level of participation by many existing park programs and could either be achieved through NPS funding, or more likely, through establishing or improving partnerships with agencies and organizations that already have the necessary expertise to provide guidance, funding, and execution of these programs. Programmatic areas where bird conservation actions are likely to be focused are:

- Inventory
- Monitoring
- Habitat Restoration
- Threat Management (includes exotic species, air quality, water quality, etc.)
- Research
- Compliance
- Outreach
- Partnerships

To the extent appropriate, each of these program areas will be discussed separately and within each, specific opportunities identified that, when implemented, will enable to park to meet its mandates (current and expected) as well as integrate NABCI into its planning and operations. With emphasis added, the park is not expected to implement any of these recommendations or be obligated to pursue any opportunity other than those the park is required to do by law or NPS program or policy. In other words, participation in this effort is currently voluntary. However, participation in these efforts at some level could become mandatory with the completion of an MOU with the FWS regarding EO 13186, **Responsibilities of Federal Agencies to Protect Migratory Birds**. The MOU will establish a formal agreement between the FWS and the NPS to promote bird conservation within the agency by incorporating goals and strategies of existing bird conservation initiatives, plans, and goals into park planning and operations.

Should the park decide to implement any of these projects, further consultation with bird conservation contacts is encouraged to obtain updated information on the relevance of these opportunities in regional bird conservation.

High priority projects are identified in **bold** print. Priorities that the park is encouraged to seek NPS funding for are marked with and asterisk (*****). These projects are those that are critical to the stabilization or improvement of a bird population in the planning region.

Inventory

The park has inventoried its bird fauna exceptionally well. Although the avifauna of BISC is well documented, additional information is needed on abundance and distribution of species. BISC is encouraged to:

- **establish a migration monitoring program throughout the park to determine use of BISC by fall migrants, especially on barrier island habitats***

- **obtain abundance and distributional information of all species that nest in BISC and others of high priority conservation concern that use the park as foraging or roosting areas, especially listed species, and those that occur in the coastal mangrove or hammock forests (White-crowned Pigeon, Yellow Warbler, Black-whiskered Vireo, Prairie Warbler, Mangrove Cuckoo)***

- **verify other avian observational data collected in the park and enter into the appropriate database (NPSpecies, eBird, or other appropriate database)**

- **standardize inventory and monitoring methodology to conform to NPS and/or FWS recommended standards (Fancy and Sauer 2000, Hunter 2000).**

Monitoring

The park's bird monitoring program is focused on primarily federally and state listed species. Efforts should be made to continue existing monitoring programs. Specific recommendations are to:

- **continue to conduct existing monitoring programs and enter data into the appropriate databases (NPSpecies, eBird, or other appropriate database)**

- **establish a mangrove/coastal hammock avian monitoring program to document abundance of species in theses habitats (see Partnerships below)**

- **determine usage of park by migrating and wintering shorebirds and adopt appropriate level of shorebird monitoring to document shorebird use of the park**

- **establish a scientifically based landbird migration monitoring program to document use of BISC during landbird migrations***

- **establish the Christmas Bird Count (CBC) as an institutional program, working with local partners to assure the CBC is conducted annually**

- **standardize inventory and monitoring methodology to conform to NPS and/or FWS recommended standards (Fancy and Sauer 2000, Hunter 2000).**

Habitat Restoration

Recently, habitat restoration efforts have increased nationwide, and on NPS lands; NPS receiving restoration emphasis and guidance in the 2001 Management Policies (NPS 2001). Habitat restoration efforts that parks may undertake are wetland restoration, grassland restoration, woodland restoration, etc. utilizing a wide range of tools to accomplish the restoration. Some of these tools may be but not limited to forest management practices, exotic species management, public use and recreation management, infrastructure development management, and prescribed fire.

Due to the protected nature of BISC lands, and generally those in the national park system, the condition of habitats for bird use may be of higher quality than other natural, developed, agricultural, or forest lands under other management regimes. However,

national park lands can be greatly improved for wildlife, and particularly bird use, by restoring processes important for habitat formation, succession, and structural development. Largely, these processes have not been managed historically in the national park system but current policy allows for active management of species, populations, and lands to provide for long-term conservation of park resources.

The park is entirely coastal/estuarine/barrier island park subject to the forces generated upon and moving across the ocean surfaces. Tropical storms, tidal fluctuations, and sea level rise are processes that influence the dynamic landscape of BISC and likewise, habitats and associated birds. Specific recommendations are to:

- **maintain or enhance water quality in surrounding waters to support aquatic biota necessary to support fish eating birds that either nest or forage in the park***

- **restore hydrological processes in park, particularly in support of restoration of South Florida ecosystems and Comprehensive Everglades Restoration Program (CERP)**

- **enhance seagrass recovery (nursery for bird prey) in the park by managing threats to this vegetation**

- **preserve remaining coastal mangrove and hammock forests for migrating land birds***

- **continue to monitor and eliminate exotic vegetation**

Threat Management

Many different factors pose threats to bird conservation at BISC, but through sound scientific data gathering, these threats can be minimized or avoided. Boats, recreation, predators, and exotic vegetation all affect bird conservation at BISC. A better understanding of the extent and impact of these threats is needed to effectively preserve park resources. The park is encouraged to:

- **manage recreational uses of the park, especially boats and pedestrian traffic to areas where birds nest on barrier islands and to avoid disturbances to foraging, migrating, and wintering colonial waterbirds and shorebirds (develop a Recreational Use Plan)***

- **manage other recreation uses of the park including personal watercraft, kayaking, canoeing, to avoid disturbance to nesting, foraging, migrating, and wintering colonial waterbirds and shorebirds (develop a Recreational Use Plan)***

- **Develop Predator Management Guidelines, similar to those developed at Cape Hatteras National Seashore (USDI 2002) (Cape Hatteras National Seashore has recently completed a feral cat reduction campaign that could be used as a model for a similar program at BISC (Altman 2002, Harrison 2002))***

- **hire additional law enforcement officers to provide protection for beach nesting, foraging, migrating, and wintering birds***

- **continue to work with adjacent landowners and neighbors, the local community, and pubic officials to curb unregulated and free roaming feral cats in the park**

- **manage fishing practices that impact fish eating birds such as providing monofilament dispensers at key locations in the park**

- identify threats from low flying aircraft

Exotic vegetation has been well managed by the South Florida Exotic Plant Management Team at BISC. Efforts should continue to

- **monitor and manage exotic vegetation**

Research

Several research projects have been identified that could improve bird conservation for birds at BISC and contribute to increased bird conservation efforts for these species in the Caribbean. These projects are:

- **Determine importance of BISC as a migration stopover**

- **Conduct impact assessment of park fishing methods and fishing gear on fish feeding birds**

- **List park needs and projects on Research Permit and Reporting System web site (RPRS)**

- Develop contact with South Florida/Caribbean Cooperative Ecosystem Studies Unit (CESU) at the Rosentiel School of Marine and Atmospheric Sciences at the University of Miami, Fl

Compliance

Park compliance with the Migratory Bird Treaty Act and the Executive Order 13186, **Responsibilities of Federal Agencies to Protect Migratory Birds,** is necessary to

assure that park activities incorporate bird conservation into park planning and operations. Further, to ensure that migratory birds are considered in all phases of park planning processes, especially during the National Environmental Policy Act (NEPA) and the Director's Order #12 Compliance processes, the park should consider adding specific language in project evaluations that requires consideration and implications of park projects on migratory birds. The MOU being developed between the NPS and the FWS will likely contain specific language requiring a park to consider implications of park projects on migratory birds, particularly those species identified in the USFWS Species of Conservation Concern 2002 (Appendix D). Additional considerations are to encourage:

- **park staff to begin specific consideration of migratory birds during park planning processes**

- park staff to attend USFWS training on implementation of EO 13186 at the National Conservation Training Center (NCTC) (when available) or other training on migratory bird conservation in North America. NCTC has several courses and training related to conservation of migratory birds (http://training.fws.gov/courses.html).

The USFWS NCTC offers and reserves two tuition free slots for National Park Service employees wishing to attend NCTC courses on a first come, first served basis. Additionally, discount lodging is also available while attending a NCTC course.

Outreach

- **participate in International Migratory Bird Day (IMBD) (http://birds.fws.gov/imbd.html) events with a local partner such as the Tropical Audubon Society and US Fish and Wildlife Service***

- **develop partnerships with local agencies and organizations to implement aspects of this plan, especially with USFWS, Tropical Audubon Society and Bill Baggs Cape Florida State Park***

- **encourage development of outreach and educational programs to enhance visibility of bird conservation issues, which may include organized bird walks, migration monitoring, and perhaps waterbird colony visits**

- **develop educational/outreach program for park fishing persons to avoid or minimize impacts or injury to fish eating birds**

- **encourage accurate documentation and reporting from randomized outings by visitors (see Cornell University's eBird monitoring program (Cornell Lab. Ornith. 2002 (http://www.ebird.org/about/index.jsp)**

- park interpretation/education staff are encouraged to attend USFWS training on Migratory Bird Education at NCTC

- consider adding links to bird conservation information, data, etc. to the park's web site home page

- support bird conservation by serving shade-grown coffees at meetings, events, and the office buildings in the park (http://www.americanbirding.org/programs/conssbcof3.htm)

- subscribe to Florida Birds, an electronic forum for listing bird sightings and publications in Florida

Partners and Partnerships

Partnerships for habitat conservation and protection will perhaps have the greatest positive influence on bird conservation above all other landscape scale planning. Specific recommendations are to:

- **keep abreast of initiatives that may affect water quality in and around BISC**

- **become active in the developing mangrove/coastal hammock avian conservation initiative with USFWS (Terry Doyle at Ten Thousand Islands National Wildlife Refuge)**

- **continue to develop and strengthen relationship with local bird clubs such as the Tropical Audubon Society to coordinate and conduct park bird conservation projects**

- **develop partnership with USFWS, especially local refuges to assist in bird inventory and monitoring efforts and implementation of aspects of this plan**

- **contact the nearest Joint Venture office (see Funding section for explanation of Joint Ventures) or BCR coordinator to develop partnerships and funding proposals tiered to priorities established by the park, this ACIP, and the bird conservation plans that pertain to BISC**

Funding Opportunities

Internal NPS funding is often an effective source to obtain funding; however, the project will have to be a fairly high priority among the park's natural resource program to successfully compete for the limited funding available in the NPS. Therefore, partnerships and outside funding programs are often more productive for securing bird

conservation funding. Within this ACIP, identified priority projects that are considered to be high park priorities as well as NABCI priorities are marked with and asterisk (*). BISC is encouraged to enter all high priority projects into the NPS Performance Management Information System (PMIS) database.

Funding for conservation projects for Neotropical migrants is also available through the Park Flight program.

With the exception of the North American Waterfowl Management Plan (NAWMP and its associated funding legislation, the North American Wetland Conservation Act), funding opportunities for bird conservation programs, plans, and initiatives have been lacking. Only within the last decade have other appropriate and specific sources for bird conservation funding been created and used. The NAWMP has been supported for approximately 14 years by the North American Wetlands Conservation Act (NAWCA 1989). This program has provided $487 million in appropriated funds matched with $1.7 billion for wetland and bird conservation projects since its inception. In 2002 alone, over $70 million US dollars were awarded to US and Canadian agencies and organizations to enhance waterfowl populations by improving, restoring, or protecting wetland habitats. To adequately evaluate projects and distribute these funds, partnerships called Joint Ventures were established. Nationally, 14 (11 US, 3 Canada)

Joint Ventures have been established, several which are funded and staffed. Internet links to Joint Ventures are:

(http://southwest.fws.gov/gulfcoastjv/ojvcontact.html) and
(http://northamerican.fws.gov/NAWMP/jv.htm).

Funding through NAWCA is highly underutilized by the NPS and any park unit that has wetland, water, or bird conservation needs associated with wetland are encouraged to investigate using this funding source. Naturally, there are certain requirements to be eligible for all grants and park managers are encouraged to consult with the nearest Joint Venture, BCR, PIF Coordinator, to learn how this program might be applicable to implementation of this plan, and other park wetland issues. BISC should contact the ACJV assistant coordinator to investigate use of this funding source and developing proposals for implementation of portions of this plan.

Internal FWS funding programs may be used to support projects, but no effective method of project proposal delivery to these sources is currently in place for the NPS. Current funding in these programs may result from FWS familiarity with NPS needs, or NPS participation in one of the area FWS Ecosystem Teams, where a project has been identified and proposed to be funded through the Ecosystem Team.

Specific congressional appropriations to protect migratory birds has recently been authorized under the Neotropical Migratory Bird Conservation Act (2000) (http://www.nfwf.org/programs/nmbcapp.htm). Appropriations through this Act are authorized up to $5 million per year. However, in 2000, appropriation was

approximately $3.75 million and a majority of this funding was directed toward projects in Central and South America.

Many of the identified projects are eligible for funding under various grant programs of the National Fish and Wildlife Foundation (http://www.nfwf.org/programs/programs.htm).

Other prominent funding sources available to NPS managers for bird conservation are listed on this projects web site at:

http://southeast.fws.gov/birds/NPSHighlits.htm.

Funding opportunities for migratory bird conservation are available yet most natural resource agencies are not fully aware of and/or understanding of how to use these sources. Perhaps a consolidated migratory bird funding source catalog will become available to managers in the future; this is needed.

Contacts

Primary contacts within the region can be obtained by viewing the web site for the Southeastern Bird Conservation Initiative, National Park Service at http://southeast.fws.gov/birds/npsbirds.htm. This web site will provide contact information of the appropriate bird conservation coordinator in the region for park personnel. Park staff are encouraged to view the web site and obtain contact information. Primary contacts for BISC are:

US Fish and Wildlife Service

Keith Watson
Asheville, NC 28801
828-350-8228
Keith_Watson@fws.gov

Craig Watson
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Craig_Watson@fws.gov

Dean Demarest
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Atlanta, GA
404-679-7371
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Chuck_Hunter@fws.gov

Jennifer Wheeler
Waterbird Conservation Plan
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APPENDIX A

SUBTROPICAL FLORIDA PRIORITY SPECIES (PARTNERS IN FLIGHT)
Priority Bird Populations and Habitats

Pine forests (including Pine Rocklands, Pine Flatwoods, Sand Pine Scrub)

Florida Scrub Jay	Currently extirpated here.
Red-cockaded Woodpecker	
American Kestrel	Southeastern U.S. subspecies; currently extirpated here.
Brown-headed Nuthatch	Nearly extirpated here.
Bachman's Sparrow	Nearly extirpated here.
Palm Warbler	Non-breeding seasons.
Sedge Wren	Non-breeding seasons.

Grassland/grassland-scrub (including dry prairie and coastal strands)

Grasshopper Sparrow	Florida subspecies; extirpated here.
Crested Caracara	Florida populations.
Burrowing Owl	Florida subspecies.
Sandhill Crane	Florida subspecies.
Mottled Duck	

Subtropical deciduous forest

Short-tailed Hawk	Florida population.
Swallow-tailed Kite	Southeastern U.S. subspecies.
White-crowned Pigeon	
Gray Kingbird	

Everglades, brackish saltwater and freshwater marsh

Snail Kite	Everglades subspecies.
Seaside Sparrow	Cape Sable subspecies.
Wood Stork	Southeast U.S. population.
Black Rail	
Reddish Egret	
Yellow Rail	Non-breeding seasons.
White Ibis	
Clapper Rail	

Mangrove Swamps

Prairie Warbler	Florida subspecies.
Yellow Warbler	Cuban subspecies.
Black-whiskered Vireo	
Mangrove Cuckoo	

APPENDIX B

Southeast Region Waterbird Priorities and Habitat Types

Table 1. Southeast U.S. Waterbird Conservation Plan species priorities and habitat suites (b=breeding, r=resident, w=winter, r=resident).*

Tier	Tier Title	Action Level	Herons and allies, Pelicans and allies typically brush and tree nesting colonial waterbirds	Larids typically beach (ground)-nesting colonial waterbirds (terns, gulls, skimmers)	Marshes/ Savannas/ Grasslands	Open water (with mud and sand flats also foraging habitat for most colonial species)	Pelagic (all non-breeding populations)
I.	**Continental Conservation Interest**						
a.	**Multiple concerns**	*Immediate management*	"Great White" Heron		Black Rail (b/r)		Bermuda Petrel
					King Rail (b/r)		Black-capped Petrel
					Yellow Rail (w)		
					Whooping Crane (w-TX, r-FL)		
b.	**High threats and/or declining**	*Immediate management*		Roseate Tern		Horned Grebe (w)	Audubon's Shearwater
		Management attention	Little Blue Heron	Gull-billed Tern			Greater Shearwater
				Least Tern			Band-rumped Storm-Petrel
				Black Skimmer			Bridled Tern
		Planning and responsibility	Masked Booby				Brown Booby
							Razorbill

c.	**Local and/or rare**	*Immediate Management*	Magnificent Frigatebird				
			Reddish Egret				
		Management attention					Cory's Shearwater
							Manx Shearwater
		Planning and responsibility		Bridled Tern			
Tier	**Tier Title**	**Action Level**	**Herons and allies, Pelicans and allies typically brush and tree nesting colonial waterbirds**	**Larids typically beach (ground)-nesting colonial waterbirds (terns, gulls, skimmers)**	**Marshes/ Savannas/ Grasslands**	**Open water (with mud and sand flats also foraging habitat for most colonial species)**	**Pelagic (all non-breeding populations)**
II.	**Regional Conservation Interest**						
a.	**High Concern**	Immediate Management	Wood Stork (b/r, FL, GA, SC, AL))		Least Bittern (b/r)	Red-throated Loon (w)	Sooty Shearwater
		Management attention	Green Heron		Purple Gallinule (b/r)	Common Tern (transient populations)	
			Black-crowned Night-Heron		American Coot (breeding populations only)	Black Tern (transient populations)	
			Wood Stork (nb, MS, LA, TX, AR, elsewhere)		Limpkin (r)		
					American Bittern (w)		

		Planning and responsibility	Yellow-crowned Night-Heron	Royal Tern			
				Sandwich Tern			
b.	**High Threats**	*Immediate management*			Sandhill Crane (Mississippi subspecies)		
		Management attention	White Ibis	Common Tern (Atlantic and Gulf coast breeding populations only)	Pied-billed Grebe (breeding populations only)	Greater Flamingo (formerly bred)	Northern Gannet
						Common Loon (w)	
						American White Pelican (w)	
Tier	**Tier Title**	**Action Level**	**Herons and allies, Pelicans and allies typically brush and tree nesting colonial waterbirds**	**Larids typically beach (ground)-nesting colonial waterbirds (terns, gulls, skimmers)**	**Marshes/ Savannas/ Grasslands**	**Open water (with mud and sand flats also foraging habitat for most colonial species)**	**Pelagic (all non-breeding populations)**
II.							
c.	**High Responsibility**	*Planning and responsibility*	Brown Pelican	Forster's Tern (actually nests in marshes)	Clapper Rail (r)	Franklin's Gull (transient populations)	Sooty Tern
			Tricolored Heron	Sooty Tern (Florida breeding population only; nests under cover)	Sandhill Crane (Florida subspecies)	Bonaparte's Gull (w)	Brown Noddy
				Brown Noddy (Florida breeding population only; elevated nests in shrubs, trees)	Sandhill Crane (Greater, Lesser, and Canadian subspecies)		

III.	**Additional Federal and State Listed Species**						
IV.	**Additional local or regional interest**	*Planning and responsibility*	Anhinga	Caspian Tern	Least Grebe (r)	Eared Grebe (w)	
			Great Blue Heron		Common Moorhen (b/r)		
			Great Egret		Virginia Rail (w)		
			Snowy Egret		Sora (w)		
			Glossy Ibis				
			White-faced Ibis				
			Roseate Spoonbill				
Tier	**Tier Title**	**Action Level**	**Herons and allies, Pelicans and allies typically brush and tree nesting colonial waterbirds**	**Larids typically beach (ground)-nesting colonial waterbirds (terns, gulls, skimmers)**	**Marshes/ Savannas/ Grasslands**	**Open water (with mud and sand flats also foraging habitat for most colonial species)**	**Pelagic (all non-breeding populations)**
IV.		*Population Control*	Neotropical Cormorant	Laughing Gull			
			Double-crested Cormorant	Herring Gull			
			Cattle Egret	Great Black-backed Gull			
	Other species covered in this plan					Pied-billed Grebe (non-breeding populations)	Wilson's Storm-Petrel

						American Coot (non-breeding populations)	Leach's Storm-Petrel
						Ring-billed Gull	Pomarine Jaeger
						Lesser Black-backed Gull	Parasitic Jaeger
							Black-legged Kittiwake
							Dovekie

*See Appendices I-III.

Tier=

I. Continental Conservation Interest (Continental WatchList): (a) Species with multiple causes for concern across their entire range; (b) Moderately abundant or widespread species with declines or high threats, and (c) Species with restricted distributions or low population size.

Species with multiple causes for concern across their entire range: These species are considered by many to be of highest continental concern and of highest priority for conservation actions at national and international scales.

Moderately abundant or widespread species with declines or high threats: These species are on the Watch List primarily because they are declining and/or threatened throughout their range, though still fairly widespread or with moderately large populations.

Species with restricted distributions or low population size: These species are on the Watch List because they are restricted to a small range or have small global populations (often both). Many of these species are not known to be declining or seriously threatened at present, but many others. We recognize that these species with small populations and restricted range are particularly vulnerable to relatively minor changes from current conditions, whether or not their populations are currently in decline.

II. Regional Conservation Interest (non-WatchList; TOT$\geq$19): (a) high regional concern (AI+PT$\geq$8); (b) high regional threats (TB+TN$\geq$7, or TB or TN=5) and includes taxa (subspecies and populations) of regional conservation interest not otherwise included in categories above; (c) high regional responsibility (as measured by percent of global, continental, or regional populations).

III Additional Federally and/or State listed.

IV Local or regional concern or interest.

Act. Level=Action Level at present based on expert opinion, but ultimately rules based on scores would be preferable.

IM=Immediate management needed to reverse or stabilize significant, long-term population declines in species with small populations, or to protect species with the smallest populations for which trends are poorly known. Lack of action may lead to extirpations or extinction.

MA=Management or other on-the-ground conservation actions needed to reverse or stabilize significant, long-term population declines in species that are still relatively abundant.

PR=Long-term Planning and Responsibility needed for species to ensure that sustainable populations are maintained for species for which a region has high responsibility for that species.

PC=Population Control/Suppression needed for species that are otherwise secure and increasing that may come into conflict with other species of higher conservation concern or other resources of interest.

APPENDIX C

Wildlife Conservation Commission

FLORIDA'S ENDANGERED SPECIES, THREATENED SPECIES AND SPECIES OF SPECIAL CONCERN

Official Lists

Publication Date: 1 August 1997

This document consolidates the state and federal official lists of endangered species, threatened species, and other species categorized in some way by the respective jurisdictional agencies as meriting special protection or consideration. The state lists of animals are maintained by the Florida Game and Fresh Water Fish Commission and categorized as endangered, threatened and of special concern, and constitute Rules 39-27.003, 39-27.004 and 39-27.005, respectively, Florida Administrative Code (F.A.C.). The state lists of plants are categorized into endangered, threatened and commercially exploited, and are administered and maintained by the Florida Department of Agriculture and Consumer Services via Chapter 5B-40, F.A.C. The federal lists of animals and plants are administered by the U.S. Fish and Wildlife Service and categorized into endangered and threatened, and are published in 50 CFR 17 (animals) and 50 CFR 23 (plants). The abbreviations used in part one are:

GFC = Florida Fish and Wildlife Conservation Commission

FDA = Florida Department of Agriculture and Consumer Services

FWS = United States Fish and Wildlife Service

E = Endangered

T = Threatened

T(S/A) = Threatened/Similarity of Appearance

T(E/P) = Threatened/Experimental Population

SSC = Species of Special Concern

C = Commercially Exploited

		Designated Status	
Scientific Name	**Common Name(s)**	**GFC**	**FWS**
Birds			
Ajaia ajaja	Roseate spoonbill	SSC	
Ammodramus maritimus juncicolus	Wakulla seaside sparrow	SSC	

		Designated Status	
Scientific Name	**Common Name(s)**	**GFC**	**FWS**
Ammodramus maritimus mirabilis	Cape Sable seaside sparrow	E	E
Ammodramus maritimus peninsulae	Scott's seaside sparrow	SSC	
Ammodramus savannarum floridanus	Florida grasshopper sparrow	E	
Aphelocoma coerulescens	Florida scrub-jay	T	T
Aramus guarauna	Limpkin	SSC	
Campephilus principalis	Ivory-billed woodpecker	E	E
Charadrius alexandrinus tenuirostris	Southeastern snowy plover	T	
Charadrius melodus	Piping plover	T	T
Cistothorus palustris griseus	Worthington's marsh wren	SSC	
Cistothorus palustris marianae	Marian's marsh wren	SSC	
Columba leucocephala	White-crowned pigeon	T	
Dendroica kirtlandii	Kirtland's warbler	E	E
Egretta caerulea	Little blue heron	SSC	
Egretta rufescens	Reddish egret	SSC	
Egretta thula	Snowy egret	SSC	
Egretta tricolor	Tricolored (=Louisiana) heron	SSC	
Eudocimus albus	White ibis	SSC	
Falco peregrinus tundrius	Arctic peregrine falcon	E	
Falco sparverius paulus	Southeastern American kestrel	T	
Grus americana	Whooping crane	SSC	T(E/P)
Grus canadensis pratensis	Florida Sandhill crane	T	
Haematopus palliatus	American oystercatcher	SSC	
Haliaeetus leucocephalus	Bald eagle	T	T
Mycteria americana	Wood stork	E	E

		Designated Status	
Scientific Name	**Common Name(s)**	**GFC**	**FWS**
Pandion haliaetus	Osprey	SSC*	
Pelecanus occidentalis	Brown pelican	SSC	
Picoides borealis	Red-cockaded woodpecker	T	E
Polyborus plancus audubonii	Audubon's crested caracara	T	T
Rostrhamus sociabilis	Snail kite	E	E
Rynchops niger	Black skimmer	SSC	
Speotyto cunicularia	Burrowing owl	SSC	
Sterna antillarum	Least tern	T	
Sterna dougallii	Roseate tern	T	T
Vermivora bachmanii	Bachman's warbler	E	E
*Applicable in Monroe County only			

APPENDIX D

US FISH AND WILDLIFE SERVICE, SPECIES OF CONSERVATION CONCERN IN PENINSULAR FLORIDA (BCR 31)

Black-capped Petrel
Audubon's Shearwater
Magnificent Frigatebird
American Bittern
Little Blue Heron
Reddish Egret
White Ibis
Swallow-tailed Kite
Short-tailed Hawk
American Kestrel (resident *paulus* ssp. only)
Peregrine Falcon
Yellow Rail
Black Rail
Limpkin
Snowy Plover
Wilson's Plover
American Oystercatcher
Whimbrel
Marbled Godwit
Red Knot
Semipalmated Sandpiper
Stilt Sandpiper
Buff-breasted Sandpiper
Short-billed Dowitcher
Gull-billed Tern
Common Tern
Least Tern
Black Tern
Black Skimmer
White-crowned Pigeon
Common Ground-Dove
Mangrove Cuckoo
Smooth-billed Ani
Burrowing Owl
Chuck-will's-widow
Red-headed Woodpecker
Loggerhead Shrike
Black-whiskered Vireo
Brown-headed Nuthatch
Yellow Warbler (resident *gundlachi* ssp. only)
Yellow-throated Warbler
Prairie Warbler
Bachman's Sparrow
Henslow's Sparrow
Nelson's Sharp-tailed Sparrow
Saltmarsh Sharp-tailed Sparrow
Seaside Sparrow
Painted Bunting

APPENDIX L.3

BUCK ISLAND REEF NATIONAL MONUMENT

DRAFT

Avian Conservation Implementation Plan
Buck Island Reef National Monument

National Park Service
Southeast Region



Compiled by J. Keith Watson
U.S. Fish and Wildlife Service
In cooperation with

BUIS Resource Management Staff, National Park Service
And Bird Conservation Partners
November 2003

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Introduction

This Avian Conservation Implementation Plan (ACIP) is provided to the staff at Buck Island Reef National Monument (BUIS) to serve as guidance to identify, document, and undertake bird conservation activities in the park and with neighboring communities, organizations, and adjacent landowners. This plan may identify goals, strategies, partnerships, and perhaps specific projects for the park to participate in existing bird conservation planning and implementation efforts associated with the North American Bird Conservation Initiative (NABCI). Under the auspice of NABCI, appropriate bird and habitat conservation goals may be recommended as identified in the appropriate existing national or regional bird conservation efforts aligned with this initiative: Partners In Flight (PIF), North American Waterfowl Management Plan (NAWMP), US Shorebird Conservation Plan (USSCP), and Waterbird Conservation for the Americas (WCA). For example, parks in the Appalachians and the Cumberland Plateau will have few if any high priority waterbird conservation issues at a regional landscape or greater scale. As such, little information regarding waterbird conservation will be presented in the ACIP, unless there is an identified park need for this species group, or other mandates, such as federal laws. Similarly, because BUIS has both coastal and upland avifauna, recommendations will be provided in the ACIP based on the PIF plan, as well as national shorebird and colonial waterbird plans. However, all high priority bird conservation issues for BUIS will be discussed and integrated as appropriate.

Information and data presented in the ACIP have been obtained from several sources: 1) interviews with BUIS staff 2) BUIS bird conservation partners 3) the PIF Puerto Rico and US Virgin Islands Bird Conservation Plan (Nunez-Garcia and Hunter 2000) 4) NPS databases, and 5) personal communications with bird conservation specialists throughout North America and the Caribbean. This plan has been reviewed by BUIS resource management staff and managers, South Florida/Caribbean Inventory and Monitoring Network (SF/C) staff, and bird conservation partners and approved by BUIS management. Optimally, this plan will be incorporated into the park's Resource Management Plan (RMP) and updated annually to reflect completed projects, newly identified needs, and shifts in bird conservation priorities in the region.

BUIS is not obligated to undertake any of the proposed actions in this plan. The plan is provided to offer guidance to BUIS to voluntarily support important park, regional, and perhaps national and international bird conservation projects for which BUIS is a primary participant in the proposed actions.

Background

During the past thirty years, monitoring programs across North America have documented declines of certain bird species populations and their habitats, often severe (Sauer et al. 2000). The decline has caused great concern among scientists, biologists, biodiversity

proponents, ecologists, land managers, etc., and the bird conservation community in general. Birds are recognized as critical components of local and global genetic, species, and population diversity, providing important and often critical ecological, social, and cultural values. Their overall decline has stimulated a worldwide focus on conservation efforts and North American interest in bird conservation is rapidly becoming a focus of government, non-government, industry, and private interests and expenditures.

Many state, federal, and non-governmental wildlife agencies and organizations (NGO's) have recognized this alarming bird decline trend and have joined forces in several extensive partnerships to address the conservation needs of various bird groups and their habitats. The primary initiatives are:

- North American Waterfowl Management Plan
- Partners in Flight
- U.S. Shorebird Conservation Plan
- Waterbird Conservation for the Americas

While efforts associated with these plans have generated some successes, it has been increasingly recognized that the overlapping conservation interests of these initiatives can be better served through more integrated planning and delivery of bird conservation. The *North American Bird Conservation Initiative (NABCI)* arose out of this realization. The vision of NABCI (http://www.nabci-us.org/main2.html) is simply to see ***"populations and habitats of North America's birds protected, restored and enhanced through coordinated efforts at international, national, regional, state and local levels, guided by sound science and effective management."*** NABCI seeks to accomplish this vision through (1) broadening bird conservation partnerships, (2) working to increase the financial resources available for bird conservation in the U.S., and (3) enhancing the effectiveness of those resources and partnerships by facilitating integrated bird conservation (U.S. NABCI Committee 2000). Together, the four bird conservation initiatives mentioned above, as well as several other local and regional partnerships, work collectively to pursue this vision.

NABCI is guided by a set of principles that establish an operational framework within which the Initiative and its partners may conduct integrated bird conservation in the U.S. These will articulate a common understanding of the relationship between NABCI, the individual bird conservation initiatives, and all partner entities to ensure recognition of existing federal legislative and international treaty obligations, state authorities, and respect for the identity and autonomy of each initiative. The fundamental components of the conservation approach to be used by NABCI are expressed within its goal:

> ***To deliver the full spectrum of bird conservation through regionally-based, biologically-driven, landscape-oriented partnerships.***

The Southeastern Bird Conservation Initiative: National Park Service: In 1999, the Southeast Region of the National Park Service (NPS) recognized the importance of coordinating existing bird conservation goals into planning and operations of national park

units in the southeast, that is, integration of NABCI. In support of this recognition, the Southeast Regional Office NPS approved and allocated eighty-eight thousand dollars, cost sharing 1:1 with the US Fish and Wildlife Service (FWS) Region 4 (Southeast) to hire a biologist to conduct this two-year project (Interagency Agreement FS028 01 0368). This project is unique in the NPS, and perhaps the nation, and represents a potential model for better coordinating regional bird conservation programs and activities within and outside the NPS. It further represents a progressive action toward institutionalizing bird conservation as a programmatic priority in the Southeast Region of NPS, and potentially the nation.

As envisioned, the integration of NABCI into the Southeastern NPS involves:

1) Development and delivery of Avian Conservation Implementation Plans (ACIP),
2) Coordination with NPS Inventory and Monitoring Program,
3) Development of a web based project site,
4) Establishment or enhancement of bird conservation partnerships,
5) Identification and exploration of potential funding opportunities, and
6) Technical guidance and assistance as needed or requested.

This ACIP fulfills one aspect of the plan outlined above, and serves as a basis for future bird conservation actions in BUIS and with adjacent partners or landowners. Concurrently, the development of a Memorandum of Understanding (MOU) between the FWS and the NPS to implement Presidential Executive Order (EO) 13186, **Responsibilities of Federal Agencies to Protect Migratory Birds**, calls for integration of programs and recommendations of existing bird conservation efforts into park planning and operations. Complementing each other, the MOU and the Southeastern Bird Conservation Initiative will advance bird conservation in the Southeast Region of the NPS beyond current regional NPS efforts.

Role of NPS in Avian Conservation

The interagency agreement that facilitates this partnership supports both FWS and NPS management policies. Specifically for the NPS, the agreement supports and advances the **Strategy for Collaboration** (March 2000), a visionary document developed and signed by the Southeast Natural Resource Leaders Advisory Group (SENRLAG), a consortium of 13 land and resource management agencies in the Southeastern United States whose vision is to encourage and support cooperation in planning and managing the region's natural resources. Furthermore, the agreement is aligned with and implements a variety of NPS Management Polices (2001) including but not limited to External Threats and Opportunities (Chapter 1.5), Environmental Leadership (Chapter 1.6), Cooperative Planning (Chapter 2.3.1.9), Land Protection (Chapter 3), and especially Natural Resource Management (Chapter 4) that details policy and management guidelines which apply to bird conservation. Important policies in this chapter includes:

- Planning for Natural Resource Management (4.1.1)
- Partnerships (4.1.4)
- Restoration of Natural Systems (4.1.5)
- Studies and Collection (4.2)
- General Principles for Managing Biological Resources (4.4.1)
- Plant and Animal Population Management Principles (4.4.1.1)
- Management of Native Plants and Animals (4.4.2)
- Management of Endangered Plants and Animals (4.4.2.3)
- Management of Natural Landscapes (4.4.2.4)
- Management of Exotic Species (4.4.4)
- Pest Management (4.4.5)
- Fire Management (4.5) and
- Water Resource Management (4.6)

The NPS is the fourth largest landowner in the United States, consisting of over 380 national park units covering 83 million acres of land and water with associated biotic resources (www.nps.gov). The 64 units in the Southeast Region of the NPS represent 16% of the total number of park units in the national park system and cover approximately 5% of the total land base in the entire system. Park units in the Southeast Region include national seashores (Canaveral National Seashore, Cape Hatteras National Seashore), national parks (Great Smoky Mountains National Park, Buck Island Reef National Monument), national recreation areas (Big South Fork National River and Recreation Area), national preserves (Big Cypress National Preserve), national battlefields (Cowpens National Battlefield, Fort Donelson National Battlefield), national monuments (Congaree Swamp National Monument, Ocmulgee National Monument), and others such as the Blue Ridge Parkway, Obed Wild and Scenic River, and Timicuan Ecological and Historic Preserve.

Southeast NPS units provide habitat for over 400 species of migrating, breeding, and wintering birds and include a wide range of Federal and State listed threatened and endangered species. Likewise, these units also provide nest, migration, and winter habitat for most of the eastern species identified in the national bird conservation plans in need of conservation attention.

Additionally, the NPS attracts over 280 million visitors to the parks each year, 120 million of these in the Southeast Region, affording excellent recreational bird watching and opportunities to strengthen bird conservation interpretation, outreach, and education programs. These opportunities, the NPS mission, policies, and organization all lead to the conclusion that the NPS is an extremely valuable partner and contributor to bird conservation in the region.

Nationally, the status of birds in national parks is largely unknown, although many parks have adequate knowledge regarding bird occurrence in the parks (http://www.npwrc.usgs.gov/resource/othrdata/chekbird/chekbird.htm). Parks often play a

role in ongoing regional bird conservation efforts. Indeed many of these parks are often important to regional, national, or international bird conservation, and many have been designated as Important Bird Areas (IBA's) by the National Audubon Society. To date, there are approximately 64 NPS units that are designated IBA's, 35 of which are considered of global importance (http://abcbirds.org/iba/aboutiba.htm). In the Southeast Region, the NPS has 13 IBA's.

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The **NPS Inventory and Monitoring (I&M) Program** has been developed to provide management driven scientific information to national park managers so that resources can be adequately protected within national parks. One of the first phases of this program is to inventory vertebrates, including birds, within the 260 national park units in the program. Once completed, data from the inventories will provide an account of the occurrence and abundance of birds in all the national parks in the program. These records will be stored in the NPS I&M NPSpecies database http://www.nature.nps.gov/im/apps/npspp/). Coordination with I&M network staff is important to developing long-term bird monitoring programs that fulfill both park and NABCI objectives.

Park Flight is a NPS international partnership initiative that directs funding toward a variety of NPS programs that involve conservation of neotropical migratory birds whose life history range covers a US national park and a Latin American protected area. A relatively new program, Park Flight offers parks the opportunity to partner with a Latin American national park or protected area to cooperate on developing bird conservation and education projects (NPS 2002).

Recent increases in NPS base funded programs such as inventory and monitoring, exotic species management, habitat restoration, and fire management all indicate that national park managers recognize that park lands are increasingly subject to a variety of threats and conditions that must be improved to provide the quality of national park experience articulated in the NPS Organic Act (1916). Programmatic funding in these areas will increase the ability of national parks to provide quality habitat and conditions for increased wildlife conservation, including birds. Furthermore, private interests and non-profit conservation organizations have initiated programs, including grant programs, to provide much needed funding to national parks to meet backlogs of identified yet unfunded needs.

Park Description

President John F. Kennedy established Buck Island Reef National Monument in 1961. The monument was created to preserve one of the Caribbean's finest marine gardens for scientific and educational interest, and for recreational uses. Buck Island is located 1.5 miles northeast of St. Croix, the largest of the U.S. Virgin Islands. The monument totals 356 ha (880 acres), 71 ha (176 acres) are uninhabited subtropical dry forest island and 285 ha (704 acres) are submerged lands. The park's significance lies primarily in the extensive elkhorn coral barrier reefs surrounding the eastern two thirds of the island.

Recent research has identified the Buck Island coral reef ecosystem as critical developmental habitat for the endangered hawksbill sea turtle. The island provides nesting habitat for two endangered species – hawksbill and leatherback turtle– and two threatened species – the green turtle and least tern, as well as several rare native plant species, and one endemic beetle (*Longitarius zandae*).

Avian Resources of Puerto Rico and the US Virgin Islands

Puerto Rico and the Virgin Islands are part of the West Indies, a chain of islands that extends from Florida to Venezuela and separate the Caribbean Sea from the Atlantic Ocean. These tropical Islands are located within 17-19° latitude North and 64-68° longitude West about 1,609 kilometers from Florida and 805 kilometers from Venezuela.

The U.S. Virgin Islands are located about 64 kilometers east of the Puerto Rico. These Islands comprise another archipelago that includes St. Thomas, St. John, St. Croix, and numerous uninhabited small islets and cays. The three main Islands were bought by the U.S.A. from Denmark in 1917 and are now U.S. Territory with a total area of 340 km^{2}.

The number, size and shape of the islands comprised within this region combined with climate, topography, geological processes, and human activities have produced a tremendous diversity of habitats. Historically different types of forest covered most of the land area of Puerto Rico and the Virgin Islands. However, forest conversion caused by agricultural and other land use practices have shaped the present landscape. Forested landscape in the U.S. Virgin Islands is typified by sub-tropical dry forest and littoral shrubs.

Including vagrants, exotics and fossils, the total number of bird species in the region sums to 364. Presently, 276 species are known to occur in Puerto Rico and 210 in the Virgin Islands for a total of 284 species in the region (Raffaele 1989). Recent studies indicate that these numbers may change as many native forms may be reclassified as species or subspecies on their own. Raffaele (1989) categorized the regional birds species as follows: 97 breeding permanent residents (94 in Puerto Rico and 60 in the Virgin Islands), 11 breed and leave (11 in Puerto Rico and 10 in the Virgin Islands), 134 non-breeding migrants and visitors (134 Puerto Rico and 129 the Virgin Islands), 31 introduced probable breeders (31 in Puerto Rico and 6 in the Virgin Islands), five introduced possible breeders (same species for both Puerto Rico and the Virgin Islands), and one species recently extirpated from Puerto Rico. As the numbers indicate, migrant species comprise almost half of the species playing a major role in the ecology of the region. Also noteworthy is the establishment of a high number of exotic species. As a result of combining both native and exotic species, Puerto Rico supports 85 species of breeding land birds, the greatest number of any West Indian island and except for Cuba, harbors the second largest total number of species in the region (Raffaele 1989).

The oceanic nature of the islands in the region has resulted in increased endemism.

Puerto Rico harbors **16 endemic** bird species including one endemic genus (*Nesospingus*) represented by a single species, the Puerto Rican Tanager (*Nesospingus speculiferus*) and one family (Todidae) shared with the rest of the West Indian islands but found nowhere else. Rafaele (1989) considered 51 species to be threatened in the region mostly because of the detrimental effects of habitat alteration.

Avian Conservation in BUIS

Avian Biodiversity: BUIS has an avian presence inventory that is considered at least 90% complete. No public checklist is available at this time. Verified records of birds in BUIS have been entered into the NPS I&M program's database, NPSpecies, and may be viewed via the internet at http://www.nature.nps.gov/im/app/npspp with a user identification and password combination authorized by the NPS for NPS personnel and NPS cooperators. Many other avian observational data need to be verified and entered into the database.

Threatened and Endangered Species: One Federally listed endangered species, the Brown Pelican, nests in the park. The recently delisted American Peregrine Falcon occurs as a rare winter visitor to the park and vicinity.

Several USVI Territory **Listed** species occur in BUIS including Brown Pelican, White-crowned Pigeon, White-cheeked Pintail, Wilson's Plover, and Least Tern.

Several high priority PIF species for the Caribbean occur in BUIS (see Appendix A and B). Prominent among these species are White-crowned Pigeon, Yellow Warbler, White-cheeked Pintail, and Brown Pelican. It is likely that several Neotropical migrants, especially wood warblers, utilize the subtropical dry forests of the park of Buck Island. Though many of these species are not listed, they are of high conservation concern in the continental U.S. and conservation efforts for this species extend to the USVI. Conservation of these species should be coordinated with the US Virgin Island Department of Planning and Natural Resources (VIDPNR) (see contacts).

Park Priorities: Park staff and consultants have identified the Brown Pelican and Least Tern as a park management concern or high priority for conservation. Additionally, since the successful eradication of tree rats on the island, the staff has an interest in obtaining information on landbirds and how their populations respond to eradication of the rats. BUIS is certain to have some species that are high priority in the USVI and conservation efforts in the park could focus on these species or groups of species.

Inventory: A complete inventory has been recognized as important information for park managers and is being conducted within the framework of the NPS I&M Program. BUIS is one of seven parks in the South Florida/Caribbean I&M Network for which a plan to conduct high priority inventory projects has been prepared (Sasso and Patterson 2000).). Although VIIS avian inventory is considered complete in relation to the NPS's I&M goals

(90% or greater species known), additional inventory is desired to determine breeding bird distribution and abundance in the upland portions of the park.

Monitoring: Currently, several avian monitoring projects are being conducted at BUIS. These are:

- Brown Pelican reproductive survey that includes counts of adults, nests, and fledglings
- Least Tern nest and egg counts
- Christmas Bird Count (CBC) that covers Buck Island

Research: Scientific research is permitted within the park, but no active avian research other than existing avian inventory and monitoring is ongoing.

Outreach: The park conducts outreach and education regarding beach closures for nesting Least Terns on Buck Island.

Park Identified Needs for Avian Conservation

BUIS has identified at two projects that would increase the avian knowledge of the park.
Inventory:

- BUIS desires to identify and quantify all resident and migratory bird species the nest or ground forage

*Monitoring**:***

- The park desires to obtain populations trends data for nesting and ground foraging species

Coordination with Regional Conservation Initiatives

North American Bird Conservation Initiative

NABCI bird conservation planning units, referred to as Bird Conservation Regions (BCR), are often larger than other planning units associated with other plans, such as Partners In Flight. For example, BUIS is within the NABCI BCR 69 that includes all of the Commonwealth of Puerto Rico, the US Virgin Islands and the British Virgin Islands and includes the physiographic region designated by Partners in Flight as Puerto Rico/Virgin Islands (Figure 2; compare to Figure 1).

Several NABCI BCR's have coordinators whose primary responsibility is to coordinate all bird conservation planning in the BCR, across all agencies and organizations. Currently, the Caribbean BCR does not have a designated coordinator; however, the assistant coordinator for the Atlantic Coast Joint Venture (ACJV) can provide valuable assistance to BUIS with implementation of aspects of this ACIP.

North American Waterfowl Management Plan (NAWMP)

The NAWMP (http://northamerican.fws.gov/NAWMP/nawmphp.htm) is completed and has been revised several times, incorporating updated goals and strategies based on new information. This plan is one of the most successful bird conservation delivery programs in the United States, being monetarily supported by the North American Wetlands Conservation Act (NAWCA).

Partners In Flight

Goals and strategies for the Caribbean can be found in the draft bird conservation plan, previously submitted to the park. A revised version of this plan should be available in the near future and may be substantially different from the current format; however, bird and habitat conservation priorities are not likely to be significantly changed. The park will receive updates of the plan as they are completed. The current plan identifies priority bird and habitat conservation goals that must be implemented in order to achieve bird conservation success in this region.

Similar to NABCI BCR's, PIF physiographic areas often do not have designated coordinators. However, state level non-game agencies with investment in PIF will establish key personnel to develop partnerships among cooperators in the physiographic area. The USVI does not have a PIF coordinator, but several VIDPNR personnel are currently engaged in bird conservation in the USVI and will be instrumental with implementation of this ACIP and projects important to bird conservation relative to Buck Island's role in implementation of the Puerto Rico and US Virgin Islands bird conservation plan.

United States Shorebird Conservation Plan (USSCP)

The USSCP has been completed and is available on the world wide web (http://shorebirdplan.fws.gov/). A regional step down plan is in preparation by FWS personnel and should be available in 2003. Since BUIS has little habitat of regional importance to shorebird conservation, recommendations for shorebird conservation are not presented.

Waterbird Conservation for the Americas (WCA)

The WCA plan has been completed and is available on the World Wide Web or can be ordered from the US Fish and Wildlife Service National Conservation Training Center (http://www.waterbirdconservation.org/).

Integration of NABCI Goals and Objectives into Park Planning and Operations

NABCI Implementation Recommendations

To successfully achieve park-established goals and actively participate in NABCI, the park could implement a variety of projects in different NPS programs. Most of these projects would require some level of participation by many existing park programs and could either be achieved through NPS funding, or more likely, through establishing or improving partnerships with agencies and organizations that already have the necessary expertise to provide guidance, funding, and execution of these programs. Programmatic areas where bird conservation actions are likely to be focused are:

- Inventory
- Monitoring
- Habitat Restoration
- Threat Management (includes exotic species, air quality, water quality, etc.)
- Research
- Compliance
- Outreach
- Partnerships

To the extent appropriate, each of these program areas will be discussed separately and within each, specific opportunities identified that, when implemented, will enable to park to meet its mandates (current and expected) as well as integrate NABCI into its planning and operations. With emphasis added, the park is not expected to implement any of these recommendations or be obligated to pursue any opportunity other than those the park is required to do by law or NPS program or policy. In other words, participation in this effort is currently voluntary. However, participation in these efforts at some level could become mandatory with the completion of an MOU with the FWS regarding EO 13186, **Responsibilities of Federal Agencies to Protect Migratory Birds**. The MOU will establish a formal agreement between the FWS and the NPS to promote bird conservation within the agency by incorporating goals and strategies of existing bird conservation initiatives, plans, and goals into park planning and operations.

Should the park decide to implement any of these projects, further consultation with bird conservation contacts is encouraged to obtain updated information on the relevance of these opportunities in regional bird conservation.

High priority projects are identified in **bold** print. Priorities that the park is encouraged to seek NPS funding for are marked with and asterisk (*****). These projects are those that are critical to the stabilization or improvement of a bird population in the planning region.

Inventory

The park has inventoried its bird fauna exceptionally well. Although the avifauna of BUIS is well documented, distribution and abundance data are desired to fully understand the status of birds in the park so that conservation actions for birds can be implemented, especially for ground nesting and foraging birds. Additionally, information on use of Buck Island by Neotropical migrant birds wintering in the park is desired. Status of high priority species as identified in the Puerto Rico/US Virgin Islands bird conservation plan is needed to effectively structure park management for the continued preservation and enhancement of the park's avifauna.

Abundance and distribution data are needed

- **for all resident and migratory landbirds that nest and forage on or near the ground***
- **for birds that nest in mangroves***
- **for High Priority forest species such as White-crowned Pigeon***
- **for nesting, migrating, and wintering shorebirds, particularly American Oystercatcher and Wilson's Plover.**

Additionally, the park is encouraged to:

- **partner with the VIDPNR and USFWS to coordinate area inventory efforts**
- **verify other avian observational data collected in the park and enter into the appropriate database (NPSpecies, eBird Monitoring Program of Cornell's Laboratory of Ornithology, Columbid Database, etc.)**
- **standardize inventory and monitoring methodology to conform to NPS and/or FWS recommended standards (Fancy and Sauer 2000, Hunter 2000).**

Monitoring

The park has an active bird monitoring program resulting in documentation of many high priority species identified for conservation effort in the Caribbean and occur in the park. Efforts should be made to continue existing monitoring programs, striving to conform to established NPS or FWS surveys protocols. Close coordination with adjacent bird conservation initiatives are needed to identify and implement high priority projects on park lands and to ensure that park efforts contribute to park or regional bird conservation rather

than undertake an action or actions that are not needed or are better conducted in other areas. Specific recommendations are to:

- **continue to conduct existing monitoring programs and enter data into the appropriate database (NPSpecies, eBird, or National Point Count Database (USGS 2001) (http://www.mp2-pwrc.usgs.gov/point/)**

- **establish point count monitoring stations along ecologically distinct or vegetative/habitat types to document abundance and distribution of terrestrial landbirds year around in response to eradication of rats**

- **establish monitoring programs based on results of inventory data for High Priority species and with potential for high conservation role for any of these species**

- **standardize inventory and monitoring methodology to conform to NPS and/or FWS recommended standards (Fancy and Sauer 2000, Hunter 2000).**

- **partner with USVI territorial Department of Natural Resources and USFWS staff to coordinate area monitoring efforts**

Habitat Restoration/Management

Recently, habitat restoration efforts have increased on NPS lands; NPS receiving restoration emphasis and guidance in the 2001 Management Policies (NPS 2001). Habitat restoration efforts that parks may undertake are wetland restoration, grassland restoration, woodland restoration, etc. utilizing a wide range of tools to accomplish the restoration. Some of these tools may be but not limited to forest management practices, exotic species management, public use and recreation management, infrastructure development management, and prescribed fire.

Due to the protected nature of BUIS lands, and generally those in the national park system, the condition of habitats for bird use may be of higher quality than other natural, developed, agricultural, or forest lands under other management regimes. However, national park lands can be greatly improved for wildlife, and particularly bird use, by restoring processes important for habitat formation, succession, and structural development. Largely, these processes have not been managed historically in the national park system but current policy allows for active management of species, populations, and lands to provide for long-term conservation of park resources.
Protection, restoration, and enhancement of habitats in BUIS can greatly contribute to established habitat goals identified in the Puerto Rico/US Virgin Islands bird conservation plan.

Research suggests that the large contiguous moist forests of St. John provide significant habitat for wintering Neotropical migrants (Askins et al. 1989). Thought the forests of Buck Island are much smaller, efforts should be made to determine the importance of this habitat to wintering Neotropical migrants.

Specific recommendations are to:

- restore and/or improve hydrological quality and processes where needed, especially in coastal mangrove and salt ponds

- assess Pre-Columbian landscape cover and determine feasibility of restoring landscape within the context of the park's enabling legislation

Threat Management

Impact of exotic species on birds at VIIS has been the greatest threat to the avifauna of BUIS. However, since the eradication of the mongoose in the 1980's and the tree rat in the early 2000's, no significant exotic mammalian threat exists on Buck Island. Current threats include human and dog intrusions on the Least Tern colony on the beach. The park is encouraged to:

- **manage visitor use, especially boat landings and dogs off lease, at the Island to protect and eliminate disturbances to the Least Tern colony***

- **identify, monitor, and document bird mortality associated with the US Coast Guard tower, especially during migrations of Neotropical migrants***

- **enforce the no dog policy***

- **identify potential bird injury or mortality associated with fishing gear and fishing practices in the park and nearby waters, especially for Brown Pelican, Brown Booby, and Magnificent Frigatebird***

Although exotic plants species may negatively impacting habitat at BUIS, the nature of this impact on native birds is unknown. It is important to

- **establish and continue inventory and monitoring of exotic plant species***

- **identify any potential impact these species have on native avifauna***

- **establish appropriate management programs to restore native forests***

If necessary, consult with regional Exotic Plant Management Team (EPMT) to remove

exotic plant species. Currently, no EPMT provides service the VIIS area. Until an EPMT is established that can provide assistance to VIIS, staff is directed to consult with the regional pest management specialist (see contacts).

Additionally, the park is encouraged to:

- **hire additional protection staff to better manage threats and implement projects identified in this plan***

- **develop aggressive outreach and education program for protection of Buck Island resources**

Research

- **list park needs and projects on Research Permit and Reporting System web site (RPRS)**

- develop contact with South Florida/Caribbean Cooperative Ecosystem Studies Unit (CESU) at the University of Miami, Miami, FL

Compliance

Park compliance with the Migratory Bird Treaty Act and the Executive Order 13186, **Responsibilities of Federal Agencies to Protect Migratory Birds,** is necessary to assure that park activities incorporate bird conservation into park planning and operations. Further, to ensure that migratory birds are considered in all phases of park planning processes, especially during the National Environmental Policy Act (NEPA) and the Director's Order #12 Compliance processes, the park should consider adding specific language in project evaluations that requires consideration and implications of park projects on migratory birds. The MOU being developed between the NPS and the FWS will likely contain specific language requiring a park to consider implications of park projects on migratory birds. Additional considerations are to encourage:

- **park staff to begin specific consideration of migratory birds during park planning processes***

- park staff to attend USFWS training on implementation of EO 13186 at the National Conservation Training Center (NCTC) (when available) or other training on migratory bird conservation in North America. NCTC has several courses and training related to conservation of migratory birds (http://training.fws.gov/courses.html).

The USFWS NCTC offers and reserves two tuition free slots for National Park Service

employees wishing to attend NCTC courses on a first come, first served basis. Additionally, discount lodging is also available while attending a NCTC course.

Outreach

- **participate in International Migratory Bird Day (IMBD) events with a local partner (http://birds.fws.gov/imbd.html)***
- **update the bird checklist for public availability***
- **nominate BUIS as an Important Bird Area (http://www.abcbirds.org/iba/nominstr.htm)**
- **continue to develop and implement outreach and educational programs to enhance visibility of bird conservation issues**
- **encourage Virgin Islands Audubon Society to participate in ongoing and new inventory and monitoring programs**
- **encourage accurate documentation and reporting from these and random outings by visitors (see Cornell University's eBird monitoring program (Cornell Lab. Ornith. 2002 (http://www.ebird.org/about/index.jsp)**
- park interpretation/education staff are encouraged to attend USFWS training on Migratory Bird Education at NCTC
- consider adding links to bird conservation information, data, etc. to the park's web site home page
- support bird conservation by serving shade-grown coffees at meetings, events, and the office buildings in the park (http://www.americanbirding.org/programs/conssbcof3.htm)
- participate in bird conservation efforts of the Society for the Conservation and Study of Caribbean Birds (SCSCB), including subscribing to this organization's electronic information forum
- explore cultural affiliation of landscape to inhabitants, both historical and contemporary. Cultures are strongly tied to the landscape they inhabit and birds often play a role in a cultural tie to the landscape. When these connections are discovered and preserved, a greater appreciation for the landscape and it's value to the culture can be achieved

Partners and Partnerships

Partnerships for land conservation and protection will perhaps have the greatest positive influence on bird conservation above all other landscape scale planning. Specific recommendations are to:

- **cooperate and USVI DNR in the preparation and implementation of the USVI Comprehensive Wildlife Conservation Plan**

- **work with the White-crowned Pigeon Working Group of the SCSCB to determine appropriate conservation actions for this species in the park**

- **become a contributing member of the Caribbean Columbid Population Data Center, a cooperative effort of the Puerto Rico Department of Natural Resources, USFWS, and other Caribbean interests to assess populations status and implement conservation actions necessary for these species**

- **contact the nearest Joint Venture office (see Funding section for explanation of Joint Ventures) or BCR coordinator to develop partnerships and funding proposals tiered to priorities established by the park, this ACIP, and the Puerto Rico and US Virgin Islands Bird conservation plan**

- **encourage the USVI territorial government to become a member of the Atlantic Coast Joint Venture, increasing USVI partners chances to utilize NAWCA funds for bird and habitat conservation projects**

- continue to maintain productive relationship with local Audubon Society

- explore the potential to utilize facilities and expertise at the Virgin Island Environmental Research Station (VIERS) to conduct needed avian research and implementation of aspects of this plan

Funding Opportunities

Internal NPS funding is often an effective source to obtain funding; however, the project will have to be a fairly high priority among the park's natural resource program to successfully compete for the limited funding available in the NPS. Therefore, partnerships and outside funding programs are often more productive for securing bird conservation funding. Within this ACIP, identified priority projects that are considered to be high park priorities as well as NABCI priorities are marked with and asterisk (*). BUIS is encouraged to enter all high priority projects into the NPS Performance Management Information System (PMIS) database.

Funding for conservation projects for neotropical migrants is also available through the Park Flight program.

With the exception of the North American Waterfowl Management Plan (NAWMP and its associated funding legislation, the North American Wetland Conservation Act), funding opportunities for bird conservation programs, plans, and initiatives have been lacking. Only within the last decade have other appropriate and specific sources for bird conservation funding been created and used. The NAWMP has been supported for approximately 14 years by the North American Wetlands Conservation Act (NAWCA 1989). This program has provided $487 million in appropriated funds matched with $1.7 billion for wetland and bird conservation projects since its inception. In 2002 alone, over $70 million US dollars were awarded to US and Canadian agencies and organizations to enhance waterfowl populations by improving, restoring, or protecting wetland habitats. To adequately evaluate projects and distribute these funds, partnerships called Joint Ventures were established. Nationally, 14 (11 US, 3 Canada)
Joint Ventures have been established, several which are funded and staffed. Internet links to Joint Ventures are:

(http://southwest.fws.gov/gulfcoastjv/ojvcontact.html) and
(http://northamerican.fws.gov/NAWMP/jv.htm).

Funding through NAWCA is highly underutilized by the NPS and any park unit that has wetland, water, or bird conservation needs associated with wetland are encouraged to investigate using this funding source. Naturally, there are certain requirements to be eligible for all grants and park managers are encouraged to consult with the nearest Joint Venture, BCR, PIF Coordinator, to learn how this program might be applicable to implementation of this plan, and other park wetland issues. BUIS is not within a region which has an operational Joint Venture, but contact with the Atlantic Coast Joint Venture, Central Hardwoods BCR, and Tennessee PIF coordinators will provide opportunity to investigate use of this funding source and developing proposals.

Internal FWS funding programs may be used to support projects, but no effective method of project proposal delivery to these sources is currently in place for the NPS. Current funding in these programs may result from FWS familiarity with NPS needs, or NPS participation in one of the area FWS Ecosystem Teams, where a project has been identified and proposed to be funded through the Ecosystem Team.

One unexplored yet potentially fruitful funding source for national parks is the myriad of grants through the FWS State Programs, where grants are awarded to private individuals engaged in habitat conservation projects. No funding is directly available to national parks, but identified projects with important or critical adjacent landowners can sometimes be funded through these sources. Similar programs are available if the adjacent landowner is a federally recognized American Indian tribe.

Specific congressional appropriations to protect migratory birds has recently been authorized under the Neotropical Migratory Bird Conservation Act (2000) (http://www.nfwf.org/programs/nmbcapp.htm). Appropriations through this Act are authorized up to $5 million per year. However, in 2000, appropriation was approximately $3.75 million and a majority of this funding was directed toward projects in Central and South America.

Many of the identified projects are eligible for funding under various grant programs of the National Fish and Wildlife Foundation (http://www.nfwf.org/programs/programs.htm).

Other prominent funding sources available to NPS managers for bird conservation are listed on this projects web site at:
http://southeast.fws.gov/birds/NPSHighlits.htm.

Funding opportunities for migratory bird conservation are available yet most natural resource agencies are not fully aware of and/or understanding of how to use these sources. Perhaps a consolidated migratory bird funding source catalog will become available to managers in the future; this is needed.

Contacts

Primary contacts within the region can be obtained by viewing the web site for the Southeastern Bird Conservation Initiative, National Park Service at http://southeast.fws.gov/birds/npsbirds.htm. This web site will provide contact information of the appropriate bird conservation coordinator in the region for park personnel. Park staff is encouraged to view the web site and obtain contact information. Primary contacts for BUIS are:

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APPENDIX A

PUERTO RICO AND VIRGIN ISLANDS (BCR 69) BASED ON CONTINENTAL AND REGIONAL WATCH LIST AMONG ALL BIRDS WITHIN SOUTHEAST U.S., AND THE WEST INDIES*

(Action Levels: IM=Immediate Management; MA=Management Attention; PR=Long-Term Planning and Responsibility) (subspecies/populations of interest noted; all species breed or are resident unless otherwise indicated; ba=number of breeding adults)

Tier I. Continental Conservation Interest

a. Multiple Causes for concern across entire range

White-tailed Tropicbird	(500-600 pairs, 14-19% in West Indies)	IM
Red-billed Tropicbird	(375-450 pairs, 14-22% in West Indies)	IM
West Indian Whistling-Duck	(<100 ba, 1-5% globally)	IM
Black Rail	(Extirpated?)	IM
Snowy Plover	(Threatened Pacific Coast; West Indies subspecies)	IM
Piping Plover	(Endangered, winter)	IM
Plain Pigeon	(Endangered; <5,000 ba, <10% globally)	IM
Puerto Rican Parrot	(Endangered; <100 ba in the wild, 100% globally)	IM
Puerto Rican Nightjar	(Endangered; <2,000 ba, 100% globally)	IM
White-necked Crow	(Endangered/Extirpated from Puerto Rico)	IM
Bicknell's Thrush	(Possible rare winter in Puerto Rico)	PR
Golden-winged Warbler	(Rare winter)	PR
Elfin-Woods Warbler	(Candidate for Listing; <1,000 ba, 100% globally	IM
Yellow-shouldered Blackbird	(Endangered; <500 ba, 100% globally)	IM

b. Moderately abundant or widespread with declines and/or high threats

Audubon's Shearwater	(~150 pairs, 2-4% in West Indies)	IM
Masked Booby	(300 pairs, 50% in West Indies)	IM
Red-footed Booby	(1,450-2,650 pairs, 15-33% in West Indies)	IM
Brown Booby	(2,075-2,300 pairs, 22-36% in West Indies)	MA
Little Blue Heron		MA
American Golden-Plover	(Rare southbound transient)	PR
Lesser Yellowlegs	(non-breeding)	MA
Solitary Sandpiper	(transient)	MA
Upland Sandpiper	(Rare transient)	PR
Whimbrel	(non-breeding)	MA
Sanderling	(non-breeding)	MA
Semipalmated Sandpiper	(non-breeding)	MA
Western Sandpiper	(non-breeding)	MA
Stilt Sandpiper	(non-breeding)	MA
Wilson's Snipe	(winter)	MA
Gull-billed Tern	(non-breeding?)	PR
Roseate Tern	(North Atl. Endangered, West Indies Threatened; 1,200-3,600 pairs, >25% in West Indies)	IM
Least Tern	(Calif. & interior subspecies Endangered; 300-450 pairs, 8-25% in West Indies)	IM
White-crowned Pigeon		MA
Mangrove Cuckoo		MA
Short-eared Owl	(Greater Antillean subspecies)	MA

Puerto Rican Vireo	(100 % globally)	MA
Prairie Warbler	(winter)	MA
Prothonotary Warbler	(winter)	MA
Worm-eating Warbler	(winter)	MA
Kentucky Warbler	(Rare winter)	PR
Greater Antillean Oriole	(10-20% globally)	MA

c. Restricted distributions and/or low population size

Magnificent Frigatebird	(700-900 pairs, 13-21% in West Indies)	IM
Reddish Egret	(Rare, non-breeding)	PR
Caribbean Coot	(1,000 ba, <50,000 West Indies)	IM
Wilson's Plover		MA
American Oystercatcher	(Eastern North American subspecies)	IM
Red Knot	(non-breeding; presumably Alaskan subspecies)	PR
Bridled Tern	(900-1,700 pairs, 15-40% in West Indies)	MA
Antillean Nighthawk		PR
Black Swift	(West Indian subspecies)	MA
Lesser Antillean Pewee	(Puerto Rican subspecies)	PR
Blue-winged Warbler	(Rare, winter)	PR
Adelaide's Warbler	(100% globally)	PR
Swainsons's Warbler	(Rare, winter)	PR

Tier II. Regional Conservation Interest

a. High Concern

Brown Pelican	(West Indies, Endangered; 520-850 pairs, 25-40% in West Indies)	IM
Green Heron		MA
Yellow-crowned Night-Heron		PR
Black-bellied Plover	(non-breeding)	MA
Ruddy Turnstone	(non-breeding)	MA
Least Sandpiper	(non-breeding)	MA
Antillean Mango	(nearly extirpated on Virgin Islands)	MA
Black-whiskered Vireo		PR

b. High Threats

Pied-billed Grebe	(breeding populations only)	MA
Least Bittern		MA
Black-crowned Night-Heron		MA
Greater Flamingo	(Extirpated as a resident, may be recolonizing)	MA
White-cheeked Pintail	(Lesser subspecies; <5,000 ba Puerto Rico-Virgin Islands; ~60,000 ba in West Indies)	MA
Ruddy Duck	(West Indian subspecies; ~1,500 ba Puerto Rico; <<50,000 ba West Indies)	MA
Masked Duck	(West Indian populations; <100 ba Puerto Rico; <<50,000 ba West Indies)	MA
Sharp-shinned Hawk	(Puerto Rican subspecies, Endangered; <100 ba)	IM
Broad-winged Hawk	(Puerto Rican subspecies, Endangered; <100 ba)	IM
American Kestrel	(Eastern Caribbean subspecies)	MA
Clapper Rail		MA

Yellow-breasted Crake	(Hispaniolan-Puerto Rican subspecies)	MA
Purple Gallinule		MA
Limpkin	(Hispaniolan-Puerto Rican subspecies)	IM
Willet		MA
Key West Quail-Dove		MA
Bridled Quail-Dove		MA
Puerto Rican Screech-Owl	(Virgin Islands subspecies, extirpated except on Culebra?)	IM
Yellow Warbler	(West Indian "Golden" subspecies)	MA
Louisiana Waterthrush	(winter)	MA

c. High Responsibility

Tricolored Heron		PR	
Black-necked Stilt			PR
Pectoral Sandpiper	(transient)		PR
Sooty Tern	(55,000-80,000 pairs, 20-40% in West Indies)		PR
Black Tern	(transient)		PR
Brown Noddy	(1,300-2,100 pairs, 7-18% in West Indies)		PR
Scaly-naped Pigeon			PR
Zenaida Dove			PR
Puerto Rican Lizard-Cuckoo	(100% global)		PR
Puerto Rican Screech-Owl	(Puerto Rican subspecies; 100% globally)		PR
Green Mango	(100% globally)		PR
Antillean Crested Hummingbird			PR
Puerto Rican Emerald	(100% globally)		PR
Puerto Rican Tody	(100% globally)		PR
Puerto Rican Woodpecker	(100% globally)		PR
Caribbean Elaenia			PR
Puerto Rican Flycatcher	(100% global, nearly extirpated Virgin Islands)		PR
Gray Kingbird			PR
Loggerhead Kingbird	(Puerto Rican-Vieques subspecies)		PR
Caribbean Martin			PR
Cave Swallow			PR
Red-legged Thrush	(Hispaniolan-Puerto Rican subspecies)		PR
Northern Parula	(winter)		PR
Cape May Warbler	(winter)		PR
Black-throated Blue Warbler	(winter)		PR
Puerto Rican Tanager			PR
Puerto Rican Spindalis			PR
Antillean Euphonia			PR
Puerto Rican Bullfinch	(Puerto Rican subspecies; 100% globally)		PR
Grasshopper Sparrow	(Puerto Rican subspecies)		PR

Tier III. Additional State, Territorial Listed Species (drawn from species in Tier IV)

Least Grebe	PR
Great Blue Heron	PR
Great Egret	PR
Snowy Egret	PR

Tier IV. Additional Local or Regional Interest Species (also Stewardship Species identified

by Avifaunal Biome supporting vast majority of breeding population)

Glossy Ibis				PR
Northern Pintail		(winter)		MA
Blue-winged Teal		(winter)		MA
Lesser Scaup		(winter)		MA
Northern Harrier	(winter)		PR	
Osprey				PR
Merlin		(mostly transient)		PR
Peregrine Falcon		(mostly transient)		PR
Sora		(winter)		PR
Common Moorhen				PR
Semipalmated Plover		(non-breeding)		PR
Killdeer				PR
Greater Yellowlegs		(non-breeding)		PR
Spotted Sandpiper		(non-breeding)		PR
White-rumped Sandpiper		(transient)		PR
Royal Tern		(115-315 pairs, >25% in West Indies)		PR
Sandwich Tern		(800-3,600 pairs, 28-71% in West Indies)	PR	
White-winged Dove				PR
Mourning Dove				PR
Yellow-billed Cuckoo				PR
Common Nighthawk				PR
Chuck-will's-widow		(Rare, winter)		PR
White-eyed Vireo		(Rare, winter)		PR
Yellow-throated Vireo		(Rare, winter)		PR
Magnolia Warbler		(Northern Forest Biome, winter)		PR
Yellow-throated Warbler		(winter)		PR
Palm Warbler		(Northern Forest Biome, winter)		PR
Blackpoll Warbler		(transient)		PR
Black-and-white Warbler	(winter)		PR	
American Redstart		(winter)		PR
Ovenbird		(winter)		PR
Northern Waterthrush		(winter)		PR
Hooded Warbler	(Rare, winter)		PR	
Indigo Bunting		(non-breeding)		PR
Bobolink		(transient)		PR
Baltimore Oriole		(transient)		PR

*

WL=WatchList score used for Continental Scoring (PIF Approach); species with WL SUBTOT combined scores of (1) 15 or more, (2) 14 with Tmax+PT $\geq$5, or (3) with 13 with PT=5 are identified. using formula:

Combined Score = PT + PS + maximum of (BD or ND) + maximum of (TB or TN)

Tier=

I. Continental Conservation Interest (Continental WatchList): (a) Species with multiple causes for concern across their entire range; (b) Moderately abundant or widespread species with declines or high threats, and (c) Species with restricted distributions or low population size.

Species with multiple causes for concern across their entire range: These species are considered by many to be of highest continental concern and of highest priority for conservation actions at national and international scales. A majority of these are legally listed as Endangered or Threatened in either the U.S. or Canada, and as such have recovery plans in place. Notable in this group, however, are several species without legal status, including Bicknell's Thrush and Saltmarsh Sharp-tailed Sparrow.

Moderately abundant or widespread species with declines or high threats: These species are on the Watch List primarily because they are declining and/or threatened throughout their range, though still fairly widespread or with moderately large populations. Many of these species still number in the millions (e.g. Dickcissel, Wood Thrush), but are threatened with serious reductions in population or geographic range in the future. Several other species (e.g. Swallow-tailed Kite, Mangrove Cuckoo, Elegant Trogon) are fairly widespread outside the U.S. and Canada, but are threatened in the U.S. portion of their range. Five species are afforded U.S. federal legal status in part of their range or for a particular recognized subspecies. This group also includes four resident game bird species with seriously declining populations.
Species with restricted distributions or low population size: These species are on the Watch List because they are restricted to a small range or have small global populations (often both). Many of these species are not known to be declining or seriously threatened at present, but many others are, (e.g. Spotted Owl, Montezuma Quail, Bendire's Thrasher, Rufous-winged Sparrow, Audubon's Oriole). We recognize that these species with small populations and restricted range are particularly vulnerable to relatively minor changes from current conditions, whether or not their populations are currently in decline.

II. Regional Conservation Interest (non-WatchList; TOT$\geq$19): (a) high regional concern (AI+PT$\geq$8); (b) high regional threats (TB+TN$\geq$7, or TB or TN=5) and includes taxa (subspecies and populations) of regional conservation interest not otherwise included in categories above; (c) high regional responsibility (as measured by percent of global, continental, or regional populations).

III Additional Federally and/or State listed.

IV Local or regional concern or interest, including Stewardship Species as defined in the Continental PIF Plan for North America:

Stewardship Species: Stewardship Species, whether on the Watch List or not, are of continental importance because they represent all the large biogeographic regions in North America. They are broadly distributed across Canada and the U.S. during the breeding seasons, in a pattern that mirrors the richness of all landbird species. Winter Stewardship Species are much more heavily concentrated in the southern U.S., particularly the southwest and into Mexico, and along the U.S. west coast. Stewardship actions that preserve healthy populations of these species will address the PIF goal of 'keeping common birds common.' These species, which are both of high overall concern and also largely dependent on a single biogeographic region, merit special attention for conservation action within their core range.

Component Scores to determine Continental WatchList (minus AI) and Regional Scores (and all smaller geographical units, Bird Conservation Regions, Physiographic Areas, States, Provinces, Territories, etc.) are defined as follows:

PT=Population Trend based on a combination of data sources, principally BBS tempered by local and state datasets for breeding species. For non-breeding species usually best professional judgment often based in part on continental trends shown in BBS and/or CBC.

5=Definite decrease
4=Possible decrease
3=Trend uncertain, No data
2=Possible increase, stable
1=Definite increase

Some guidelines based on BBS data, but for waterbirds trends are often dramatic and not linear so an inspection of trend graphs often is required to make a judgment as to trend score, again tempered by local and state data sets if they exist.

Significant increase (BBS trend ≥1.36%/yr, $P \leq 0.10$, df>13)	1
Possible increase (≥0.47 to 1.36%/ yr, $P \leq 0.35$, w/any df)	2a
Possible increase (≥1.36%/yr, $0.1 < P \leq 0.35$, df>13)	2a
Possible increase (≥1.36%/yr, $P \leq 0.10$, df<13)	2a
Stable (> -0.54 to < +0.47%/yr, and UCI<0.47 OR LCI>-0.54)	2b
- except when trend is negative and P≤0.10 and LCI<-0.54, then Possible decrease	4
Trend uncertain (≤-0.54%/yr or ≥0.47%/yr and $P>0.35$)	3
Trend uncertain (>-0.54%/yr and <0.47%/yr and UCI>0.47 AND LCI<-0.54)	3
No data	3
Possible decrease (either of next 3 options, but based on 6-13 degrees of freedom)	4
Possible decrease (≤-0.54 to -2.27%/yr, $P=0.0$-0.35)	4
Possible decrease (≤-2.27%/yr, $0.1 < P \leq 0.35$)	4
Significant decrease (≤-2.27%/yr and $P \leq 0.10$)	5

PS=Population Size based on best population estimates globally
5=Rare (<50 thousand breeding individuals globally)
4=Uncommon (50-500 thousand breeding individuals globally)
3=Fairly Common (500 thousand-5 million breeding individuals globally)
2=Common (5 million to 50 million breeding individuals globally)
1=Abundant (50 million + breeding individuals globally)

TB and TN=Threats Breeding and Threats Non-breeding

5=Extreme deterioration in the future suitability of breeding/non-breeding conditions is expected; species is in danger of regional extirpation or major range contraction, or has already been extirpated
4=Severe deterioration in the future suitability of breeding/non-breeding conditions is expected
3=Slight to moderate decline in the future suitability of breeding/non-breeding conditions is expected
2=Expected future conditions for breeding/non-breeding populations are expected to remain stable; no known threats
1=Expected future conditions for breeding/non-breeding populations are enhanced by human activities or land-uses; potentially a 'problem' species

BD and ND=Breeding Distribution and Non-breeding Distribution

5=Very Local Distribution (<500,000 km2, or very restricted coastal areas or interior uplands)
4=Local Distribution (>500,000 and <1,000,000 km2, or <1,600 km of coast)
3=Moderate Distribution (>1,000,000 and <2,000,000 km2, or >1,600 to <5,000 km of coast)
2=Widespread (>2,000,000 and <4,000,000 km2, or >5,000 to <8,000 km of coast)
1=Very Widespread (>4,000,000 km2, or >8,000 km of coast)

SUBTOT=Subtotal of six scores (absent AI) used to calculate Combined Score for Continental WatchList

AI=Area Importance, "relative" relative abundance for the species for each area within range scaled against its maximum relative abundance (i.e., the BCR or physiographic area supporting the highest relative abundance)

5=Very High relative abundance (~50+% of maximum relative abundance)
4=High relative abundance (~25-49% of maximum relative abundance)

3=Moderate relative abundance (~10-24% of maximum relative abundance)
2=Low relative abundance (~1-9% of maximum relative abundance)
1=Peripheral, scattered occurrences.

TOT=Total Score of all seven factors used for identifying Tiers for which species best fits for conservation planning at Planning Region/Bird Conservation Region/Physiographic Area.

Act. Level=Action Level at present based on expert opinion, but ultimately rules based on scores would be preferable.

IM=Immediate management needed to reverse or stabilize significant, long-term population declines in species with small populations, or to protect species with the smallest populations for which trends are poorly known. Lack of action may lead to extirpations or extinction.

MA=Management or other on-the-ground conservation actions needed to reverse or stabilize significant, long-term population declines in species that are still relatively abundant.

PR=Long-term Planning and Responsibility needed for species to ensure that sustainable populations are maintained for species for which a region has high responsibility for that species.

PC=Population Control/Suppression needed for species that are otherwise secure and increasing that may come into conflict with other species of higher conservation concern or other resources of interest.

APPENDIX B

Bird-Habitat Relationships for Puerto Rico and Virgin Islands, West Indies.

Conservation Tier	Limestone and montane forests	Mangrove and coastal woodlands	Shrub-scrub	Grassland/ Open lands	Landbird Transients	Marshes/long-legged waders	Open water	Mudflats	Beach front and salt ponds	Nesting seabirds
I a. Multiple concerns continentally	Plain Pigeon	West Indian Whistling-Duck	Yellow-shouldered Blackbird			West Indian Whistling-Duck	West Indian Whistling-Duck		Snowy Plover	White-tailed Tropicbird
	Puerto Rican Parrot	Yellow-shouldered Blackbird				Black Rail			Piping Plover*	Red-billed Tropicbird
	Puerto Rican Nightjar									
	White-necked Crow									
	Bicknell's Thrush*									
	Golden-winged Warbler*									
	Elfin-woods Warbler									
I b. High continental threats and/or declining	Mangrove Cuckoo**	White-crowned Pigeon**	Prairie Warbler*	American Golden-Plover*		Little Blue Heron*		Lesser Yellowlegs*	Sanderling*	Audubon's Shearwater
	Puerto Rican Vireo	Mangrove Cuckoo**		Upland Sandpiper*		Wilson's Snipe		Solitary Sandpiper*	Gull-billed Tern	Masked Booby
	Worm-eating Warbler*	Prothonotary Warbler*		Short-eared Owl				Whimbrel*		Red-footed Booby

	Kentucky Warbler*							Semipalmated Sandpiper*		Brown Booby
	Greater Antillean Oriole							Western Sandpiper*		Roseate Tern
								Stilt Sandpiper*		Least Tern
								Short-billed Dowticher*		
Conservation Tier	**Limestone and montane forests**	**Mangrove and coastal woodlands**	**Shrub-scrub**	**Grassland/ Open lands**	**Landbird Transients**	**Marshes/long-legged waders**	**Open water**	**Mudflats**	**Beach front and salt ponds**	**Nesting seabirds**
I c. Local and/or rare continentally	Black Swift**	Lesser Antillean Pewee	Lesser Antillean Pewee	Antillean Nighthawk**		Caribbean Coot	Caribbean Coot		Reddish Egret	Magnificent Frigatebird
	Lesser Antillean Pewee		Adelaide's Warbler						Wilson's Plover*	Bridled Tern
	Blue-winged Warbler*								American Oystercatcher*	
	Adelaide's Warbler								Red Knot*	
	Swainson's Warbler*									
II a. High concern regionally	Black-whiskered Vireo**	Green Heron*	Antillean Mango			Green Heron*		Black-bellied Plover*	Ruddy Turnstone*	Brown Pelican
		Yellow-crowned Night Heron*				Yellow-crowned Night Heron*		Least Sandpiper*		

II b. High threats regionally	Sharp-shinned Hawk	Clapper Rail	American Kestrel	American Kestrel (w/nest trees)		Pied-billed Grebe	Pied-billed Grebe	Greater Flamingo	Willet*	
	Broad-winged Hawk	Yellow "Golden" Warbler	Key West Quail-Dove			Least Bittern*	White-cheeked Pintail			
	Limpkin					Black-crowned Night-Heron*	Ruddy Duck			
	Bridled Quail-Dove					White-cheeked Pintail	Masked Duck			
	Puerto Rican Screech- Owl (VI)					Ruddy Duck				
	Louisiana Waterthrush*					Masked Duck				
						Yellow-breasted Crake				
						Purple Gallinule*				
Conservation Tier	**Limestone and montane forests**	**Mangrove and coastal woodlands**	**Shrub-scrub**	**Grassland/ Open lands**	**Landbird Transients**	**Marshes/long-legged waders**	**Open water**	**Mudflats**	**Beach front and salt ponds**	**Nesting seabirds**
II c. High responsibility regionally	Scaly-naped Pigeon	Puerto Rican Flycatcher	Antillean Crested Hummingbird	Zenaida Dove		Tricolored Heron*		Black-necked Stilt*	Black-necked Stilt*	Sooty Tern
	Puerto Rican Lizard-Cuckoo	Northern Parula*	Caribbean Elaenia	Gray Kingbird**				Pectoral Sandpiper*	Black Tern*	Brown Noddy
	Puerto Rican Screech-Owl (PR subsp.)	Cape May Warbler*	Puerto Rican Flycatcher	Caribbean Martin**						
	Green Mango		Gray Kingbird**	Cave Swallow						
	Puerto Rican Emerald		Northern Parula*	Grasshopper Sparrow						
	Puerto Rican Tody		Puerto Rican Bullfinch							

	Puerto Rican Woodpecker									
	Puerto Rican Flycatcher									
	Loggerhead Kingbird									
	Red-legged Thrush									
	Northern Parula*									
	Cape May Warbler*									
	Black-throated Blue Warbler*									
	Puerto Rican Tanager									
	Puerto Rican Spindalis									
	Antillean Euphonia									
	Puerto Rican Bullfinch									
Conservation Tier	**Limestone and montane forests**	**Mangrove and coastal woodlands**	**Shrub-scrub**	**Grassland/ Open lands**	**Landbird Transients**	**Marshes/long-legged waders**	**Open water**	**Mudflats**	**Beach front and salt ponds**	**Nesting seabirds**
III. Additional State Listed						Least Grebe (USVI)	Least Grebe (USVI)			
						Great Blue Heron (USVI)				
						Great Egret* (USVI)				

						Snowy Egret* (USVI)				
IV. Local or regional interest	Chuck-will's-widow*	White-winged Dove	White-winged Dove	Northern Harrier	Merlin*	Glossy Ibis	Northern Pintail	Semipalmated Plover*		Royal Tern
	Yellow-throated Vireo*	Yellow-billed Cuckoo*	Yellow-billed Cuckoo*	Killdeer	Peregrine Falcon*	Sora	Blue-winged Teal*	Greater Yellowlegs*		Sandwich Tern
	Magnolia Warbler*	Yellow-throated Warbler*	White-eyed Vireo*	Mourning Dove	Common Nighthawk*	Common Moorhen*	Lesser Scaup	Spotted Sandpiper*		
	Blackpoll Warbler*	Palm Warbler*	Indigo Bunting*	Indigo Bunting*	Bobolink*		Osprey*	White-rumped Sandpiper*		
	Black-and-white Warbler*	Blackpoll Warbler*			Baltimore Oriole*					
	American Redstart*	Black-and-white Warbler*								
	Ovenbird*	American Redstart*								
	Hooded Warbler*	Northern Waterthrush*								
		Hooded Warbler*								

*Nearctic-Neotropical Migrant species, those species with populations principally breeding in temperate North American areas that winter principally in tropical North American and/or South America areas.

**Intratropical Migrants species, those species breeding in the northern tropical areas of North America that winter principally further south in tropical North America and/or South America areas.

APPENDIX L.4

DRY TORTUGAS NATIONAL PARK

FINAL DRAFT

Avian Conservation Implementation Plan
Dry Tortugas National Park

National Park Service
Southeast Region



Compiled by J. Keith Watson
U.S. Fish and Wildlife Service
In cooperation with

DRTO Resource Management Staff, National Park Service
And Bird Conservation Partners
January 2005

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- US Fish and Wildlife Service Species of Conservation Concern in Peninsular Florida (BCR 31)

Introduction

This Avian Conservation Implementation Plan (ACIP) is provided to the staff at Dry Tortugas National Park (DRTO) to help identify and prioritize bird conservation opportunities, and to provide information and guidance for the successful implementation of needed conservation activities. This plan may identify goals, strategies, partnerships, and perhaps specific projects for the park to participate in existing bird conservation planning and implementation efforts associated with the North American Bird Conservation Initiative (NABCI). Under the auspice of NABCI, appropriate bird and habitat conservation goals may be recommended as identified in the appropriate existing national or regional bird conservation efforts aligned with this initiative: Partners In Flight (PIF), North American Waterfowl Management Plan (NAWMP), US Shorebird Conservation Plan (USSCP), and Waterbird Conservation for the Americas (WCA). For example, parks in the Appalachians and the Cumberland Plateau will have few if any high priority waterbird conservation issues at a regional landscape or greater scale. As such, little information regarding waterbird conservation will be presented in the ACIP, unless there is an identified park need for this species group, or other mandates, such as federal laws. Similarly, because DRTO is oceanic in nature, very few landbird conservation priorities will be made, except as they may relate to seabirds and coastal species utilizing the land base of DRTO. However, all high priority bird conservation issues for DRTO will be discussed and integrated as appropriate.

Information and data presented in the ACIP have been obtained from several sources: 1) interviews with DRTO staff 2) DRTO bird conservation partners 3) the PIF Subtropical Florida Bird Conservation Plan (in preparation) 4) NPS databases, 5) peer reviewed bird conservation and management literature, and 6) personal communications with bird conservation specialists throughout North America, especially in the southeastern United States. This plan has been reviewed by DRTO resource management staff and managers, South Florida/Caribbean Inventory and Monitoring (SF/C I&M) Network staff, and bird conservation partners and approved by DRTO management. Optimally, this plan will be incorporated into the park's natural resource planning and management documents and updated annually to reflect completed projects, newly identified needs, and shifts in bird conservation priorities in the region.

DRTO is not obligated to undertake any of the proposed actions in this plan. The plan is provided to offer guidance to DRTO to voluntarily support important park, regional, and perhaps national and international bird conservation projects for which DRTO is a primary participant in the proposed actions.

Background

During the past thirty years, monitoring programs across North America have documented declines of certain bird species populations and their habitats, often severe (Sauer et al. 2000). The decline has caused great concern among scientists, biologists,

biodiversity proponents, ecologists, land managers, etc., and the bird conservation community in general. Birds are recognized as critical components of local and global genetic, species, and population diversity, providing important and often critical ecological, social, economic, and cultural values. Their overall decline has stimulated a worldwide focus on conservation efforts and North American interest in bird conservation is rapidly becoming a focus of government, non-government, industry, and private interests and expenditures.

Many state, federal, and non-governmental wildlife agencies and non-government organizations (NGO's) have recognized this alarming bird decline trend and have joined forces in several extensive partnerships to address the conservation needs of various bird groups and their habitats. The primary initiatives are:

- North American Waterfowl Management Plan
- Partners in Flight
- U.S. Shorebird Conservation Plan
- Waterbird Conservation for the Americas

The North American Bird Conservation Initiative: While efforts associated with these plans have generated some successes, it has been increasingly recognized that the overlapping conservation interests of these initiatives can be better served through more integrated planning and delivery of bird conservation. The *North American Bird Conservation Initiative (NABCI;* http://www.nabci-us.org/main2.html*)* arose out of this realization. The vision of NABCI is simply to see ***"populations and habitats of North America's birds protected, restored and enhanced through coordinated efforts at international, national, regional, state and local levels, guided by sound science and effective management."*** NABCI seeks to accomplish this vision through (1) broadening bird conservation partnerships, (2) working to increase the financial resources available for bird conservation in the U.S., and (3) enhancing the effectiveness of those resources and partnerships by facilitating integrated bird conservation (U.S. NABCI Committee 2000). Together, the four bird conservation initiatives mentioned above, as well as several other local and regional partnerships, work collectively to pursue this vision.

NABCI is guided by a set of principles that establish an operational framework within which the Initiative and its partners may conduct integrated bird conservation in the U.S. These will articulate a common understanding of the relationship between NABCI, the individual bird conservation initiatives, and all partner entities to ensure recognition of existing federal legislative and international treaty obligations, state authorities, and respect for the identity and autonomy of each initiative. The fundamental components of the conservation approach to be used by NABCI are expressed within its goal:

> ***To deliver the full spectrum of bird conservation through regionally-based, biologically-driven, landscape-oriented partnerships.***

The Southeastern Bird Conservation Initiative: National Park Service: In 1999, the Southeast Region of the National Park Service (NPS) recognized the importance of coordinating existing bird conservation goals into planning and operations of national park units in the southeast, that is, integration of NABCI. In support of this recognition, the Southeast Regional Office NPS approved and allocated eighty-eight thousand dollars, cost sharing 1:1 with the US Fish and Wildlife Service (FWS) Region 4 (Southeast) to hire a biologist to conduct this two-year project (Interagency Agreement FS028 01 0368). This project is unique in the NPS, and perhaps the nation, and represents a potential model for better coordinating regional bird conservation programs and activities within and outside the NPS. It further represents a progressive action toward institutionalizing bird conservation as a programmatic priority in the Southeast Region of NPS, and potentially the nation.

As envisioned, the integration of NABCI into the Southeastern NPS involves:

1) Development and delivery of Avian Conservation Implementation Plans,
2) Coordination with NPS Inventory and Monitoring Program,
3) Development of a web based project site,
4) Establishment or enhancement of bird conservation partnerships,
5) Identification and exploration of potential funding opportunities, and
6) Technical guidance and assistance as needed or requested.

This ACIP fulfills one aspect of the plan outlined above, and serves as a basis for future bird conservation actions in DRTO and with adjacent partners or landowners.

Concurrently, the development of a Memorandum of Understanding (MOU) between the FWS and the NPS (Appendix A) to implement Presidential Executive Order (EO) 13186, Responsibilities of Federal Agencies to Protect Migratory Birds **(**US Government 2000), calls for integration of programs and recommendations of existing bird conservation efforts into park planning and operations. Complementing each other, the MOU and the Southeastern Bird Conservation Initiative will advance bird conservation in the Southeast Region of the NPS beyond current regional NPS efforts.

Role of NPS in Avian Conservation

The interagency agreement that facilitates this partnership supports both FWS and NPS management policies. Specifically for the NPS, the agreement supports and advances the Strategy for Collaboration, a visionary document developed and signed by the Southeast Natural Resource Leaders Advisory Group (SENRLAG 2000), a consortium of 13 land and resource management agencies in the Southeastern United States whose vision is to encourage and support cooperation in planning and managing the region's natural resources. Furthermore, the agreement is aligned with and implements a variety of NPS Management Polices (2001) including, but not limited to, External Threats and Opportunities, Environmental Leadership, Cooperative Planning, Land Protection, and especially Natural Resource Management that details policy and

management guidelines which apply to bird conservation. Important policies in the Natural Resource Management chapter include:

- Planning for Natural Resource Management
- Partnerships
- Restoration of Natural Systems
- Studies and Collection
- General Principles for Managing Biological Resources
- Plant and Animal Population Management Principles
- Management of Native Plants and Animals
- Management of Endangered Plants and Animals
- Management of Natural Landscapes
- Management of Exotic Species
- Pest Management
- Fire Management and
- Water Resource Management

The NPS is the fourth largest landowner in the United States, consisting of over 380 national park units covering 83 million acres of land and water with associated biotic resources (www.nps.gov). The 64 units in the Southeast Region of the NPS represent 16% of the total number of park units in the national park system and cover approximately 5% of the total land base in the entire system. Park units in the Southeast Region include national seashores (Canaveral National Seashore, Cape Hatteras National Seashore), national parks (Great Smoky Mountains National Park, Dry Tortugas National Park), national recreation areas (Big South Fork National River and Recreation Area), national preserves (Big Cypress National Preserve), national battlefields (Cowpens National Battlefield, Fort Donelson National Battlefield), national monuments (Fort Matanzas National Monument, Ocmulgee National Monument), and others such as the Blue Ridge Parkway, Obed Wild and Scenic River, and Timicuan Ecological and Historic Preserve.

Southeast NPS units provide habitat for over 400 species of migrating, breeding, and wintering birds and include a wide range of Federal and State listed threatened and endangered species. Likewise, these units also provide nest, migration, and winter habitat for most of the eastern species identified in the national bird conservation plans in need of conservation attention.

Additionally, the NPS attracts over 280 million visitors to the parks each year, 120 million of these in the Southeast Region, affording excellent recreational bird watching and opportunities to strengthen bird conservation interpretation, outreach, and education programs. These opportunities, the NPS mission, policies, and organization all lead to the conclusion that the NPS is an extremely valuable partner and contributor to bird conservation in the region.

Nationally, the status of birds in national parks is largely unknown, although many parks have adequate knowledge regarding bird occurrence in the parks (http://www.npwrc.usgs.gov/resource/othrdata/chekbird/chekbird.htm). Parks often play a role in ongoing regional bird conservation efforts. Indeed many of these parks are often important to regional, national, or international bird conservation, and many have been designated as Important Bird Areas (IBA's) by the National Audubon Society. To date, there are approximately 64 NPS units that are designated IBA's, 35 of which are considered of global importance (http://abcbirds.org/iba/aboutiba.htm). In the Southeast Region, the NPS has 13 global IBA's.

The **NPS Inventory and Monitoring (I&M) Program** has been developed to provide management driven scientific information to national park managers so that resources can be adequately protected within national parks. One of the first phases of this program is to inventory vertebrates, including birds, within the 260 national park units in the program. Once completed, data from the inventories will provide an account of the occurrence and abundance of birds in all the national parks in the program. These records will be stored in the NPS I&M NPSpecies database (http://www.nature.nps.gov/im/apps/npspp/). Coordination with I&M network staff is important to developing long-term bird monitoring programs that fulfill both park and NABCI objectives.

Park Flight is a NPS international partnership initiative that directs funding toward a variety of NPS programs that involve conservation of Neotropical migratory birds whose life history range covers a U.S. national park and a Latin American protected area. A relatively new program, Park Flight offers parks the opportunity to partner with a Latin American national park or protected area to cooperate on developing bird conservation and education projects (USDI NPS 2002).

Recent increases in NPS base funded programs such as inventory and monitoring, exotic species management, habitat restoration, and fire management all indicate that national park managers recognize that park lands are increasingly subject to a variety of threats and conditions that must be improved to provide the quality of national park experience articulated in the NPS Organic Act (1916). Programmatic funding in these areas will increase the ability of national parks to provide quality habitat and conditions for increased wildlife conservation, including birds. Furthermore, private interests and non-profit conservation organizations have initiated programs, including grant programs, to provide much needed funding to national parks to meet backlogs of identified yet unfunded needs.

Park Description

Almost 70 miles (112.9 km) west of Key West lies a cluster of seven islands, composed of coral reefs and sand, called the Dry Tortugas. Fort Jefferson National Monument was established by Presidential Proclamation on January 4, 1935, to protect historic Fort Jefferson, a military and architecturally significant nineteenth century fort.

Congress re-designated the 25,900 ha (64,000 acres) area as a National Park in October 1992 to provide additional management protection for the area's subtropical marine system, including coral reefs, fisheries, nesting birds and sea turtles, and other wildlife (Public Law 102-525). Dry Tortugas National Park possesses one of the greatest concentrations of historic shipwrecks in North America, with some vessels dating back to the 1600's. Because of its isolation, the islands, magnificent subtropical waters and coral reefs serve as an important resting place for migrating birds and a foraging and nesting place for sea turtles. Pristine subtropical waters, lush coral and seagrass habitat, and hundreds of species of birds and fish affords scientists an outstanding opportunity for education and scientific research. Some of the earliest known coral reef investigations date back to the 1880's when the Carnegie Institution operated one of the first subtropical marine science laboratories in the Western Hemisphere on Loggerhead Key (Sasso and Patterson 2000).

Avian Resources of Subtropical Florida

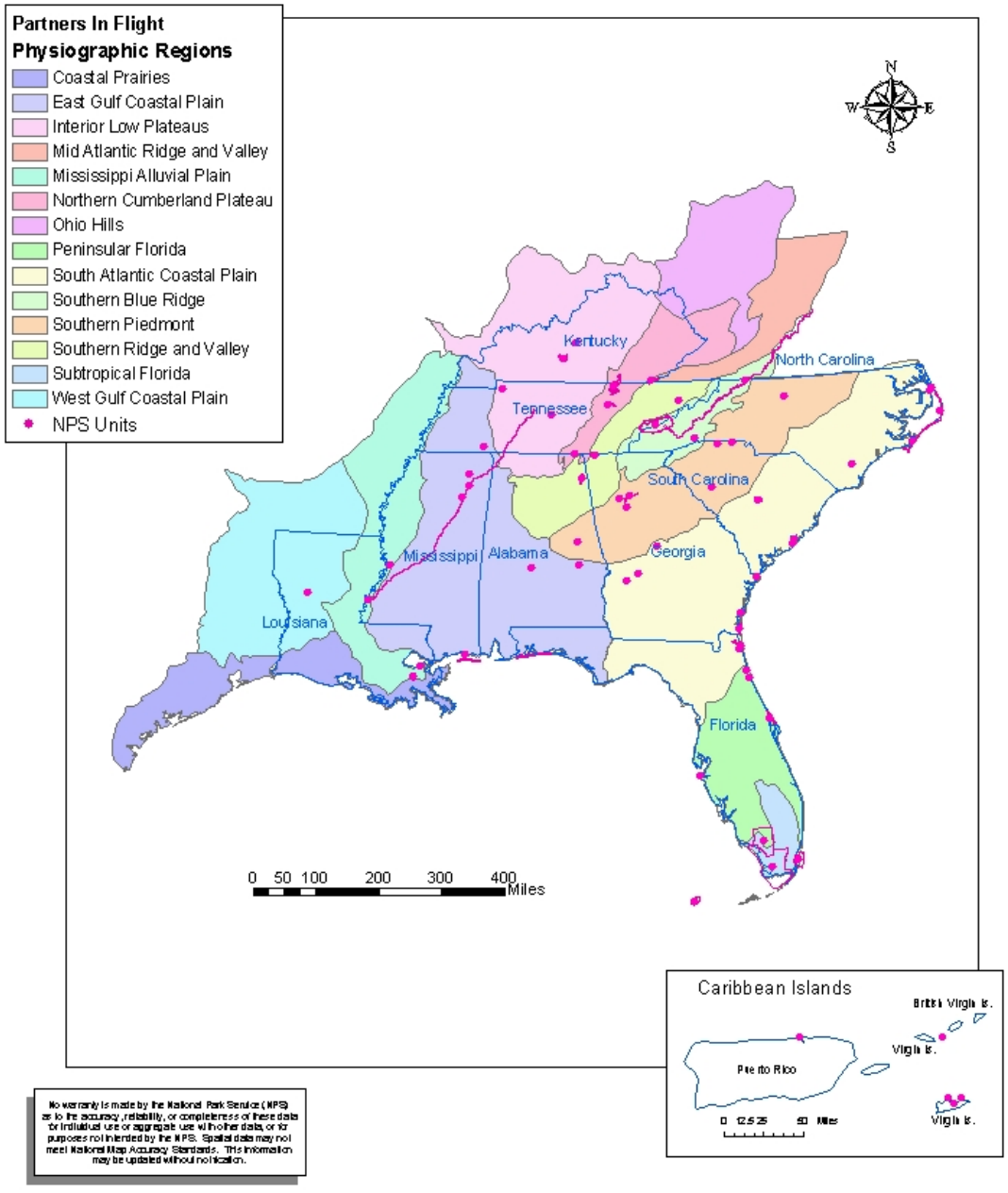
This physiographic area is entirely contained within Florida, and extends from the northern edge of Lake Okeechobee south through the Florida Keys (see PIF and NPS locations maps below). The region has very little topographic relief, but slight changes in elevation have important consequences for vegetation and the diversity of habitat types. The highest points of elevation are less than 2 meters and correspond with fairly recent shorelines (less than 5,000 years before present). Underlying sediments consist of freshwater marl, peat, freshwater lake and marine sediments, and to a lesser extent, sand deposited during the Pleistocene and Holocene. The subtropical Florida region can be divided into four smaller sub-regions: 1) the Everglades, 2) Big Cypress, 3) Miami Ridge and Atlantic Coastal Ridge, and 4) Southern Coasts and Islands. The Everglades is the most extensive of these areas, followed by the Big Cypress, Miami Ridge and Southern Coasts. Across all subregions, much of the physical and ecological characteristics of the region resemble tropical ecosystems where seasonal changes are reflected by changing rainfall patterns rather than by dramatic temperature changes. Distinctive dry (winter/spring) and wet (summer) seasons occur annually, and the nesting cycles of many birds are tied to these changes. At least two major forms of disturbance play key roles in the ecology of the region. Fire is an important feature in many pine dominated communities and many marsh and prairie communities. Frequent fires are essential in pine-dominated stands and prairies if understory conditions suitable to many nesting birds are to be maintained. However, the ideal fire frequency in some pine communities is not known. Hurricanes are a second form of disturbance that less frequently but predictably provide early successional habitats or open forest cover (Partners in Flight 2000).

Bird conservation priorities for Subtropical Florida have been stratified by habitat type. Recognized habitat types where high priority conservation actions are needed for both birds and habitats are pine forests (including pine rocklands, pine Flatwoods, sand

Partners in Flight (PIF) Regions

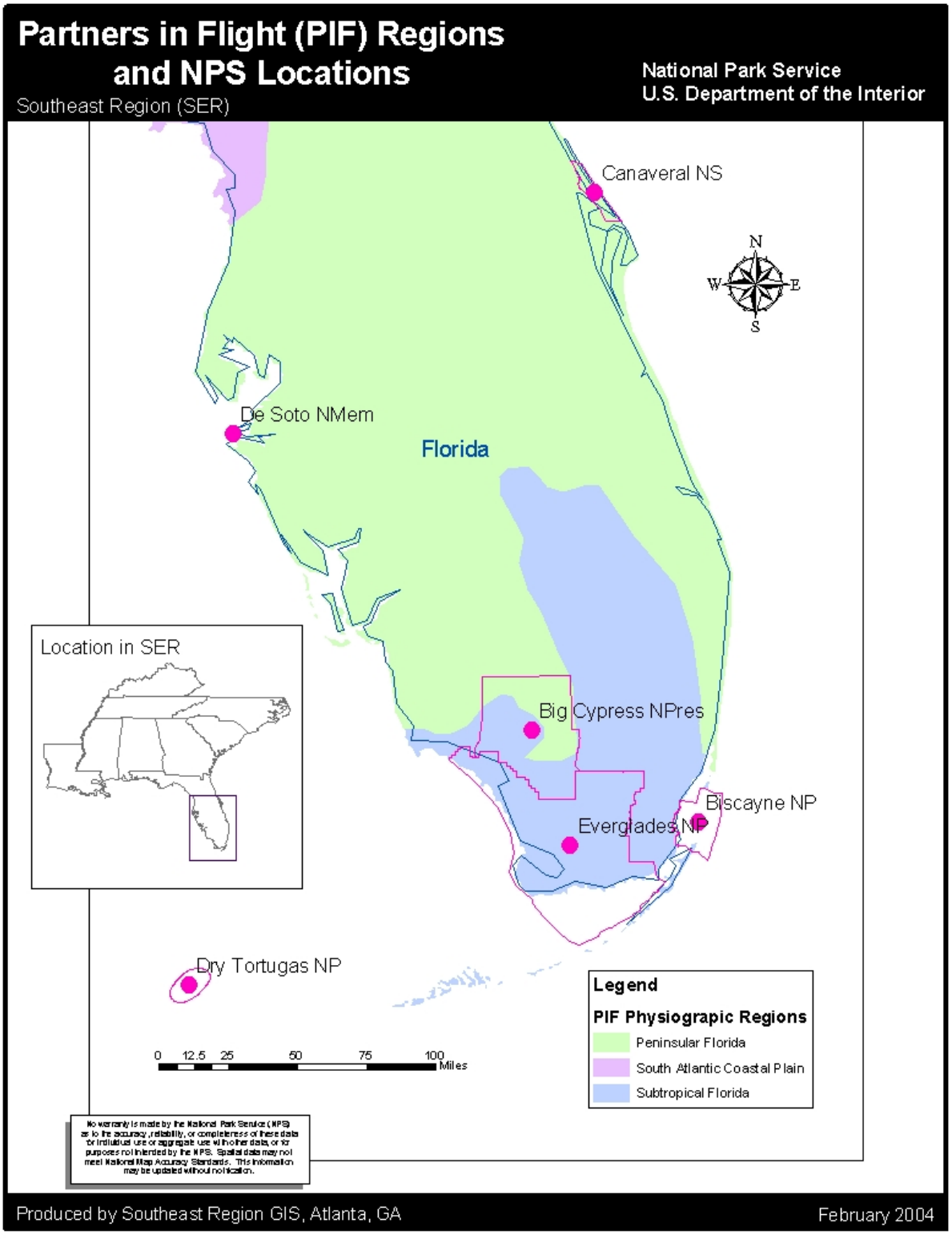
Southeast Region (SER)

National Park Service
U.S. Department of the Interior



Produced by Southeast Regional Office GIS, Atlanta, GA

March 2004


Partners in Flight (PIF) Regions
and NPS Locations
Southeast Region (SER)
National Park Service
U.S. Department of the Interior
Canaveral NS
N
W
E
S
De Soto NMem
Florida
Location in SER
Big Cypress NPres
Biscayne NP
Everglades NP
Dry Tortugas NP
Legend
PIF Physiograpic Regions
Peninsular Florida
South Atlantic Coastal Plain
Subtropical Florida
0 12.5 25 50 75 100
Miles
No warranty is made by the National Park Service (NPS) as to the accuracy, reliability, or completeness of these data for individual use or aggregate use with other data, or for purposes not intended by the NPS. Spatial data may not meet National Map Accuracy Standards. This information may be updated without notification.
Produced by Southeast Region GIS, Atlanta, GA
February 2004

pine scrub), grassland/grassland-scrub (including dry prairie and coastal strands), subtropical deciduous forest, Everglades, brackish saltwater and freshwater marsh, and mangrove swamps. Species associated with each of these habitats and identified as high priority for conservation needs are given below.

Florida Scrub Jay, Red-cockaded Woodpecker, Southeastern American Kestrel, Brown-headed Nuthatch, Bachman's Sparrow, Pine Warbler and Sedge Wren are associated with the pine forests. Both Florida Scrub Jay and Southeastern American Kestrel have been extirpated in Subtropical Florida and the Brown-headed Nuthatch and Bachman's Sparrow are nearly extirpated here. Both Palm Warbler and Sedge Wren are present only in the non-breeding seasons.

Grasshopper Sparrow, Crested Caracara, Burrowing Owl, Sandhill Crane and Mottled Duck are all species associated with grassland to grassland scrub habitats. Grasshopper Sparrow has been extirpated in South Florida.

In the subtropical deciduous forest, Short-tailed Hawk, Swallow-tailed Kite and Gray Kingbird are high priorities for conservation.

In the Everglades, brackish saltwater and freshwater marshes, Snail Kite, Cape Sable Seaside Sparrow, Wood Stork, Black Rail, Reddish Egret, Yellow Rail, White Ibis, and Clapper Rail are species of conservation attention.

Prairie Warbler, Yellow Warbler, Black-whiskered Vireo White-crowned Pigeon, and Mangrove Cuckoo, species associated with Mangrove swamps and forests, are of high priority conservation concern.

Human population growth has been phenomenal in subtropical Florida for the last 40 years. The impacts of such tremendous growth include increased infrastructure that directly reduces habitat availability, but also secondary impacts to bird habitats, such as pollution. Other land uses include production of sugarcane, winter vegetables, and citrus. Drastic changes in hydroperiod and natural water cycles are secondary impacts of increasingly intensive agriculture. However, among the best opportunities in the Southeast to work with existing public lands occur in Subtropical Florida, where over 54% of the area is publicly owned. Therefore, primary conservation programs include efforts to reduce impacts from adjacent or nearby lands on management of existing public lands. Many programs have been developed and are in various phases of implementation. These include the Save Our Everglades program, the Surface Water Improvement and Management Act, Florida's everglades Forever Act and the development of the South Florida Ecosystem Restoration Task Force as well as aggressive acquisition programs. These and other programs serve the basis for bird conservation efforts in the region.

This description of South Florida aviafaunal conservation priorities hardly seems relevant to DRTO. Indeed, DRTO has a bird fauna more similar to the Caribbean region

than Subtropical Florida. Yet, bird conservation plans for both Subtropical Florida and Puerto Rico and the US Virgin Islands do not adequately address priority bird conservation issues in DRTO. However, because bird conservation priorities are more closely affiliated with the Caribbean, recommendations in this plan will be tiered to the Puerto Rico and US Virgin Islands bird conservation plan.

Avian Conservation in DRTO

Avian Biodiversity: DRTO has an avian inventory and a checklist of birds that is available for the public. Managers recognize the need to update the inventory and checklist. Approximately 291 species have been observed in the Dry Tortugas, yet only 7 species regularly nest there. This number seems low, especially considering that numbers of birds in spring often exceed 100,000. However, these large numbers are the result of nesting Sooty Tern and Brown Noddy. Other regular nesters there are Masked Booby, Magnificent Frigatebird (only colony in US jurisdiction), Mourning Dove, and Brown Pelican.

Verified records of birds in DRTO have been entered into the NPS I&M program's database, NPSpecies, and may be viewed via the internet at http://www.nature.nps.gov/im/app/npspp with a user identification and password combination authorized by the NPS for NPS personnel and NPS cooperators. Many other avian observational data need to be verified and entered into the database.

Inventory: The park's avian inventory has been recognized as important information for park managers and is considered complete within the framework of the NPS I&M Program. DRTO is one of seven parks in the NPS South Florida/Caribbean I&M Network for which a plan to conduct high priority inventory projects has been prepared (Sasso and Patterson 2000). At this time, no inventory efforts are planned for DRTO.

Threatened and Endangered Species: Two federally listed threatened species occur in DRTO, the Brown Pelican and Roseate Tern. The Brown Pelican nests in the park and the Roseate Tern is now an irregular nesting species and regular winter resident.

One additional Florida listed species, the Least Tern, occurs in DRTO. Other transient species occurring in DRTO are listed in several states, signifying the park's importance to bird migration.

Park Priorities: Park staff and consultants have identified the Sooty Tern, Magnificent Frigatebird and Brown Noddy as species of significant management concern and high priority for conservation. Additionally, the park's significance as a stopover for Neotropical migrants is well known remains a high priority for conservation attention.

Monitoring: Currently, several avian monitoring projects are being conducted at DRTO. These are:

- Sooty Tern and Brown Noddy colony monitoring using point count index methodology; vegetation is also monitored at these sites
- Migration monitoring by private interests, mainly for Neotropical migrants
- Brown Pelican, Masked Booby, and Magnificent Frigatebird colony monitoring using direct count methodology

Randomized recreational birding provides additional bird observation data.

Research: Scientific research is permitted within the park, and currently two projects are ongoing. These are:

- Long-term banding of Sooty Tern chicks in 3 m square plots to track parentage and nest site fidelity
- Determination of causes in shift of breeding season for Sooty Tern, including an analysis of all environmental variables possibly associated with Sooty Tern nesting

Outreach: Some educational information related to birds is conveyed to visitors to DRTO.

- Law enforcement staff inform visitors of the importance of and protecting the tern colonies, as well as other waterbirds
- An observation log is maintained in the visitor center where
- In visitor center, information is available on the practice of gull feeding by visitors
- In visitor center, information is available on importance of DRTO for landbird migration

Park Identified Needs for Avian Conservation

DRTO has identified several projects that would increase the avian knowledge of the park. They are:

Inventory:
- better understand the role the park has for fall migrants

*Monitoring**:***
- Christmas Bird Count
- Scientifically based Migration Monitoring

Research:
- Sooty Tern colony banding is desired
- Nesting chronology and demography of the Magnificent Frigatebird Colony
- Masked Booby nesting chronology and reproductive success
- Determination of importance of DRTO as a migration stopover

Data Management:

- Verify and enter avian observational data into NPSpecies, eBird, or another appropriate database (DRTO data is stored in Everglades National Park databases)

Coordination with Regional Conservation Initiatives

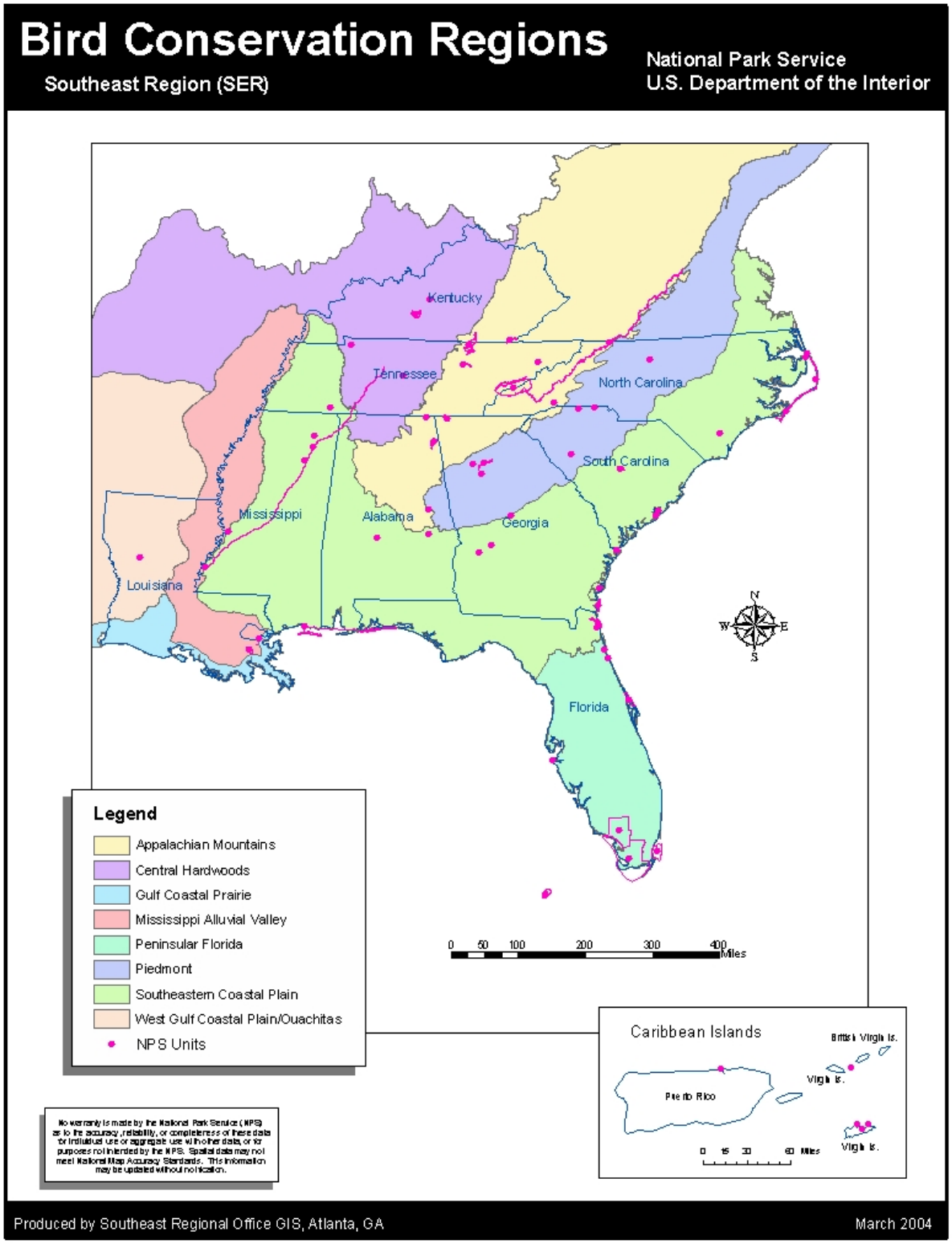
North American Bird Conservation Initiative: NABCI bird conservation planning units, referred to as Bird Conservation Regions (BCR), are often larger than other planning units associated with other plans, such as Partners In Flight. For example, DRTO is within the NABCI Peninsular Florida BCR that covers all of Southern Florida south of approximately Jacksonville (see NABCI BCR map below) and encompasses two PIF physiographic areas (the planning unit for PIF)(compare to PIF map).

Several NABCI BCR's have coordinators whose primary responsibility is to coordinate all bird conservation planning in the BCR, across all agencies and organizations. Currently, the Peninsular Florida BCR does not have a designated coordinator; however, the Atlantic Coast Joint Venture (ACJV) has staff that with responsibility to provide bird conservation assistance to agencies and organizations in the area. This staff can provide valuable assistance to DRTO with implementation of aspects of this ACIP.

North American Waterfowl Management Plan (NAWMP): The NAWMP (http://northamerican.fws.gov/NAWMP/nawmphp.htm) is completed and has been revised several times, incorporating updated goals and strategies based on new information. This plan is one of the most successful bird conservation delivery programs in the United States, being monetarily supported by the North American Wetlands Conservation Act (NAWCA). The ACJV coordinators are responsible for coordination and implementation of this program.

Partners In Flight: Goals and strategies for the Subtropical Florida are not yet fully developed into a draft bird conservation plan. However, as previously noted, bird conservation priorities for DRTO are better aligned with Puerto Rico and the US Virgin Islands goals, yet are largely the responsibility of the NPS and the State of Florida, an arrangement that can make bird conservation at DRTO challenging.

Similar to NABCI BCR's, PIF physiographic areas often do not have designated coordinators. However, state level non-game agencies with investment in PIF will establish key personnel to develop partnerships among cooperators in the physiographic area. The State of Florida has a non-game bird coordinator who can be instrumental in assisting DRTO to implement recommendations identified in this ACIP and projects important to bird conservation relative to Florida and the Caribbean's role in implementation of the respective geographical plans.


Bird Conservation Regions
Southeast Region (SER)
National Park Service
U.S. Department of the Interior
Kentucky
Tennessee
North Carolina
South Carolina
Mississippi
Alabama
Georgia
Louisiana
Florida
N
W
E
S
0 50 100 200 300 400 Miles
Legend
Appalachian Mountains
Central Hardwoods
Gulf Coastal Prairie
Mississippi Alluvial Valley
Peninsular Florida
Piedmont
Southeastern Coastal Plain
West Gulf Coastal Plain/Ouachitas
NPS Units
Caribbean Islands
British Virgin Is.
Virgin Is.
Puerto Rico
Virgin Is.
0 15 30 60 Miles
Produced by Southeast Regional Office GIS, Atlanta, GA
March 2004

United States Shorebird Conservation Plan (USSCP): The USSCP has been completed and is available on the World Wide Web (http://shorebirdplan.fws.gov/). A regional step down plan is in preparation by FWS personnel and should be available in 2003.

Waterbird Conservation for the Americas (WCA): The WCA plan has been completed and is available on the World Wide Web or can be ordered from the US Fish and Wildlife Service National Conservation Training Center (http://www.waterbirdconservation.org/). Most conservation priorities for DRTO are for waterbirds and this plan will eventually provide the best guidance for DRTO bird conservation.

Integration of NABCI Goals and Objectives into Park Planning and Operations

NABCI Implementation Recommendations

To successfully achieve park-established goals and actively participate in NABCI, the park could implement a variety of projects in different NPS programs. Most of these projects would require some level of participation by many existing park programs and could either be achieved through NPS funding, or more likely, through establishing or improving partnerships with agencies and organizations that already have the necessary expertise to provide guidance, funding, and execution of these programs. Programmatic areas where bird conservation actions are likely to be focused are:

- Inventory
- Monitoring
- Habitat Restoration
- Threat Management (includes exotic species, air quality, water quality, etc.)
- Research
- Compliance
- Outreach
- Partnerships

To the extent appropriate, each of these program areas will be discussed separately and within each, specific opportunities identified that, when implemented, will enable to park to meet its mandates (current and expected) as well as integrate NABCI into its planning and operations. With emphasis added, the park is not expected to implement any of these recommendations or be obligated to pursue any opportunity other than those the park is required to do by law or NPS program or policy. In other words, participation in this effort is currently voluntary. However, implementation of EO 13186 (US Government 2000) will require NPS to incorporate a wide range of bird conservation programs into planning and operations. The development of the MOU between the FWS and the NPS will establish a formal agreement to promote bird

conservation within the agency by incorporating goals and strategies of existing bird conservation initiatives, plans, and goals into park planning and operations.

Should the park decide to implement any of these projects, further consultation with bird conservation contacts is encouraged to obtain updated information on the relevance of these opportunities in regional bird conservation.

High priority projects are identified in **bold** print. Priorities that the park is encouraged to seek NPS funding for are marked with an asterisk (*****). These projects are those that are critical to the stabilization or improvement of a bird population in the planning region.

Inventory: The park has inventoried its bird fauna exceptionally well. Although Nonetheless, additional information is needed on fall migration. DRTO is encouraged to:

- **establish a migration monitoring program throughout the islands to determine use of DRTO by fall migrants***

Additionally, DRTO is encouraged to

- **verify other avian observational data collected in the park and enter into the appropriate database (Everglades NP databases, NPSpecies, eBird, or other appropriate database)***

- **standardize inventory and monitoring methodology to conform to NPS and/or FWS recommended standards (Fancy and Sauer 2000, Hunter 2000)**

Monitoring: The park's bird monitoring program is focused on waterbird colonies, two of which occur nowhere else in the United States. Efforts should be made to continue existing monitoring programs and to ensure that park efforts contribute to park or regional bird conservation rather than undertake an action or actions that are not needed or are better conducted in other areas. Specific recommendations are to:

- **continue to conduct existing monitoring programs and enter data into the appropriate databases (NPSpecies, eBird, or other appropriate database)***

- **communicate with other biologists and research scientists working with Sooty Tern, Brown Noddy, and Magnificent Frigatebird to determine DRTO's importance for these nesting species***

- **establish a scientifically based landbird migration monitoring program to document use of DRTO during landbird migrations***

- **establish a gull monitoring program to document increase in gulls and gull predation**

- **establish a Christmas Bird Count area centered on the Dry Tortugas**

- **standardize inventory and monitoring methodology to conform to NPS and/or FWS recommended standards (Fancy and Sauer 2000, Hunter 2000)**

Habitat Restoration: Recently, habitat restoration efforts have increased on NPS lands due to the increased restoration emphasis of the Management Policies (USDI NPS 2001). Parks may use a wide range of management tools to restore wetland, grassland, woodland, and other habitats. Restoration tools include, but are not limited to, forest management practices (e.g. silviculture), prescribed fire, exotic species management, and public use and recreation management. In addition, parks can coordinate infrastructure development (e.g. roads and buildings) with restoration activities to mitigate potential adverse impacts.

Due to the protected nature of DRTO lands, and generally those in the national park system, the condition of habitats for bird use may be of higher quality than other natural, developed, agricultural, or forest lands under other management regimes. However, national park lands can be greatly improved for wildlife, and particularly bird use, by restoring processes important for habitat formation, succession, and structural development. Largely, these processes have not been managed historically in the national park system but current policy allows for active management of species, populations, and lands to provide for long-term conservation of park resources. Protection of habitats in DRTO can contribute to continued waterbird colony nesting, thus contributing to species population goals in South Florida and the Caribbean.

The park is entirely oceanic island park subject to the forces generated upon and moving across the ocean surfaces. Tropical storms, tidal fluctuations, and sea level rise are processes that influence the dynamic landscape of DRTO and likewise, the waterbird colonies. Specific recommendations are to:

- **maintain or enhance water quality in surrounding waters to support aquatic biota necessary to support existing tern and waterbird colonies***

- **manage vegetation on Bush Key to assure Sooty Tern and Brown Noddy have adequate and suitable nesting area***

- **determine feasibility to improve habitat for nesting Masked Booby and implement appropriate actions to improve habitat for nesting Masked Booby***

- **preserve remaining coastal hammock forests and shrub scrub habitats for migrating land birds***

- **document all major habitat management activities, including location (e.g. UTM coordinates) and a description of methods and of pre- and post-management habitat conditions. This information, when coupled with bird distribution and abundance data, is useful for assessing and replicating conservation actions**

Threat Management: Potentially the greatest impact to birds at DRTO is the presence of rats. The recent establishment of a land bridge between Fort Jefferson and Bush Key, where the tern colonies reside, could result rat predation of the tern colony. However, park staff have responded with an aggressive trapping program and rats do not seem to be negatively impacting the tern colony. The park is encouraged to:

- **continue the aggressive removal of rats from Bush Key, striving to eradicate all rats***

- **consider removing the land bridge between Garden and Bush Key to prevent future invasions of mammalian predators and unauthorized visitors and associated disturbance**

- **eliminate gull feeding by visiting public and potentially reduce gull populations to reduce predation on Sooty Terns**

- **manage commercial fishing offal to eliminate attraction to gulls**

- **assess and managed gull predation on Sooty Tern**

- **manage fishing practices that impact fish eating birds**

Exotic vegetation has been well managed at DRTO. Efforts should continue to

- monitor and manage exotic vegetation

Research: Several research projects have been identified that could improve bird conservation for birds at DRTO and contribute to increased bird conservation efforts for these species in the Caribbean. These projects are:

- **Sooty Tern colony banding is desired (10K)***

- **demography and nesting chronology of the Magnificent Frigatebird***

- **determination of importance of DRTO as a migration stopover***

- **Masked Booby nesting chronology and reproductive success***

- **assess gull population dynamics and gull predation on Sooty Tern colony***

- **impact assessment of fishing gear on fish feeding birds**

- **continue to improve knowledge on developing mangrove forest and potential for increased bird nesting**

- **list park needs and projects on Research Permit and Reporting System web site (RPRS)**

- develop contact with South Florida/Caribbean Cooperative Ecosystem Studies Unit (CESU) at the Rosentiel School of Marine and Atmospheric Sciences at the University of Miami, Fl.

Compliance: Park compliance with the Migratory Bird Treaty Act and the Executive Order 13186 (US Government 2000) is necessary to assure that park activities incorporate bird conservation into park planning and operations. Further, to ensure that migratory birds are considered in all phases of park planning processes, especially during the National Environmental Policy Act (NEPA) and the Director's Order #12 Compliance processes, the park should consider adding specific language in project evaluations that requires consideration and implications of park projects on migratory birds. The MOU being developed between the NPS and the FWS will likely contain specific language requiring a park to consider implications of park projects on migratory birds, particularly those species identified in the USFWS Species of Conservation Concern 2002 (Appendix D). Additional considerations are to encourage:

- **park staff to begin specific consideration of migratory birds during park planning processes***

- park staff to attend USFWS training on implementation of EO 13186 at the National Conservation Training Center (NCTC) (when available) or other training on migratory bird conservation in North America. NCTC has several courses and training related to conservation of migratory birds (http://training.fws.gov/courses.html).

The USFWS NCTC offers and reserves two tuition free slots for National Park Service employees wishing to attend NCTC courses on a first come, first served basis. Additionally, discount lodging is also available while attending a NCTC course.

Outreach

- **participate in International Migratory Bird Day (IMBD) events with a local partner** (**http://birds.fws.gov/imbd.html**)

- **encourage development of outreach and educational programs to enhance visibility of bird conservation issues, which may include organized bird walks, migration monitoring, and perhaps waterbird colony visits***

- **develop educational/outreach program for park fishing persons to avoid or minimize impacts or injury to fish eating birds***

- **develop aggressive outreach and enforcement program to eliminate gull feeding by visiting public***

- **encourage accurate documentation and reporting from randomized outings by visitors (see Cornell University's eBird monitoring program (Cornell Lab. Ornith. 2002 (http://www.ebird.org/about/index.jsp)***

- park interpretation/education staff are encouraged to attend USFWS training on Migratory Bird Education at NCTC

- consider adding links to bird conservation information, data, etc. to the park's web site home page

- support bird conservation by serving shade-grown coffees at meetings, events, and the office buildings in the park (http://www.americanbirding.org/programs/conssbcof3.htm)

- subscribe to Florida Birds, an electronic forum for listing bird sightings and publications in Florida

Partners and Partnerships: Partnerships for habitat conservation and protection will perhaps have the greatest positive influence on bird conservation above all other landscape scale planning. Specific recommendations are to:

- **keep abreast of initiatives that may affect water quality in and around DRTO***

- **partner with Caribbean seabird experts to collaborate on conservation issues with DRTO waterbird colonies***

- **continue to develop and strengthen relationship with local bird clubs such as the Key West Audubon Society and Tropical Audubon Society to coordinate and conduct park bird conservation projects***

- **develop partnership with USFWS, particularly with Key West National Wildlife Refuge***

- **contact the nearest Joint Venture office (see Funding section for explanation of Joint Ventures) or BCR coordinator to develop partnerships and funding proposals tiered to priorities established by the park, this ACIP, and the bird conservation plans that pertain to DRTO**

Funding Opportunities: Internal NPS funding is often an effective source to obtain funding; however, the project will have to be a fairly high priority among the park's natural resource program to successfully compete for the limited funding available in the NPS. Therefore, partnerships and outside funding programs are often more productive for securing bird conservation funding. Funding for conservation projects for Neotropical migrants is also available through the Park Flight program. DRTO is encouraged to enter all high priority projects into the NPS Performance Management Information System (PMIS) database. Needed at DRTO is:

- **increased base funding to implement basic protection and management needs for birds and their habitats (habitat-based management not only benefits the birds but other wildlife as well)**

With the exception of the North American Waterfowl Management Plan (NAWMP and its associated funding legislation, the North American Wetland Conservation Act), funding opportunities for bird conservation programs, plans, and initiatives have been lacking. Only within the last decade have other appropriate and specific sources for bird conservation funding been created and used. The NAWMP has been supported for approximately 14 years by the North American Wetlands Conservation Act (NAWCA 1989). This program has provided $487 million in appropriated funds matched with $1.7 billion for wetland and bird conservation projects since its inception. In 2002 alone, over $70 million US dollars were awarded to US and Canadian agencies and organizations to enhance waterfowl populations by improving, restoring, or protecting wetland habitats. To adequately evaluate projects and distribute these funds, partnerships called Joint Ventures were established. Nationally, 14 (11 US, 3 Canada) Joint Ventures have been established, several which are funded and staffed. Internet links to Joint Ventures are:

(http://southwest.fws.gov/gulfcoastjv/ojvcontact.html) and
(http://northamerican.fws.gov/NAWMP/jv.htm).

Funding through NAWCA is highly underutilized by the NPS and any park unit that has wetland, water, or bird conservation needs associated with wetland are encouraged to investigate using this funding source. Naturally, there are certain requirements to be eligible for all grants and park managers are encouraged to consult with the nearest Joint Venture, BCR, PIF Coordinator, to learn how this program might be applicable to implementation of this plan, and other park wetland issues. DRTO should contact the ACJV assistant coordinator to investigate use of this funding source and developing proposals for implementation of portions of this plan.

Internal FWS funding programs may be used to support projects, but no effective method of project proposal delivery to these sources is currently in place for the NPS. Current funding in these programs may result from FWS familiarity with NPS needs, or NPS participation in one of the area FWS Ecosystem Teams, where a project has been identified and proposed to be funded through the Ecosystem Team.

Specific congressional appropriations to protect migratory birds has recently been authorized under the Neotropical Migratory Bird Conservation Act (2000) (http://www.nfwf.org/programs/nmbcapp.htm). Appropriations through this Act are authorized up to $5 million per year. However, in 2000, appropriation was approximately $3.75 million and a majority of this funding was directed toward projects in Central and South America.

Many of the identified projects are eligible for funding under various grant programs of the National Fish and Wildlife Foundation (http://www.nfwf.org/programs/programs.htm).

Other prominent funding sources available to NPS managers for bird conservation are listed on this projects web site at: http://southeast.fws.gov/birds/NPSHighlits.htm.

Funding opportunities for migratory bird conservation are available yet most natural resource agencies are not fully aware of and/or understanding of how to use these sources. Perhaps a consolidated migratory bird funding source catalog will become available to managers in the future; this is needed.

Contacts: Primary contacts within the region can be obtained by viewing the web site for the Southeastern Bird Conservation Initiative, National Park Service at http://southeast.fws.gov/birds/npsbirds.htm. This web site will provide contact information of the appropriate bird conservation coordinator in the region for park personnel. Primary contacts for DRTO are:

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APPENDIX A

EXCERPT FROM SOUTHEAST WATERBIRD CONSERVATION PLAN
PRIORITY BREEDING COLONIAL BIRDS

Appendix I. BREEDING COLONIAL WATERBIRD SCORES AND STATUS FOR THE SOUTHEAST U.S. WATERBIRD CONSERVATION PLAN*

DRAFT (September 8, 2003)

Species/Region (Colonial Breeding Waterbirds)	PT	PS	TB	TN	BD	ND	SUB TOT	AI	TOT	WL	Tier	Act. Level	Per. Resp.	Est. Pop. Cat.	Pop. Obj. Cat.
Masked Booby	**4**	**4**	**4**	**3**	**3**	**2**	20			**15**			**<1 global**		
Southeast U.S. Reg.	**2**		**4**	**3**				**2**	**20**		**I b**	**PR**	**100us-can**	**2**	**2**
PENFL (BCR 31)	**2**		**4**	**3**				**2**	**20**		**I b**	**PR**	**100 reg.**	**2**	**2**
STFL	*2*		*4*	*3*				*2*	*20*		*I b*	*PR*	*(100)*		
Brown Pelican	**1**	**4**	**3**	**2**	**3**	**3**	16						**45 global**		
PENFL (BCR 31)	**3**		**3**	**2**				**5**	**23**		**II a**	**MA**	**22 reg.**	**7a**	
PENFL (BBS)	*4*		*4*	*2*				*5*	*25*		*II a*	*MA*			
STFL	*2*		*3*	*2*				*5*	*20*		*II c*	*PR*			
Magnificent Frigatebird	**4**	**4**	**4**	**3**	**4**	**3**	22			**16**			**<1 global**		
Southeast U.S. Reg.	**5**		**5**	**3**				**2**	**26**		**I c**	**IM**	**100 us-can**	**3**	**4**

Species/Region (Colonial Breeding Waterbirds)	PT	PS	TB	TN	BD	ND	SUB TOT	AI	TOT	WL	Tier	Act. Level	Per. Resp.	Est. Pop. Cat.	Pop. Obj. Cat.
PENFL (BCR 31)	**5**		**5**	**3**				**2**	**26**		**I c**	**IM**	**100 reg.**	**3**	
Roseate Tern	**4**	**5**	**4**	**3**	**3**	**3**	22			**16**			**1 global**		
(North American-West Indies/Florida breeding pops.)	**4**	**5**	**4**	**3**	**5**	**5**									
Southeast U.S. Reg.	**3**		**4**	**3**				**2**	**27/23**		**I b**	**IM**	**7 us-can**	**4**	**5**
PENFL (BCR 31)	**3**		**4**	**3**				**2**	**27/23**		**I b**	**IM**	**100 reg.**	**4**	
STFL	*3*		*4*	*3*				*2*	*27/23*		*I b*	*IM*	*(100)*		
Sooty Tern	**3**	**2**	**3**	**2**	**3**	**2**	15						**<1 global**		
Southeast U.S. Reg.	**2**		**3**	**2**				**5**	**19**		**II c**	**PR**	**100 us-can**	**8**	**8a**
PENFL (BCR 31)	**2**		**3**	**2**				**5**	**19**		**II c**	**PR**	**99 reg.**	**8**	
STFL	*2*		*3*	*2*				*5*	*19*		*II c*	*PR*			
Brown Noddy	**3**	**3**	**3**	**2**	**3**	**2**	16						**<1 global**		
Southeast U.S. Reg.	**2**		**3**	**2**				**4**	**19**		**II c**	**PR**	**100 us-can**	**6**	**6a**
PENFL (BCR 31)	**2**		**3**	**2**				**4**	**19**		**II c**	**PR**	**100 reg.**	**6**	

Species/Region (Colonial Breeding Waterbirds)	PT	PS	TB	TN	BD	ND	SUB TOT	AI	TOT	WL	Tier	Act. Level	Per. Resp.	Est. Pop. Cat.	Pop. Obj. Cat.
STFL	*2*		*3*	*2*				*4*	*19*		*II c*	*PR*	*(100)*		

***Region**

Southeast U.S.: all bird conservation regions making up the Southeast U.S. Waterbird Conservation Planning Area for Waterbirds of the Americas.
EP (BCR 20): Edwards Plateau (TX)
OP (BCR 21): Oaks and Prairies (TX, OK)
WGCP (BCR 25): West Gulf Coastal Plain-Ouachita Mountains (OK, AR, TX, LA)
MAV (BCR 26): Mississippi Alluvial Valley (IL, MO, KY, TN, MS, AR, LA)
SECP (BCR 27): Southeastern Coastal Plain (KY, TN, LA, MS, AL, FL, GA, SC, NC, VA)
SACP: South Atlantic Coastal Plain (VA, NC, SC, GA, FL east of Apalachicola watershed)
EGCP: East Gulf Coastal Plain (KY, TN, LA, MS, AL, FL west of Apalachicola watershed)
APPS (BCR 28): Appalachians (AL, TN, KY, WV, OH, GA, SC, NC, VA, MD, PA, NY, NJ); many distinct physiographic areas with emphasis
here on the Southern Appalachians including Southern Blue Ridge, Southern Ridge and Valley and Southern Cumberland Plateau, Northern Cumberland Plateau, (less emphasis on Mid Atlantic Ridge and Valley and Allegheny Mountains, and

Ohio Hills). With the exception of Great Blue Heron and Green Heron found throughout this BCR, almost all species treated here when recorded in the Appalachians are mostly restricted to the Southern Ridge and Valley especially along the Tennessee River Valley (AL, TN, GA)

PIED (BCR 29): Piedmont (AL, GA, SC, NC, VA, MD, PA, NJ) with emphasis here on Southern Piedmont (AL, GA, SC, NC)

PENFL (BCR 31); Peninsular Florida (FL)

PENFL: Peninsular Florida, essentially north of Lake Okeechobee (Fort Myers and northward on Gulf side, Fort Lauderdale on Atlantic side)

on to northern extent of black mangrove on both coasts and Florida scrub.

STFL: Subtropical Florida, essentially south from Lake Okeechobee (Fort Myers and Fort Lauderdale) to include Florida Keys, Dry Tortugas

TAMB (BCR 36): Tamaulipan Brushlands (TX, Tam.)

GCP (BCR 37): Gulf Coastal Prairies (LA, TX)

LA: Louisiana including both Deltaic and Chenier Plains

UTX: Upper Texas Coast from Sabine River to East Matagorda Bay

CTX: Central Texas Coast from east Matagorda Bay to Baffin Bay

STX/Tam.:South Texas Coast from Baffin Bay (Tamaulipan Prairies, Laguna Madre, Padre Island) south into Tamaulipas, Mexico.

PT=Population Trend based on a combination of data sources, principally BBS tempered by local and state datasets for breeding species. For non-breeding species usually best professional judgment often based in part on continental trends shown in BBS and/or CBC.

5=Definite decrease
4=Possible decrease
3=Trend uncertain, No data
2=Possible increase, stable
1=Definite increase

Some guidelines based on BBS data, but for waterbirds trends are often dramatic and not linear so an inspection of trend graphs often is required to make a judgment as to trend score, again tempered by local and state data sets if they exist.

Significant increase (BBS trend ≥1.36%/yr, *P*≤0.10, df>13)	1	
Possible increase (≥0.47 to 1.36%/ yr, *P*≤0.35, w/any df)	2a	
Possible increase (≥1.36%/yr, 0.1<*P*≤0.35, df>13)	2a	
Possible increase (≥1.36%/yr, *P*≤0.10, df<13)		2a
Stable (> -0.54 to < +0.47%/yr, and UCI<0.47 OR LCI>-0.54)		2b
- except when trend is negative and P≤0.10 **and LCI<-0.54**, then Possible decrease		4
Trend uncertain (≤-0.54%/yr or ≥0.47%/yr and *P*>0.35)		3
Trend uncertain (>-0.54%/yr and <0.47%/yr and UCI>0.47 AND LCI<-0.54)		3
No data	3	
Possible decrease (either of next 3 options, but based on 6-13 degrees of freedom)		4
Possible decrease (≤-0.54 to -2.27%/yr, *P*=0.0-0.35)		4
Possible decrease (≤-2.27%/yr, 0.1<*P*≤0.35)		4
Significant decrease (≤-2.27%/yr and *P*≤0.10)		5

PS=Population Size based on best population estimates globally, most based on Delany and Scott (2002) and Kushlan et al. 2002.

5=Rare (<50 thousand breeding individuals globally)
4=Uncommon (50-500 thousand breeding individuals globally)
3=Fairly Common (500 thousand-5 million breeding individuals globally)
2=Common (5 million to 50 million breeding individuals globally)
1=Abundant (50 million + breeding individuals globally)

TB and TN=Threats Breeding and Threats Non-breeding

5=Extreme deterioration in the future suitability of breeding/non-breeding conditions is expected; species is in danger of regional extirpation or major range contraction, or has already been extirpated
4=Severe deterioration in the future suitability of breeding/non-breeding conditions is expected
3=Slight to moderate decline in the future suitability of breeding/non-breeding conditions is expected
2=Expected future conditions for breeding/non-breeding populations are expected to remain stable; no known threats
1=Expected future conditions for breeding/non-breeding populations are enhanced by human activities or land-uses; potentially a 'problem' species

BD and ND=Breeding Distribution and Non-breeding Distribution

5=Very Local Distribution (<500,000 km2, or very restricted coastal areas or interior uplands)
4=Local Distribution (>500,000 and <1,000,000 km2, or <1,600 km of coast)
3=Moderate Distribution (>1,000,000 and <2,000,000 km2, or >1,600 to <5,000 km of coast)
2=Widespread (>2,000,000 and <4,000,000 km2, or >5,000 to <8,000 km of coast)
1=Very Widespread (>4,000,000 km2, or >8,000 km of coast)

SUBTOT=Subtotal of six scores (absent AI)

AI=Area Importance, "relative" relative abundance for the species for each area within range scaled against its maximum relative abundance (i.e., the BCR or physiographic area supporting the highest relative abundance)

5=Very High relative abundance (~50+% of maximum relative abundance)
4=High relative abundance (~25-49% of maximum relative abundance)
3=Moderate relative abundance (~10-24% of maximum relative abundance)
2=Low relative abundance (~1-9% of maximum relative abundance)
1=Peripheral, scattered occurrences.

TOT=Total Score of all seven factors used for identifying Tiers for which species best fits for conservation planning at Planning Region/Bird Conservation Region/Physiographic Area.

WL=WatchList score used for Continental Scoring (PIF Approach); species with WL scores of 14 or more, or with 13 with PT=5 are identified. using formula: Total Continental Score = PT + PS + maximum of (BD or ND) + maximum of (TB or TN)

Tier=

I. Continental Conservation Interest (Continental WatchList): (a) Species with multiple causes for concern across their entire range; (b) Moderately abundant or widespread species with declines or high threats, and (c) Species with restricted distributions or low population size.

Species with multiple causes for concern across their entire range: These species are considered by many to be of highest continental concern and of highest priority for conservation actions at national and international scales.

Moderately abundant or widespread species with declines or high threats: These species are on the Watch List primarily because they are declining and/or threatened throughout their range, though still fairly widespread or with moderately large populations.

Species with restricted distributions or low population size: These species are on the Watch List because they are restricted to a small range or have small global populations (often both). Many of these species are not known to be declining or seriously threatened at present, but many others. We recognize that these species with small populations and restricted range are particularly vulnerable to relatively minor changes from current conditions, whether or not their populations are currently in decline.

II. Regional Conservation Interest (non-WatchList; TOT≥19): (a) high regional concern (AI+PT≥8); (b) high regional threats (TB+TN≥7, or TB or TN=5), (d) taxa (subspecies and populations) of regional conservation interest not otherwise included in categories above; (c) high regional responsibility (as measured by percent of global, continental, or regional populations).

III Additional Federally and/or State listed.

IV Local concern or interest.

Act. Level=Action Level at present based on expert opinion, but ultimately rules based on scores would be preferable.

IM=Immediate management needed to reverse or stabilize significant, long-term population declines in species with small populations, or to protect species with the smallest populations for which trends are poorly known. Lack of action may lead to extirpations or extinction.

MA=Management or other on-the-ground conservation actions needed to reverse or stabilize significant, long-term population declines in species that are still relatively abundant.

PR=Long-term Planning and Responsibility needed for species to ensure that sustainable populations are maintained for species for which a region has high responsibility for that species.

PC=Population Control/Suppression needed for species that are otherwise secure and increasing that may come into conflict with other species of higher conservation concern or other resources of interest.

Per. Resp.: Percent of Responsibility, that is percent of populations within planning region with respect to global population estimates (Delany and Scott 2002, Kushlan et al.2002) and temperate North America (U.S.-Canada) and within bird conservation region and physiographic area with respect to planning region estimates (based on collective estimates among State waterbird conservation coordinators).

Est. Pop. Cat. and **Pop. Obj. Cat.**= **estimated population category** is based on collective estimates among state waterbird conservation coordinators and **population objective category** is still under discussion, but regional suggestions are provided.

[1]Key to population categories:

(1) <10 pairs

(2b) 1>20 pairs
(2) 10-50 pairs
(2a) 40<60 pairs

(3b) 40>60 pairs
(3) 50-100 pairs
(3a) 90<200 pairs

(4b) 90>200 pairs
(4) 100-500 pairs
(4a) 400<600 pairs

(5b) 400>600 pairs
(5) 500-1,000 pairs
(5a) 900<2,000 pairs

(6b) 900>2,000 pairs
(6) 1,000-5,000 pairs
(6a) 4,000<6,000

(7b) 4,000>6,000 pairs
(7) 5,000-10,000 pairs
(7a) 9,000<20,000 pairs

(8b) 9,000>20,000 pairs
(8) 10,000-50,000 pairs
(8a) 40,000<60,000 pairs

(9b) 40,000>60,000 pairs
(9) 50,000-100,000 pairs
(9a) 90,000<200,000 pairs

(10b) 90,000>200,000 pairs
(10) 100,000-500,000 pairs
(10a) 400,000<600,000 pairs

APPENDIX B

Southeast Region Waterbird Priorities and Habitat Types

Table 1. Southeast U.S. Waterbird Conservation Plan species priorities and habitat suites (b=breeding, r=resident, w=winter, r=resident).*

Tier	Tier Title	Action Level	Herons and allies, Pelicans and allies typically brush and tree nesting colonial waterbirds	Larids typically beach (ground)-nesting colonial waterbirds (terns, gulls, skimmers)	Marshes/ Savannas/ Grasslands	Open water (with mud and sand flats also foraging habitat for most colonial species)	Pelagic (all non-breeding populations)
I.	**Continental Conservation Interest**						
a.	**Multiple concerns**	*Immediate management*	"Great White" Heron		Black Rail (b/r)		Bermuda Petrel
					King Rail (b/r)		Black-capped Petrel
					Yellow Rail (w)		
					Whooping Crane (w-TX, r-FL)		
b.	**High threats and/or declining**	*Immediate management*		Roseate Tern		Horned Grebe (w)	Audubon's Shearwater
		Management attention	Little Blue Heron	Gull-billed Tern			Greater Shearwater
				Least Tern			Band-rumped Storm-Petrel
				Black Skimmer			Bridled Tern

Tier	Tier Title	Action Level	Herons and allies, Pelicans and allies typically brush and tree nesting colonial waterbirds	Larids typically beach (ground)-nesting colonial waterbirds (terns, gulls, skimmers)	Marshes/ Savannas/ Grasslands	Open water (with mud and sand flats also foraging habitat for most colonial species)	Pelagic (all non-breeding populations)
		Planning and responsibility	Masked Booby				Brown Booby
							Razorbill
c.	**Local and/or rare**	*Immediate Management*	Magnificent Frigatebird				
			Reddish Egret				
		Management attention					Cory's Shearwater
							Manx Shearwater
		Planning and responsibility		Bridled Tern			
Tier	**Tier Title**	**Action Level**	**Herons and allies, Pelicans and allies typically brush and tree nesting colonial waterbirds**	**Larids typically beach (ground)-nesting colonial waterbirds (terns, gulls, skimmers)**	**Marshes/ Savannas/ Grasslands**	**Open water (with mud and sand flats also foraging habitat for most colonial species)**	**Pelagic (all non-breeding populations)**
II.	**Regional Conservation Interest**						
a.	**High Concern**	Immediate Management	Wood Stork (b/r, FL, GA, SC, AL))		Least Bittern (b/r)	Red-throated Loon (w)	Sooty Shearwater

Tier	Tier Title	Action Level	Herons and allies, Pelicans and allies typically brush and tree nesting colonial waterbirds	Larids typically beach (ground)-nesting colonial waterbirds (terns, gulls, skimmers)	Marshes/ Savannas/ Grasslands	Open water (with mud and sand flats also foraging habitat for most colonial species)	Pelagic (all non-breeding populations)
		Management attention	Green Heron		Purple Gallinule (b/r)	Common Tern (transient populations)	
			Black-crowned Night-Heron		American Coot (breeding populations only)	Black Tern (transient populations)	
			Wood Stork (nb, MS, LA, TX, AR, elsewhere)		Limpkin (r)		
					American Bittern (w)		
		Planning and responsibility	Yellow-crowned Night-Heron	Royal Tern			
				Sandwich Tern			
b.	**High Threats**	*Immediate management*			Sandhill Crane (Mississippi subspecies)		
		Management attention	White Ibis	Common Tern (Atlantic and Gulf coast breeding populations only)	Pied-billed Grebe (breeding populations only)	Greater Flamingo (formerly bred)	Northern Gannet
						Common Loon (w)	

Tier	Tier Title	Action Level	Herons and allies, Pelicans and allies typically brush and tree nesting colonial waterbirds	Larids typically beach (ground)-nesting colonial waterbirds (terns, gulls, skimmers)	Marshes/ Savannas/ Grasslands	Open water (with mud and sand flats also foraging habitat for most colonial species)	Pelagic (all non-breeding populations)
						American White Pelican (w)	
II.							
c.	**High Responsibility**	*Planning and responsibility*	Brown Pelican	Forster's Tern (actually nests in marshes)	Clapper Rail (r)	Franklin's Gull (transient populations)	Sooty Tern
			Tricolored Heron	Sooty Tern (Florida breeding population only; nests under cover)	Sandhill Crane (Florida subspecies)	Bonaparte's Gull (w)	Brown Noddy
				Brown Noddy (Florida breeding population only; elevated nests in shrubs, trees)	Sandhill Crane (Greater, Lesser, and Canadian subspecies)		
III.	**Additional Federal and State Listed Species**						
IV.	**Additional local or regional interest**	*Planning and responsibility*	Anhinga	Caspian Tern	Least Grebe (r)	Eared Grebe (w)	
			Great Blue Heron		Common Moorhen (b/r)		

Tier	Tier Title	Action Level	Herons and allies, Pelicans and allies typically brush and tree nesting colonial waterbirds	Larids typically beach (ground)-nesting colonial waterbirds (terns, gulls, skimmers)	Marshes/ Savannas/ Grasslands	Open water (with mud and sand flats also foraging habitat for most colonial species)	Pelagic (all non-breeding populations)
			Great Egret		Virginia Rail (w)		
			Snowy Egret		Sora (w)		
			Glossy Ibis				
			White-faced Ibis				
			Roseate Spoonbill				
IV.		*Population Control*	Neotropical Cormorant	Laughing Gull			
			Double-crested Cormorant	Herring Gull			
			Cattle Egret	Great Black-backed Gull			
	Other species covered in this plan					Pied-billed Grebe (non-breeding populations)	Wilson's Storm-Petrel
						American Coot (non-breeding populations)	Leach's Storm-Petrel
						Ring-billed Gull	Pomarine Jaeger
						Lesser Black-backed Gull	Parasitic Jaeger

Tier	Tier Title	Action Level	Herons and allies, Pelicans and allies typically brush and tree nesting colonial waterbirds	Larids typically beach (ground)-nesting colonial waterbirds (terns, gulls, skimmers)	Marshes/ Savannas/ Grasslands	Open water (with mud and sand flats also foraging habitat for most colonial species)	Pelagic (all non-breeding populations)
							Black-legged Kittiwake
							Dovekie

*See Appendices I-III.

Tier=

I. Continental Conservation Interest (Continental WatchList): (a) Species with multiple causes for concern across their entire range; (b) Moderately abundant or widespread species with declines or high threats, and (c) Species with restricted distributions or low population size.

Species with multiple causes for concern across their entire range: These species are considered by many to be of highest continental concern and of highest priority for conservation actions at national and international scales.

Moderately abundant or widespread species with declines or high threats: These species are on the Watch List primarily because they are declining and/or threatened throughout their range, though still fairly widespread or with moderately large populations.

Species with restricted distributions or low population size: These species are on the Watch List because they are restricted to a small range or have small global populations (often both). Many of these species are not known to be declining or seriously threatened at present, but many others. We recognize that these species with small populations and restricted range are particularly vulnerable to relatively minor changes from current conditions, whether or not their populations are currently in decline.

II. Regional Conservation Interest (non-WatchList; TOT≥19): (a) high regional concern (AI+PT≥8); (b) high regional threats (TB+TN≥7, or TB or TN=5) and includes taxa (subspecies and populations) of regional conservation interest not otherwise included in categories above; (c) high regional responsibility (as measured by percent of global, continental, or regional populations).

III Additional Federally and/or State listed.

IV Local or regional concern or interest.

Act. Level=Action Level at present based on expert opinion, but ultimately rules based on scores would be preferable.

IM=Immediate management needed to reverse or stabilize significant, long-term population declines in species with small populations, or to protect species with the smallest populations for which trends are poorly known. Lack of action may lead to extirpations or extinction.

MA=Management or other on-the-ground conservation actions needed to reverse or stabilize significant, long-term population declines in species that are still relatively abundant.

PR=Long-term Planning and Responsibility needed for species to ensure that sustainable populations are maintained for species for which a region has high responsibility for that species.

PC=Population Control/Suppression needed for species that are otherwise secure and increasing that may come into conflict with other species of higher conservation concern or other resources of interest.

APPENDIX C

Wildlife Conservation Commission

FLORIDA'S ENDANGERED SPECIES, THREATENED SPECIES AND SPECIES OF SPECIAL CONCERN

Official Lists

Publication Date: 1 August 1997

This document consolidates the state and federal official lists of endangered species, threatened species, and other species categorized in some way by the respective jurisdictional agencies as meriting special protection or consideration. The state lists of animals are maintained by the Florida Game and Fresh Water Fish Commission and categorized as endangered, threatened and of special concern, and constitute Rules 39-27.003, 39-27.004 and 39-27.005, respectively, Florida Administrative Code (F.A.C.). The state lists of plants are categorized into endangered, threatened and commercially exploited, and are administered and maintained by the Florida Department of Agriculture and Consumer Services via Chapter 5B-40, F.A.C. The federal lists of animals and plants are administered by the U.S. Fish and Wildlife Service and categorized into endangered and threatened, and are published in 50 CFR 17 (animals) and 50 CFR 23 (plants). The abbreviations used in part one are:

GFC = Florida Fish and Wildlife Conservation Commission

FDA = Florida Department of Agriculture and Consumer Services

FWS = United States Fish and Wildlife Service

E = Endangered

T = Threatened

T(S/A) = Threatened/Similarity of Appearance

T(E/P) = Threatened/Experimental Population

SSC = Species of Special Concern

C = Commercially Exploited

		Designated Status	
Scientific Name	**Common Name(s)**	**GFC**	**FWS**
Birds			
Ajaia ajaja	Roseate spoonbill	SSC	
Ammodramus maritimus juncicolus	Wakulla seaside sparrow	SSC	

		Designated Status	
Scientific Name	**Common Name(s)**	**GFC**	**FWS**
Ammodramus maritimus mirabilis	Cape Sable seaside sparrow	E	E
Ammodramus maritimus peninsulae	Scott's seaside sparrow	SSC	
Ammodramus savannarum floridanus	Florida grasshopper sparrow	E	
Aphelocoma coerulescens	Florida scrub-jay	T	T
Aramus guarauna	Limpkin	SSC	
Campephilus principalis	Ivory-billed woodpecker	E	E
Charadrius alexandrinus tenuirostris	Southeastern snowy plover	T	
Charadrius melodus	Piping plover	T	T
Cistothorus palustris griseus	Worthington's marsh wren	SSC	
Cistothorus palustris marianae	Marian's marsh wren	SSC	
Columba leucocephala	White-crowned pigeon	T	
Dendroica kirtlandii	Kirtland's warbler	E	E
Egretta caerulea	Little blue heron	SSC	
Egretta rufescens	Reddish egret	SSC	
Egretta thula	Snowy egret	SSC	
Egretta tricolor	Tricolored (=Louisiana) heron	SSC	
Eudocimus albus	White ibis	SSC	
Falco peregrinus tundrius	Arctic peregrine falcon	E	
Falco sparverius paulus	Southeastern American kestrel	T	

		Designated Status	
Scientific Name	**Common Name(s)**	**GFC**	**FWS**
Grus americana	Whooping crane	SSC	T(E/P)
Grus canadensis pratensis	Florida Sandhill crane	T	
Haematopus palliatus	American oystercatcher	SSC	
Haliaeetus leucocephalus	Bald eagle	T	T
Mycteria americana	Wood stork	E	E
Pandion haliaetus	Osprey	SSC*	
Pelecanus occidentalis	Brown pelican	SSC	
Picoides borealis	Red-cockaded woodpecker	T	E
Polyborus plancus audubonii	Audubon's crested caracara	T	T
Rostrhamus sociabilis	Snail kite	E	E
Rynchops niger	Black skimmer	SSC	
Speotyto cunicularia	Burrowing owl	SSC	
Sterna antillarum	Least tern	T	
Sterna dougallii	Roseate tern	T	T
Vermivora bachmanii	Bachman's warbler	E	E
*Applicable in Monroe County only			

APPENDIX D

US FISH AND WILDLIFE SERVICE, SPECIES OF CONSERVATION CONCERN IN PENINSULAR FLORIDA (BCR 31)

Black-capped Petrel
Audubon's Shearwater
Magnificent Frigatebird
American Bittern
Little Blue Heron
Reddish Egret
White Ibis
Swallow-tailed Kite
Short-tailed Hawk
American Kestrel (resident *paulus* ssp. only)
Peregrine Falcon
Yellow Rail
Black Rail
Limpkin
Snowy Plover
Wilson's Plover
American Oystercatcher
Whimbrel
Marbled Godwit
Red Knot
Semipalmated Sandpiper
Stilt Sandpiper
Buff-breasted Sandpiper
Short-billed Dowitcher
Gull-billed Tern
Common Tern
Least Tern
Black Tern
Black Skimmer
White-crowned Pigeon
Common Ground-Dove
Mangrove Cuckoo
Smooth-billed Ani
Burrowing Owl
Chuck-will's-widow
Red-headed Woodpecker
Loggerhead Shrike
Black-whiskered Vireo
Brown-headed Nuthatch
Yellow Warbler (resident *gundlachi* ssp. only)
Yellow-throated Warbler
Prairie Warbler
Bachman's Sparrow
Henslow's Sparrow
Nelson's Sharp-tailed Sparrow
Saltmarsh Sharp-tailed Sparrow
Seaside Sparrow

APPENDIX L.5

EVERGLADES NATIONAL PARK

FINAL DRAFT

Avian Conservation Implementation Plan
Everglades National Park

National Park Service
Southeast Region



Compiled by J. Keith Watson
U.S. Fish and Wildlife Service
In cooperation with

EVER Resource Management Staff, National Park Service
And Bird Conservation Partners
January 2005

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Introduction

This Avian Conservation Implementation Plan (ACIP) is provided to the staff at Everglades National Park (EVER) to help identify and prioritize bird conservation opportunities, and to provide information and guidance for the successful implementation of needed conservation activities. This plan may identify goals, strategies, partnerships, and perhaps specific projects for the park to participate in existing bird conservation planning and implementation efforts associated with the North American Bird Conservation Initiative (NABCI). Under the auspice of NABCI, appropriate bird and habitat conservation goals may be recommended as identified in the appropriate existing national or regional bird conservation efforts aligned with this initiative: Partners In Flight (PIF), North American Waterfowl Management Plan (NAWMP), US Shorebird Conservation Plan (USSCP), and Waterbird Conservation for the Americas (WCA). For example, parks in the Appalachians and the Cumberland Plateau will have few if any high priority waterbird conservation issues at a regional landscape or greater scale. As such, little information regarding waterbird conservation will be presented in the ACIP, unless there is an identified park need for this species group, or other mandates, such as federal laws. Similarly, because EVER is primarily a subtropical wetland interspersed with various forest types, waterbird and landbird conservations recommendations will be derived from the appropriate national level plans. However, all high priority bird conservation issues for EVER will be discussed and integrated as appropriate.

Information and data presented in the ACIP have been obtained from several sources: 1) interviews with EVER staff 2) EVER bird conservation partners 3) the PIF Subtropical Florida Bird Conservation Plan Executive Summary (PIF 2000) 4) NPS databases, 5) peer reviewed bird conservation and management literature, and 6) personal communications with bird conservation specialists throughout North America, especially in the southeastern United States. This plan has been reviewed by EVER resource management staff and managers, South Florida/Caribbean Inventory and Monitoring Network (SF/C I&M) staff, and bird conservation partners and approved by EVER management. Optimally, this plan will be incorporated into the park's natural resource planning and management documents and updated annually to reflect completed projects, newly identified needs, and shifts in bird conservation priorities in the region.

EVER is not obligated to undertake any of the proposed actions in this plan. The plan is provided to offer guidance to EVER to voluntarily support important park, regional, and perhaps national and international bird conservation projects for which EVER is a primary participant in the proposed actions.

Background

During the past thirty years, monitoring programs across North America have documented declines of certain bird species populations and their habitats, often severe (Sauer et al. 2000). The decline has caused great concern among scientists, biologists,

biodiversity proponents, ecologists, land managers, etc., and the bird conservation community in general. Birds are recognized as critical components of local and global genetic, species, and population diversity, providing important and often critical ecological, social, economic, and cultural values. Their overall decline has stimulated a worldwide focus on conservation efforts and North American interest in bird conservation is rapidly becoming a focus of government, non-government, industry, and private interests and expenditures.

Many state, federal, and non-governmental wildlife agencies and non-government organizations (NGO's) have recognized this alarming bird decline trend and have joined forces in several extensive partnerships to address the conservation needs of various bird groups and their habitats. The primary initiatives are:

- North American Waterfowl Management Plan
- Partners in Flight
- U.S. Shorebird Conservation Plan
- Waterbird Conservation for the Americas

The North American Bird Conservation Initiative: While efforts associated with these plans have generated some successes, it has been increasingly recognized that the overlapping conservation interests of these initiatives can be better served through more integrated planning and delivery of bird conservation. The *North American Bird Conservation Initiative (NABCI*; http://www.nabci-us.org/main2.html*)* arose out of this realization. The vision of NABCI is simply to see ***"populations and habitats of North America's birds protected, restored and enhanced through coordinated efforts at international, national, regional, state and local levels, guided by sound science and effective management."*** NABCI seeks to accomplish this vision through (1) broadening bird conservation partnerships, (2) working to increase the financial resources available for bird conservation in the U.S., and (3) enhancing the effectiveness of those resources and partnerships by facilitating integrated bird conservation (U.S. NABCI Committee 2000). Together, the four bird conservation initiatives mentioned above, as well as several other local and regional partnerships, work collectively to pursue this vision.

NABCI is guided by a set of principles that establish an operational framework within which the Initiative and its partners may conduct integrated bird conservation in the U.S. These will articulate a common understanding of the relationship between NABCI, the individual bird conservation initiatives, and all partner entities to ensure recognition of existing federal legislative and international treaty obligations, state authorities, and respect for the identity and autonomy of each initiative. The fundamental components of the conservation approach to be used by NABCI are expressed within its goal:

> ***To deliver the full spectrum of bird conservation through regionally-based, biologically-driven, landscape-oriented partnerships.***

The Southeastern Bird Conservation Initiative: National Park Service: In 1999, the Southeast Region of the National Park Service (NPS) recognized the importance of coordinating existing bird conservation goals into planning and operations of national park units in the southeast, that is, integration of NABCI. In support of this recognition, the Southeast Regional Office NPS approved and allocated eighty-eight thousand dollars, cost sharing 1:1 with the US Fish and Wildlife Service (FWS) Region 4 (Southeast) to hire a biologist to conduct this two-year project (Interagency Agreement FS028 01 0368). This project is unique in the NPS, and perhaps the nation, and represents a potential model for better coordinating regional bird conservation programs and activities within and outside the NPS. It further represents a progressive action toward institutionalizing bird conservation as a programmatic priority in the Southeast Region of NPS, and potentially the nation.

As envisioned, the integration of NABCI into the Southeastern NPS involves:

1) Development and delivery of Avian Conservation Implementation Plans,
2) Coordination with NPS Inventory and Monitoring Program,
3) Development of a web based project site,
4) Establishment or enhancement of bird conservation partnerships,
5) Identification and exploration of potential funding opportunities, and
6) Technical guidance and assistance as needed or requested.

This ACIP fulfills one aspect of the plan outlined above, and serves as a basis for future bird conservation actions in EVER and with adjacent partners or landowners. Concurrently, the development of a Memorandum of Understanding (MOU) between the FWS and the NPS to implement Presidential Executive Order (EO) 13186, Responsibilities of Federal Agencies to Protect Migratory Birds (US Government 2000), calls for integration of programs and recommendations of existing bird conservation efforts into park planning and operations. Complementing each other, the MOU and the Southeastern Bird Conservation Initiative will advance bird conservation in the Southeast Region of the NPS beyond current regional NPS efforts.

Role of NPS in Avian Conservation

The interagency agreement that facilitates this partnership supports both FWS and NPS management policies. Specifically for the NPS, the agreement supports and advances the Strategy for Collaboration, a visionary document developed and signed by the Southeast Natural Resource Leaders Advisory Group (SENRLAG 2000), a consortium of 13 land and resource management agencies in the Southeastern United States whose vision is to encourage and support cooperation in planning and managing the region's natural resources. Furthermore, the agreement is aligned with and implements a variety of NPS Management Polices (2001) including, but not limited to, External Threats and Opportunities, Environmental Leadership, Cooperative Planning, Land Protection, and especially Natural Resource Management that details policy and management guidelines which apply to bird conservation. Important policies in the Natural Resource Management chapter include:

- Planning for Natural Resource Management
- Partnerships
- Restoration of Natural Systems
- Studies and Collection
- General Principles for Managing Biological Resources
- Plant and Animal Population Management Principles
- Management of Native Plants and Animals
- Management of Endangered Plants and Animals
- Management of Natural Landscapes
- Management of Exotic Species
- Pest Management
- Fire Management and
- Water Resource Management

The NPS is the fourth largest landowner in the United States, consisting of over 380 national park units covering 83 million acres of land and water with associated biotic resources (www.nps.gov). The 64 units in the Southeast Region of the NPS represent 16% of the total number of park units in the national park system and cover approximately 5% of the total land base in the entire system. Park units in the Southeast Region include national seashores (Canaveral National Seashore, Cape Hatteras National Seashore), national parks (Great Smoky Mountains National Park, Everglades National Park), national recreation areas (Big South Fork National Recreation Area), national preserves (Big Cypress National Preserve), national battlefields (Cowpens National Battlefield, Fort Donelson National Battlefield), national monuments (Ocmulgee National Monument), and others such as the Blue Ridge Parkway, Obed Wild and Scenic River, and Timicuan Ecological and Historic Preserve.

Southeast NPS units provide habitat for over 400 species of migrating, breeding, and wintering birds and include a wide range of Federal and State listed threatened and endangered species. Likewise, these units also provide nest, migration, and winter habitat for most of the eastern species identified in the national bird conservation plans in need of conservation attention.

Additionally, the NPS attracts over 280 million visitors to the parks each year, 120 million of these in the Southeast Region, affording excellent recreational bird watching and opportunities to strengthen bird conservation interpretation, outreach, and education programs. These opportunities, the NPS mission, policies, and organization all lead to the conclusion that the NPS is an extremely valuable partner and contributor to bird conservation in the region.

Nationally, the status of birds in national parks is largely unknown, although many parks have adequate knowledge regarding bird occurrence in the parks (http://www.npwrc.usgs.gov/resource/othrdata/chekbird/chekbird.htm). Parks often play

a role in ongoing regional bird conservation efforts. Indeed many of these parks are often important to regional, national, or international bird conservation, and many have been designated as Important Bird Areas (IBA's) by the National Audubon Society. To date, there are approximately 64 NPS units that are designated IBA's, 35 of which are considered of global importance (http://abcbirds.org/iba/aboutiba.htm). In the Southeast Region, the NPS has 13 global IBA's.

The **NPS Inventory and Monitoring (I&M) Program** has been developed to provide management driven scientific information to national park managers so that resources can be adequately protected within national parks. One of the first phases of this program is to inventory vertebrates, including birds, within the 260 national park units in the program. Once completed, data from the inventories will provide an account of the occurrence and abundance of birds in all the national parks in the program. These records will be stored in the NPS I&M NPSpecies database (http://www.nature.nps.gov/im/apps/npspp/). Coordination with I&M network staff is important to developing long-term bird monitoring programs that fulfill both park and NABCI objectives.

Park Flight is a NPS international partnership initiative that directs funding toward a variety of NPS programs that involve conservation of Neotropical migratory birds whose life history range covers a U.S. national park and a Latin American protected area. A relatively new program, Park Flight offers parks the opportunity to partner with a Latin American national park or protected area to cooperate on developing bird conservation and education projects (USDI NPS 2002).

Recent increases in NPS base funded programs such as inventory and monitoring, exotic species management, habitat restoration, and fire management all indicate that national park managers recognize that park lands are increasingly subject to a variety of threats and conditions that must be improved to provide the quality of national park experience articulated in the NPS Organic Act (1916). Programmatic funding in these areas will increase the ability of national parks to provide quality habitat and conditions for increased wildlife conservation, including birds. Furthermore, private interests and non-profit conservation organizations have initiated programs, including grant programs, to provide much needed funding to national parks to meet backlogs of identified yet unfunded needs.

Park Description

Established in 1947, the Everglades National Park's 610,497 ha (1.5 million acres) include habitats ranging from freshwater marshes in Shark River Slough to Florida Bay, an occasionally hypersaline, seagrass-dominated marine lagoon. Other prominent natural communities are subtropical hardwood hammocks, the last large intact remnant of South Florida upland pineland forests and an extensive mangrove dominated estuary. Everglades National Park is designated as an International Biosphere Reserve (1976), Wilderness Designation (1976), a World Heritage Site (1979), and a Wetland of International Significance (1987). The Park is the southeast's largest designated

wilderness and hosts 14 threatened and endangered species. It is a significant North American breeding ground for subtropical wading birds and contains the largest mangrove ecosystem in the Western Hemisphere. Together with neighboring Big Cypress National Preserve and Biscayne National Park, these protected habitats are almost 1 million hectares (2,471,053 acres) in size and are significant elements of the South Florida ecosystem, a natural continuum that begins in the Kissimmee River Basin and ends at the Gulf of Mexico and Florida Keys (Sasso and Patterson 2000).

Avian Resources of Subtropical Florida

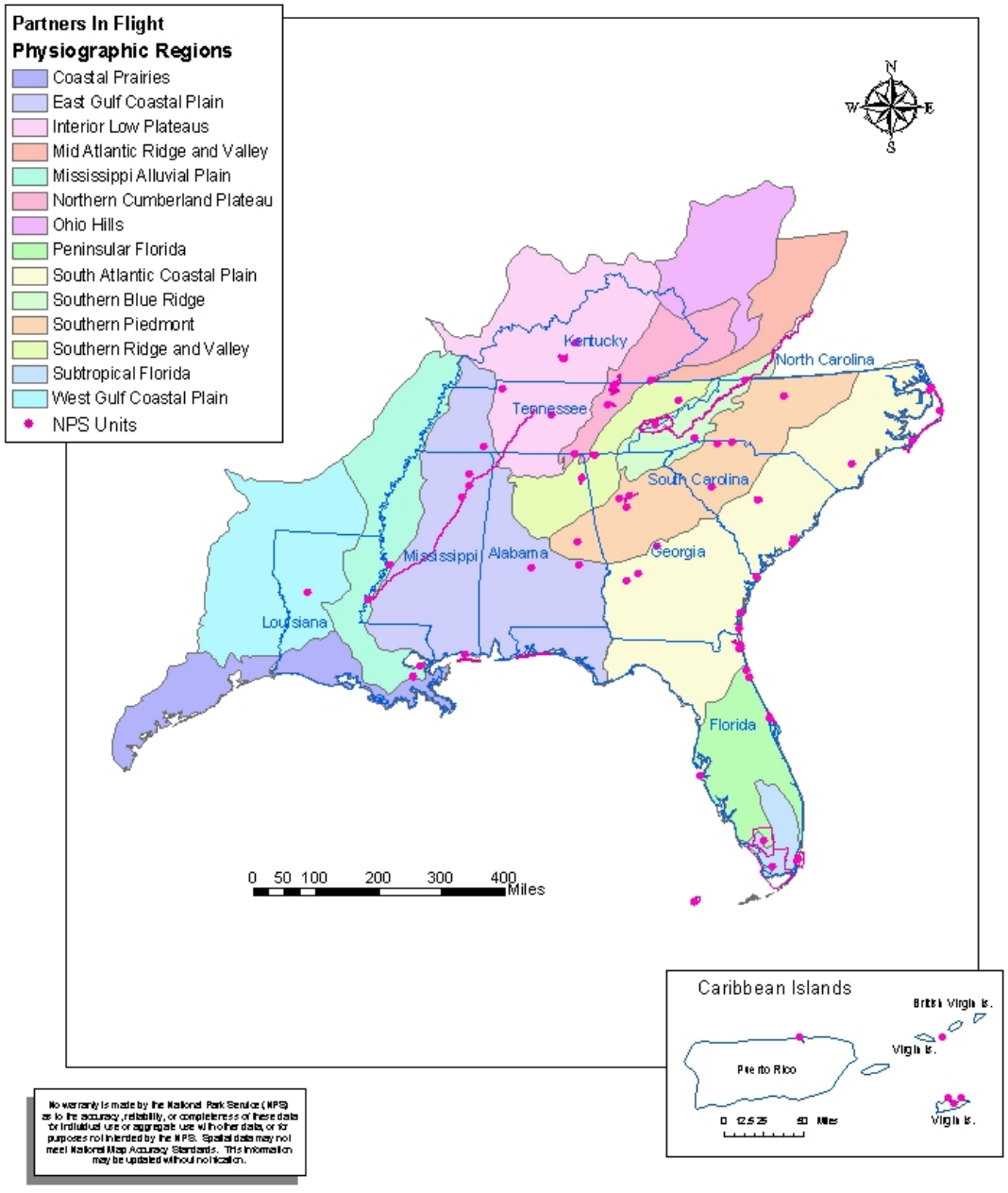
This physiographic area is entirely contained within Florida, and extends from the northern edge of Lake Okeechobee south through the Florida Keys (see PIF and NPS location maps below). The region has very little topographic relief, but slight changes in elevation have important consequences for vegetation and the diversity of habitat types. The highest points of elevation are less than 2 meters and correspond with fairly recent shorelines (less than 5,000 years before present). Underlying sediments consist of freshwater marl, peat, freshwater lake and marine sediments, and to a lesser extent, sand deposited during the Pleistocene and Holocene. The subtropical Florida region can be divided into four smaller sub-regions: 1) the Everglades, 2) Big Cypress, 3) Miami Ridge and Atlantic Coastal Ridge, and 4) Southern Coasts and Islands. The Everglades is the most extensive of these areas, followed by the Big Cypress, Miami Ridge and Southern Coasts. Across all subregions, much of the physical and ecological characteristics of the region resemble tropical ecosystems where seasonal changes are reflected by changing rainfall patterns rather than by dramatic temperature changes. Distinctive dry (winter/spring) and wet (summer) seasons occur annually, and the nesting cycles of many birds are tied to these changes. At least two major forms of disturbance play key roles in the ecology of the region. Fire is an important feature in many pine dominated communities and many marsh and prairie communities. Frequent fires are essential in pine-dominated stands and prairies if understory conditions suitable to many nesting birds are to be maintained. However, the ideal fire frequency in some pine communities is not known. Hurricanes are a second form of disturbance that less frequently but predictably provide early successional habitats or open forest cover (PIF http://www.blm.gov/wildlife/pl_01sum.htm).

Bird conservation priorities for Subtropical Florida have been stratified by habitat type. Recognized habitat types where high priority conservation actions are needed for both birds and habitats are pine forests (including pine rocklands, pine Flatwoods, sand pine scrub), grassland/grassland-scrub (including dry prairie and coastal strands), subtropical deciduous forest, everglades, brackish saltwater and freshwater marsh, and mangrove swamps. Species associated with each of these habitats and identified as high priority for conservation needs are given below.

Partners in Flight (PIF) Regions

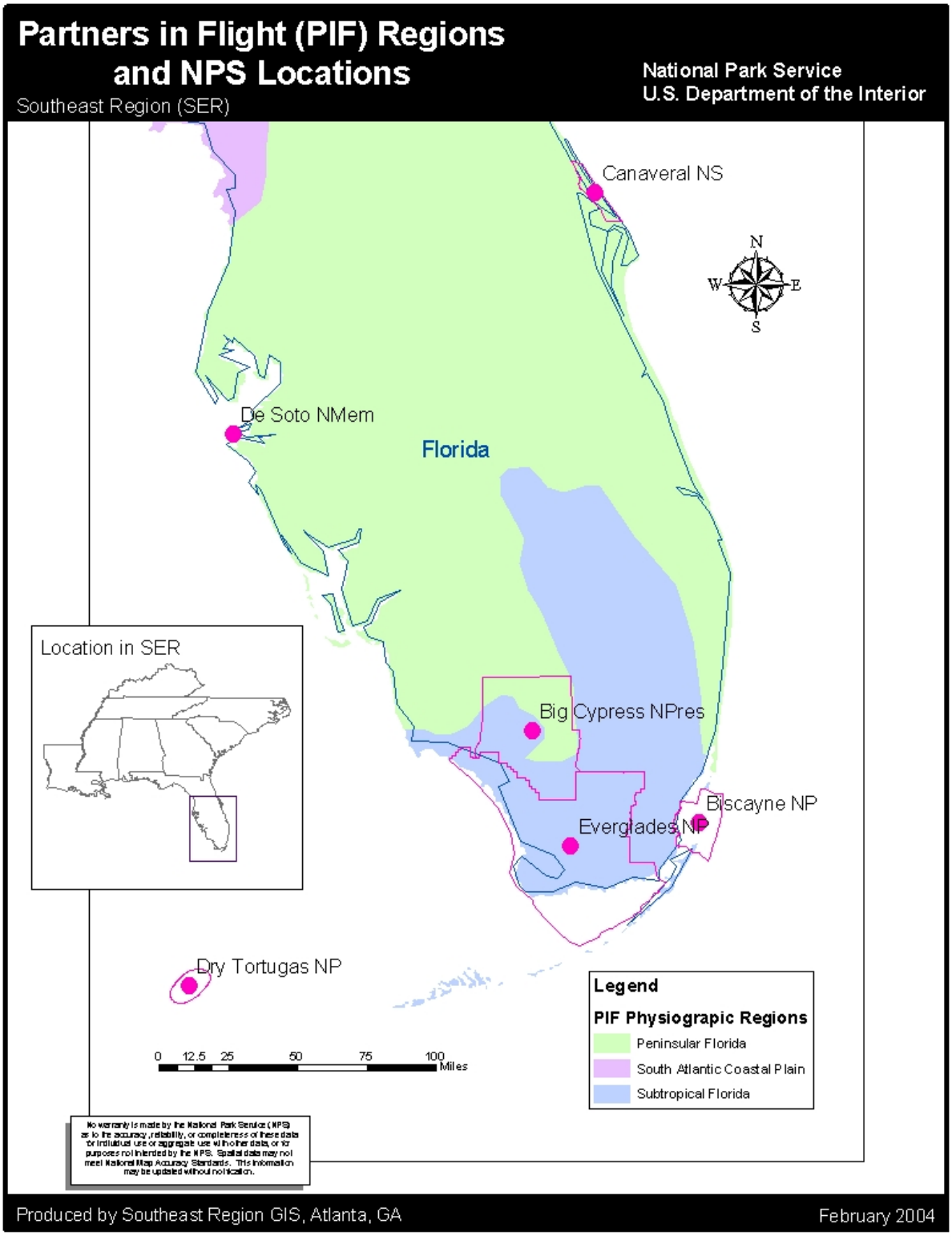
Southeast Region (SER)

National Park Service
U.S. Department of the Interior



Produced by Southeast Regional Office GIS, Atlanta, GA

March 2004


Partners in Flight (PIF) Regions
and NPS Locations
Southeast Region (SER)
National Park Service
U.S. Department of the Interior
Canaveral NS
N
W
E
S
De Soto NMem
Florida
Location in SER
Big Cypress NPres
Biscayne NP
Everglades NP
Dry Tortugas NP
Legend
PIF Physiograpic Regions
Peninsular Florida
South Atlantic Coastal Plain
Subtropical Florida
0 12.5 25 50 75 100
Miles
No warranty is made by the National Park Service (NPS) as to the accuracy, reliability, or completeness of these data for individual use or aggregate use with other data, or for purposes not intended by the NPS. Spatial data may not meet National Map Accuracy Standards. This information may be updated without notification.
Produced by Southeast Region GIS, Atlanta, GA
February 2004

Florida Scrub Jay, Red-cockaded Woodpecker, Southeastern American Kestrel, Brown-headed Nuthatch, Bachman's Sparrow, Pine Warbler and Sedge Wren are associated with the pine forests. Both Florida Scrub Jay and Southeastern American Kestrel have been extirpated in Subtropical Florida and the Brown-headed Nuthatch and Bachman's Sparrow are nearly extirpated here. Recently, however, EVER and Big Cypress National Preserve (BICY) cooperated on a project to reintroduce Brown-headed Nuthatch and Eastern Bluebird into EVER, a successful project that points the way to potential future relocations of these species throughout South Florida (Slater 2001). Both Palm Warbler and Sedge Wren are present only in the non-breeding seasons.

Grasshopper Sparrow, Crested Caracara, Burrowing Owl, Sandhill Crane and Mottled Duck are all species associated with grassland to grassland scrub habitats. Grasshopper Sparrow has been extirpated as a breeder in South Florida.

In the subtropical deciduous forest, Short-tailed Hawk, Swallow-tailed Kite and Gray Kingbird are high priorities for conservation.

In the Everglades, brackish saltwater and freshwater marshes, Snail Kite, Cape Sable Seaside Sparrow, Wood Stork, Black Rail, Reddish Egret, Yellow Rail, White Ibis, and Clapper Rail are species in need of conservation attention.

Prairie Warbler, Yellow Warbler, Black-whiskered Vireo, White-crowned Pigeon and Mangrove Cuckoo, species associated with Mangrove swamps and forests are of high priority conservation concern.

Human population growth has been phenomenal in subtropical Florida for the last 40 years. The impacts of such tremendous growth include increased infrastructure that directly reduces habitat availability, but also secondary impacts to bird habitats, such as pollution. Other land uses include production of sugarcane, winter vegetables, and citrus. Drastic changes in hydroperiod and natural water cycles are secondary impacts of increasingly intensive agriculture. However, among the best opportunities in the Southeast to work with existing public lands occur in Subtropical Florida, where over 54% of the area is publicly owned. Therefore, primary conservation programs include efforts to reduce impacts from adjacent or nearby lands on management of existing public lands. Many programs have been developed and are in various phases of implementation. These include the Save Our Everglades program, the Surface Water Improvement and Management Act, Florida's Everglades Forever Act and the development of the South Florida Ecosystem Restoration Task Force as well as aggressive acquisition programs. These and other programs serve the basis for bird conservation efforts in the region (PIF http://www.blm.gov/wildlife/pl_01sum.htm).

Avian Conservation in EVER

Avian Biodiversity: EVER has a complete avian inventory and a checklist of birds that is available for the public. Over 350 species have been observed in EVER, and

birdwatching in the park is a primary recreational pursuit due to the large number of species found in the park.

Verified records of birds in EVER have been entered into the NPS I&M program's database, NPSpecies, and may be viewed via the internet at http://www.nature.nps.gov/im/app/npspp with a user identification and password combination authorized by the NPS for NPS personnel and NPS cooperators. Many other avian observational data need to be verified and entered into the database.

Park Priorities: Park staff and consultants have not identified any particular species that is a park management concern or high priority for conservation. However, the presence of 7 Federally listed birds requires compliance with the Endangered Species Act and a large amount of staff time is given to managing these species and their habitats. Additionally, park staff is concerned about conserving all birds and their habitats in EVER. However, several species that occur in EVER are high priority in Subtropical Florida and conservation efforts in the park could focus on these species or groups of species. Generally, great effort in put forth to monitor colonial waterbird species and their nesting success.

Threatened and Endangered Species: Seven Federally listed threatened or endangered species occur in EVER. Wood Stork, Bald Eagle, Snail Kite, Cape Sable Seaside Sparrow, Brown Pelican all nest in the park while Piping Plover is an uncommon winter resident and Roseate Tern is a rare winter visitor. Red-cockaded Woodpecker formerly nested in EVER but is now extirpated. The recently delisted American Peregrine Falcon is a rare but regular fall transient and winter visitor.

In addition to the Federally listed species, several Florida listed species occur in EVER as well. Prominent among these are: White-crowned Pigeon, Florida Sandhill Crane, and Least Tern and Grasshopper Sparrow in winter (rare).

In addition to the species listed above Partners In Flight (PIF) has also listed Brown-headed Nuthatch, Bachman's Sparrow, Mottled Duck, Short-tailed Hawk, Swallow-tailed Kite, Gray Kingbird, Black Rail, Reddish Egret, White Ibis, Clapper Rail, Florida Prairie Warbler, Yellow Warbler, Mangrove Cuckoo, Black-whiskered Vireo and non-breeding populations of Palm Warbler and Sedge Wren as species of high conservation concern in Subtropical Florida (PIF http://www.blm.gov/wildlife/pl_01sum.htm).

Inventory: Bird inventory data provide important information for park management,, and the inventory at EVER is considered complete. However, EVER has identified additional needs to document distribution and abundance of the park's avifauna.

Monitoring: Currently, several avian monitoring projects are being conducted at EVER. These are:

- Cape Sable Seaside Sparrow population monitoring, including banding

- Waterbirds (wading birds) monitoring conducted monthly from December to May and once again in dry season (August to December); distribution and abundance (number of nest and number of birds/species) data are collected; includes Wood Stork nest counts
- Snail Kite Monitoring in Shark Slough Conservation Areas
- Bald Eagle nest surveys conducted by EVER
- Osprey nest surveys conducted by EVER
- Brown Pelican nest surveys conducted by EVER
- Roseate Spoonbill colony nest counts conducted by Florida Audubon Society
- Breeding Bird Survey (BBS) routes in park; two are active but have not been operated lately
- Christmas Bird Count (CBC) circles exist in Coot Bay, Long Pine Key, and Upper Keys
- Brown-headed Nuthatch, Eastern Bluebird, and Wild Turkey monitoring following translocations from Big Cypress National Preserve
- Migration monitoring for landbirds in pine forests during fall and spring
- Regular Breeding Bird Survey route conducted by US Fish and Wildlife Service
- Randomized recreational birding

Research: Scientific research is permitted within the park, and several recent projects have been concluded, focusing on several of the listed species that occur in the park. Current research projects include:

- Breeding ecology of Cape Sable Seaside Sparrow, including demographic analysis and habitat mapping
- Fire effects on populations of Cape Sable Seaside Sparrow
- Determination of winter population of Short-tailed Hawk and their use of EVER habitats

Outreach:

- Educational and outreach programs related to wading birds are undertaken in the park, primarily during high visitor use season
- Birds are emphasized on Environmental Education curricula
- Everglades BirdFest, a three day birding and ecology festival is conducted each winter in the park and organized by the Broward County Audubon Society

Park Identified Needs for Avian Conservation

EVER has identified several high priority projects that would increase the avian knowledge of the park and would assist park managers in making more informed decision regarding bird conservation in EVER.

Inventory: EVER would like to initiate a mangrove avian inventory and monitoring program.

Research: EVER has identified several research projects that need to be completed (Please see Research section below).

Coordination with Regional Conservation Initiatives

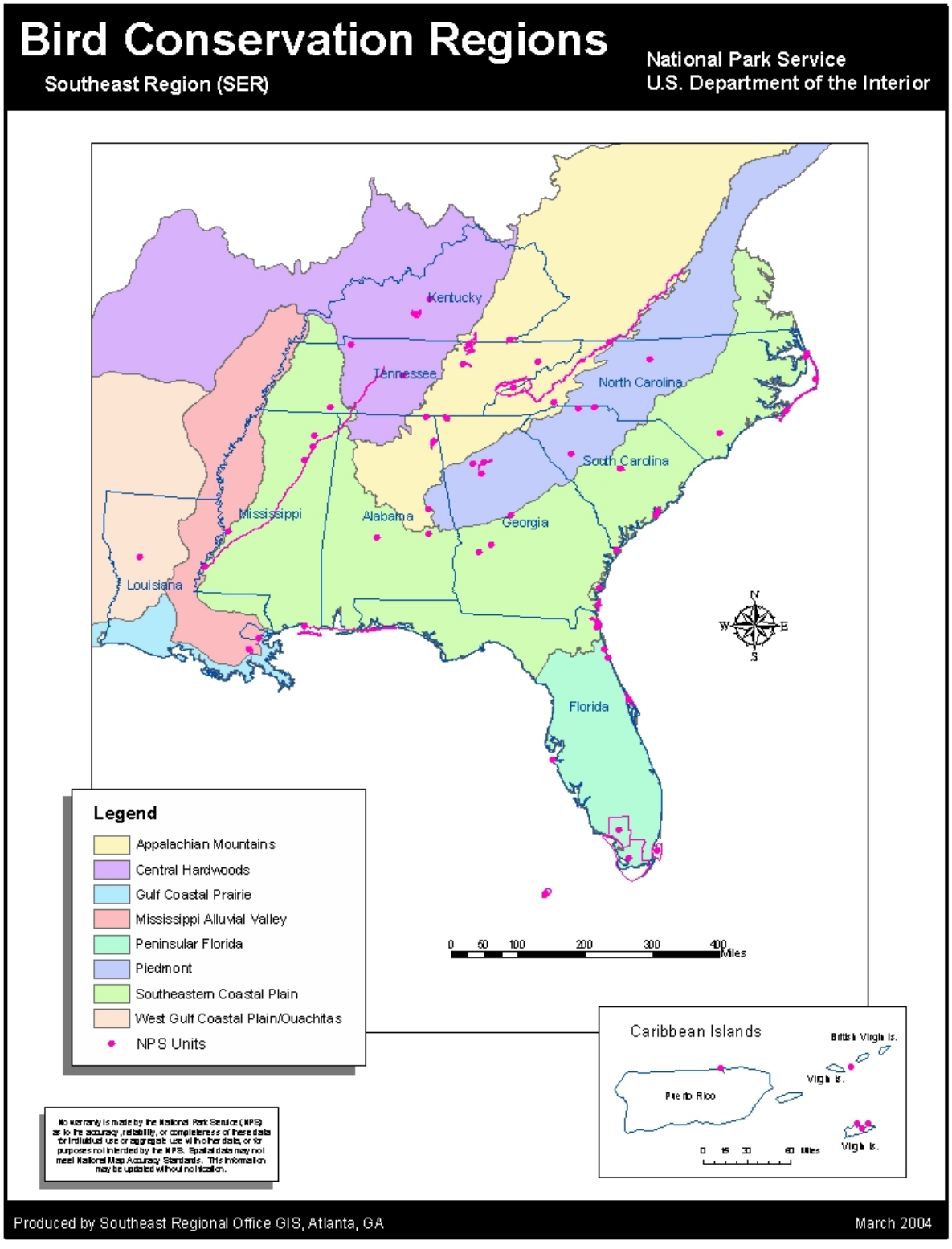
North American Bird Conservation Initiative: NABCI bird conservation planning units, referred to as Bird Conservation Regions (BCR), are often larger than other planning units associated with other plans, such as Partners In Flight. For example, EVER is within the NABCI Peninsular Florida BCR located entirely within Florida (see NABCI BCR map below) and encompasses two PIF physiographic areas (the planning unit for PIF) (compare to PIF map).

Several NABCI BCR's have coordinators whose primary responsibility is to coordinate all bird conservation planning in the BCR, across all agencies and organizations. Currently, Peninsular Florida does not have a designated coordinator; however, a large portion of the BCR lies within the Atlantic Coast Joint Venture area (Maine to Florida and includes Puerto Rico) and the ACJV has several professional bird conservationists base throughout the region to assist partners in bird conservation efforts (see contacts below). This staff can provide valuable assistance to EVER with implementation of aspects of this ACIP.

North American Waterfowl Management Plan (NAWMP): The NAWMP (http://northamerican.fws.gov/NAWMP/nawmphp.htm) is completed and has been revised several times, incorporating updated goals and strategies based on new information. This plan is one of the most successful bird conservation delivery programs in the United States, being monetarily supported by the North American Wetlands Conservation Act (NAWCA).

Partners In Flight: Goals and strategies for Subtropical Florida have yet to be fully identified and organized into a bird conservation plan. Personnel from the Florida Fish and Wildlife Conservation Commission (FFWCC) are currently working on completing the Partners in Flight bird conservation plan for South Florida. In the meantime, Florida's avian priorities and conservation needs are identified in Millsap et al. (1990).

Similar to NABCI BCR's, PIF physiographic areas often do not have designated coordinators. However, state level non-game agencies with investment in PIF will establish key personnel to develop partnerships among cooperators in the physiographic area. The State of Florida has a non-game bird conservation coordinator and can be instrumental in assisting EVER to implement recommendations identified in this ACIP and projects important to bird conservation relative to Florida's role in implementation of the bird conservation goals in Subtropical Florida.


Bird Conservation Regions
Southeast Region (SER)
National Park Service
U.S. Department of the Interior
Kentucky
Tennessee
North Carolina
South Carolina
Mississippi
Alabama
Georgia
Louisiana
Florida
N
W
E
S
0 50 100 200 300 400 Miles
Legend
Appalachian Mountains
Central Hardwoods
Gulf Coastal Prairie
Mississippi Alluvial Valley
Peninsular Florida
Piedmont
Southeastern Coastal Plain
West Gulf Coastal Plain/Ouachitas
NPS Units
No warranty is made by the National Park Service (NPS) as to the accuracy, reliability, or completeness of these data for individual use or aggregate use with other data, or for purposes not intended by the NPS. Spatial data may not meet National Map Accuracy Standards. This information may be updated without notification.
Caribbean Islands
British Virgin Is.
Virgin Is.
Puerto Rico
Virgin Is.
0 15 30 60 Miles
Produced by Southeast Regional Office GIS, Atlanta, GA
March 2004

United States Shorebird Conservation Plan (USSCP): The USSCP has been completed and is available on the World Wide Web (http://shorebirdplan.fws.gov/). A regional step down plan is in preparation by FWS personnel and should be available in 2004.

Waterbird Conservation for the Americas (WCA): The WCA plan has been completed and is available on the World Wide Web or can be ordered from the US Fish and Wildlife Service National Conservation Training Center (http://www.waterbirdconservation.org/). EVER will utilize this regional plan extensively when completed.

Integration of NABCI Goals and Objectives into Park Planning and Operations

NABCI Implementation Recommendations

To successfully achieve park-established goals and actively participate in NABCI, the park could implement a variety of projects in different NPS programs. Most of these projects would require some level of participation by many existing park programs and could either be achieved through NPS funding, or more likely, through establishing or improving partnerships with agencies and organizations that already have the necessary expertise to provide guidance, funding, and execution of these programs. Programmatic areas where bird conservation actions are likely to be focused are:

- Inventory
- Monitoring
- Habitat Restoration/Management
- Threat Management (includes exotic species, air quality, water quality, etc.)
- Research
- Compliance
- Outreach
- Partnerships

To the extent appropriate, each of these program areas will be discussed separately and within each, specific opportunities identified that, when implemented, will enable to park to meet its mandates (current and expected) as well as integrate NABCI into its planning and operations. With emphasis added, the park is not expected to implement any of these recommendations or be obligated to pursue any opportunity other than those the park is required to do by law or NPS program or policy. In other words, participation in this effort is currently voluntary. However, implementation of EO 13186 (US Government 2000) will require NPS to incorporate a wide range of bird conservation programs into planning and operations. The development of the MOU between the FWS and the NPS will establish a formal agreement to promote bird

conservation within the agency by incorporating goals and strategies of existing bird conservation initiatives, plans, and goals into park planning and operations.

Should the park decide to implement any of these projects, further consultation with bird conservation contacts is encouraged to obtain updated information on the relevance of these opportunities in regional bird conservation.

High priority projects are identified in **bold** print. Priorities that the park is encouraged to seek NPS funding for are marked with an asterisk (*****). These projects are those that are critical to the stabilization or improvement of a bird population in the planning region.

Inventory: The park has inventoried its bird fauna exceptionally well and has documented over 350 species. Although the avifauna of EVER is well documented, distribution and abundance data are desired to fully understand the status of birds in the park so that conservation actions for birds can be implemented. Information regarding the status of high priority species is needed to effectively structure park management for the continued preservation and enhancement of the park's avifauna. Additional abundance and distribution data is needed for

- **Mangrove birds***
- **Marshbirds***
- **Wet and Dry Prairie birds***
- **Pine Hammock birds***
- **Tropical Hardwood Hammock birds***
- **Shorebirds, especially during migration***

Additionally, EVER is encouraged to

- **partner with BICY, Ten Thousand Islands National Wildlife Refuge (TTINWR), Great White Heron National Wildlife Refuge (GWHNWR), Big Cypress Seminole Indians, Miccosukee Indians, Florida Wildlife and Conservation Commission (FWCC), Rookery Bay National Esutarine Research Reserve (RBNERR), Fakahatchee Strand Preserve State Park (FSPSP) and South Florida Water Management District (SFWMD) to coordinate area inventory efforts**

- **verify other avian observational data collected in the park and enter into the appropriate database (NPSpecies, eBird, etc.)**

- **standardize inventory and monitoring methodology to conform to NPS and/or FWS recommended standards (Fancy and Sauer 2000, Hunter 2000)**

Monitoring: The park has an active bird monitoring program resulting in documentation of many high priority. Efforts should be made to continue existing monitoring programs, striving to conform to established NPS or FWS surveys protocols.

Close coordination with State of Florida biologists, researchers, and local federal land managers is needed to identify and implement high priority projects on park lands and to ensure that park efforts contribute to park or regional bird conservation rather than undertake an action or actions that are not needed or are better conducted in other areas. The park is encouraged to consider establishing permanent monitoring stations in main habitat types to collect baseline data on the distribution and relative abundances of priority species. This information will be useful for documented potential changes in park avifauna resulting from habitat change or management activities. Links to literature detailing inventory and monitoring methodologies for various avian groups (e.g. songbirds, shorebirds, raptors, etc.) can be found at: http://biology.dbs.umt.edu/landbird/mbcp/groups.htm. Specific recommendations are to:

- **continue to conduct existing monitoring programs and enter data into the appropriate database (NPSpecies, eBird, etc.) and provide data to cooperators***

- **conduct follow up monitoring on translocations of Brown-headed Nuthatch, Eastern Bluebird and Wild Turkey to from BICY***

- **establish an inventory and monitoring program to document the avian life in coastal mangrove and coastal hammock forests***

- **establish additional avian monitoring program based on distribution and abundance surveys that focus on regionally identified high priority species***

- **consider expanding wading bird surveys to include summer months***

- **consider establishment of a shorebird survey based on International Shorebird Survey (ISS) protocol during migration and winter**

- **establish a pre and post fire inventory program to document response of birds to prescribed fire**

- **standardize inventory and monitoring methodology to conform to NPS and/or FWS recommended standards (Fancy and Sauer 2000, Hunter 2000).**

- **partner with BICY, TTINWR, GWHNWR, Rookery Bay National Esutarine Research Reserve (RBNERR), Fakahatchee Strand Preserve State Park (FSPSP), Big Cypress Seminole Indians, Miccosukee Indians, FWCC, and SFWMD to coordinate area monitoring efforts**

Habitat Restoration: Landscape conditions in the Southeastern US have changed dramatically since early European explorers began documenting the area, its habitats, and its inhabitants. Historic landscapes were influenced by Native American burning,

wildfire, bison, beaver, and elk, as well as by insect outbreaks and weather events (Hunter et al. 2001, Williams 2002), thus resulting in a landscape mosaic that supported a rich and diverse bird fauna in the Southeast (Barden 1997; Brawn et al. 2001). The arrival of Europeans and the subsequent change in landscape has dramatically effected bird habitat and bird populations. Bird conservationists have long recognized that habitat restoration is critical to restoration of bird populations, stabilizing or reversing bird declines, and removing birds from both State and Federal Threatened and Endangered Species lists.

Recently, habitat restoration efforts have increased on NPS lands due to the increased restoration emphasis of the Management Policies (USDI NPS 2001). Parks may use a wide range of management tools to restore wetland, grassland, woodland, and other habitats. Restoration tools include, but are not limited to, forest management practices (e.g. silviculture), prescribed fire, exotic species management, and public use and recreation management. In addition, parks can coordinate infrastructure development (e.g. roads and buildings) with restoration activities to mitigate potential adverse impacts.

Due to the protected nature of EVER lands, and generally those in the national park system, the condition of habitats for bird use may be of higher quality than other natural, developed, agricultural, or forest lands under other management regimes. However, national park lands can be greatly improved for wildlife, and particularly bird use, by restoring processes important for habitat formation, succession, and structural development. Largely, these processes have not been managed historically in the national park system but current policy allows for active management of species, populations, and lands to provide for long-term conservation of park resources. Protection, restoration, and enhancement of habitats in EVER can greatly contribute to established habitat goals identified for Subtropical Florida.

EVER is primarily a large wetland that covers a variety of habitats, including freshwater marsh, wet and dry prairies, forested wetlands, mangrove forest, and shallow sloughs. Preservation of these habitats and many species have evolved through a dependence on wildfire. Indeed, EVER is one of the most fire effected landscapes in Florida and currently conducts the largest prescribed fire program in the NPS. Specific habitat recommendations are to:

- **continue to be an active participant in the effort to implement the Comprehensive Everglades Restoration Plan (CERP) to restore hydrological cycles and regimes***

- **increase the amount of prescribed fire (when appropriate) to restore and improve conditions in all habitats, but especially in marshes, prairies, mangroves, and pinelands***

- **collaborate with adjacent partners to conduct a joint fire effects project***

- **enhance or maintain water quality to support aquatic biota necessary to support existing waterbirds, marshbirds, and other birds that use water for nesting and foraging**

- **protect existing snag trees, where not identified as a safety hazard, as important to cavity nesting birds**

- **document all major habitat management activities, including location (e.g. UTM coordinates) and a description of methods and of pre- and post-management habitat conditions. This information, when coupled with bird distribution and abundance data, is useful for assessing and replicating conservation actions**

- assess historic landscape cover and determine feasibility of restoring landscape within the context of the park's enabling legislation.

Threat Management: Historically, the plume hunting trade in the early 1900's drastically reduced the colonial waterbird population by as much as 90%. Currently, the greatest impact to birds at EVER is the disruption of natural processes, including alteration of hydrological cycles and reduction in wildfire frequency and extent. Changes in these processes through time have resulted in a shift in habitat quantity and quality and is prominent in the listing of several species under the Endangered Species Act. EVER is actively engaged in restoration of these processes and is encouraged to:

- **continue current efforts to restore hydrological processes***

- **increase the use of prescribed fire to achieve habitat restoration and improvement goals***

Impact of exotic species on birds at EVER is largely unquantified but feral hogs do occur in the park. However, feral hogs are a prey item of the endangered Florida Panther and are not a managed threat. However, impact from feral hog on ground nesting birds is unknown and the park is encouraged to:

- **evaluate the impact of feral hogs on ground nesting birds***

Significant exotic plants, particularly Melaleuca, Brazilian Pepper, Australian Pine, and Old World Climbing Fern, occur in EVER and are a potentially threat to habitat at EVER. It is important to establish and continue inventory and monitoring for exotic plant species and implement aggressive removal/reduction projects for these species. The South Florida Exotic Plant Management Team can assist in coordination and implementation of exotic plant management. EVER is encouraged to:

- **implement an aggressive exotic plant reduction program to restore and improve habitat quality**

Additional unquantified threats to birds and their habitats at EVER include recreational boaters, communications towers, recreational activity, fishing gear (hooks and monofilament line entanglement), and presence of heavy metal toxins, such a mercury in the soils and sediments of the park. To address these issues, the park is encouraged to:

- **establish buffer zone around bird nesting islands and roosting areas for Double-crested Cormorants, Bald Eagle, Osprey, Roseate Spoonbills, and wading bird colony protection***

- **decommission out of date or unused communication towers***

- **assess avian mortality at prominent towers and establish a mortality monitoring program to document tower kill of birds***

- **implement a monofilament line recycling or disposal system at strategic areas in the park***

- **hire additional law enforcement officers and interpretive staff to implement aspects of this plan***

- **assess the extent of avian injury and/or death associated with fishing gear (hooks and monofilament line)**

- **assess the threat of heavy metal toxins to birds in the park and initiate appropriate actions to mitigate presence of any toxins**

Research: Several research projects have been identified that would provide additional information to EVER managers for bird conservation purposes. The South Florida/Caribbean Field Unit of the US Geological Survey, Biological Resources Division is located in the South Florida Natural Resource Center in EVER and can provide excellent service and expertise for implementation of these research projects and consultation on appropriate inventory and monitoring protocols for other projects mentioned in this plan. EVER's identified research needs are:

- **determine the response of Cape Sable Seaside Sparrow to prescribed fire***

- **determine the effects of wildfire and fuel treatments on the avifauna of the pine rockland ecosystem in southern Florida***

- **assess the effects of prescribed burning on wintering and breeding birds of wet prairie habitats***

- **determine impacts or recreational boating in Florida Bay to breeding, foraging, and migrant birds***

- **determine recreational impacts to birds***
- **determine winter and Neotropical and temperate migrants use of park***
- **determine impacts of feral hogs on ground nesting birds***
- **determine demographics and ecology of Limpkin in EVER and BICY**
- **assess threat of heavy metal loads to birds**
- **assess colonial bird nesting mortality due to avian nematode**
- **determine the extent of avian mortality from existing communications towers in the park**

Additionally, the park is encouraged to:

- **list park needs and projects on Research Permit and Reporting System web site (RPRS)***
- **incorporate scientific information needs from the South Florida Ecosystem Restoration program into the park's planning process***
- develop contact with South Florida/Caribbean Cooperative Ecosystem Studies Unit at the University of Miami, Miami, Fl

Compliance: Park compliance with the Migratory Bird Treaty Act and the Executive Order 13186 (US Government 2000) is necessary to assure that park activities incorporate bird conservation into park planning and operations. Further, to ensure that migratory birds are considered in all phases of park planning processes, especially during the National Environmental Policy Act (NEPA) and the Director's Order #12 Compliance processes, the park should consider adding specific language in project evaluations that requires consideration and implications of park projects on migratory birds. The MOU being developed between the NPS and the FWS will likely contain specific language requiring a park to consider implications of park projects on migratory birds, particularly those species identified in the USFWS Species of Conservation Concern 2002 (Appendix C). Additional considerations are to encourage:

- **park staff to begin specific consideration of migratory birds during park planning processes**
- park staff to attend USFWS training on implementation of EO 13186 at the National Conservation Training Center (NCTC) (when available) or other training on migratory bird conservation in North America. NCTC has several courses

and training related to conservation of migratory birds (http://training.fws.gov/courses.html).

The USFWS NCTC offers and reserves two tuition free slots for National Park Service employees wishing to attend NCTC courses on a first come, first served basis. Additionally, discount lodging is also available while attending a NCTC course.

Outreach:

- **participate in International Migratory Bird Day (IMBD) events with a local partner (http://birds.fws.gov/imbd.html), such as BICY, Crocodile Lakes NWR, Tropical Audubon Society, etc.***

- **continue to host the Everglades BirdFest coordinated by the Broward County Audubon Society highlighting bird conservation issues in EVER and South Florida***

- **develop outreach and educational programs to enhance visibility of bird conservation issues, which may include organized bird walks, owl prowls, and raptor surveys with the public***

- **provide bird conservation information in visitors centers***

- **develop education brochure on proper disposal of monofilament fishing line and potential techniques to avoid hooking birds while fishing***

- **continue to develop and foster relationship with local area bird clubs, such as Tropical Audubon Society and local bird clubs***

- **encourage accurate documentation and reporting from these and random outings by visitors (see Cornell University's eBird monitoring program (Cornell Lab. Ornith. 2002 (http://www.ebird.org/about/index.jsp)***

- **develop relationship with Big Cypress Seminole Indian Reservation and Miccosukee Indian Reservation personnel to cooperate on a joint bird conservation project***

- park interpretation/education staff are encouraged to attend USFWS training on Migratory Bird Education at NCTC

- consider adding links to bird conservation information, data, etc. to the park's web site home page

- support bird conservation by serving shade-grown coffees at meetings, events, and the office buildings in the park (http://www.americanbirding.org/programs/conssbcof3.htm)

- subscribe to Florida Birds, an electronic forum for listing bird sightings and publications in Florida

- explore cultural affiliation of landscape to inhabitants, both historical and contemporary. Cultures are strongly tied to the landscape they inhabit and birds often play a role in a cultural tie to the landscape. When these connections are discovered and preserved, a greater appreciation for the landscape and it's value to the culture can be achieved.

Partners and Partnerships: Partnerships for land conservation and protection will perhaps have the greatest positive influence on bird conservation above all other landscape scale planning. Specific recommendations are to:

- **continue to keep abreast of Dade, Collier, Monroe, Broward, and Hendry Counties and other South Florida initiatives or programs that could impact park resources***

- **develop relationship with Big Cypress Seminole Indian Reservation and Miccosukee Indian Reservation personnel***

- **contact US Fish and Wildlife Service private lands biologists to discuss private landowner initiatives applicable to the area***

Several private landowner programs could be implemented that would serve to protect areas adjacent to EVER and potentially improve water and habitat quality in the vicinity

- **develop partnership with FWCC, SFWMD, TTINWR, BICY, Rookery Bay National Esutarine Research Reserve (RBNERR), Fakahatchee Strand Preserve State Park (FSPSP) and other local partners to coordinate and implement various aspects of this ACIP***

- **contact the nearest Joint Venture office (see Funding section for explanation of Joint Ventures) or BCR coordinator to develop partnerships and funding proposals tiered to priorities established by the park, this ACIP, and the Subtropical Florida bird conservation plan***

- partner with and engage the local bird clubs, including Tropical Audubon Society, Audubon Society of the Everglades, Broward County Audubon Society, Naples Bird Club, and Collier County Audubon as active partners in EVER's bird conservation program

- develop land use agreements with local landowners through state, FWS programs to protect important habitats and landscapes adjacent to EVER

Funding Opportunities: Internal NPS funding is often an effective source to obtain funding; however, the project will have to be a fairly high priority among the park's natural resource program to successfully compete for the limited funding available in the NPS. Therefore, partnerships and outside funding programs are often more productive for securing bird conservation funding. Funding for conservation projects for Neotropical migrants is also available through the Park Flight program. EVER is encouraged to enter all high priority projects into the NPS Performance Management Information System (PMIS) database. Needed at EVER is:

- **increased base funding to implement basic protection and management needs for birds and their habitats (habitat based management not only benefits the birds but other wildlife as well)**

With the exception of the North American Waterfowl Management Plan (NAWMP and its associated funding legislation, the North American Wetland Conservation Act), funding opportunities for bird conservation programs, plans, and initiatives have been lacking. Only within the last decade have other appropriate and specific sources for bird conservation funding been created and used. The NAWMP has been supported for approximately 14 years by the North American Wetlands Conservation Act (NAWCA 1989). This program has provided $487 million in appropriated funds matched with $1.7 billion for wetland and bird conservation projects since its inception. In 2002 alone, over $70 million US dollars were awarded to US and Canadian agencies and organizations to enhance waterfowl populations by improving, restoring, or protecting wetland habitats. To adequately evaluate projects and distribute these funds, partnerships called Joint Ventures were established. Nationally, 14 (11 US, 3 Canada) Joint Ventures have been established, several which are funded and staffed. Internet links to Joint Ventures are:

(http://southwest.fws.gov/gulfcoastjv/ojvcontact.html) and
(http://northamerican.fws.gov/NAWMP/jv.htm).

Funding through NAWCA is highly underutilized by the NPS and any park unit that has wetland, water, or bird conservation needs associated with wetland are encouraged to investigate using this funding source. Naturally, there are certain requirements to be eligible for all grants and park managers are encouraged to consult with the nearest Joint Venture, BCR, PIF Coordinator, to learn how this program might be applicable to implementation of this plan, and other park wetland issues. EVER is not within a region which has an operational Joint Venture, but contact with the Atlantic Coast Joint Venture, Central Hardwoods BCR, and Tennessee PIF coordinators will provide opportunity to investigate use of this funding source and developing proposals.

Internal FWS funding programs may be used to support projects, but no effective method of project proposal delivery to these sources is currently in place for the NPS. Current funding in these programs may result from FWS familiarity with NPS needs, or NPS participation in one of the area FWS Ecosystem Teams, where a project has been identified and proposed to be funded through the Ecosystem Team.

One unexplored yet potentially fruitful funding source for national parks is the myriad of grants through the FWS State Programs, where grants are awarded to private individuals engaged in habitat conservation projects. No funding is directly available to national parks, but identified projects with important or critical adjacent landowners can sometimes be funded through these sources. Similar programs are available if the adjacent landowner is a federally recognized American Indian tribe.

Specific congressional appropriations to protect migratory birds has recently been authorized under the Neotropical Migratory Bird Conservation Act (2000) (http://www.nfwf.org/programs/nmbcapp.htm). Appropriations through this Act are authorized up to $5 million per year. However, in 2000, appropriation was approximately $3.75 million and a majority of this funding was directed toward projects in Central and South America.

Many of the identified projects are eligible for funding under various grant programs of the National Fish and Wildlife Foundation http://www.nfwf.org/programs/programs.htm.

Other prominent funding sources available to NPS managers for bird conservation are listed on this projects web site at: http://southeast.fws.gov/birds/NPSHighlits.htm.

Funding opportunities for migratory bird conservation are available yet most natural resource agencies are not fully aware of and/or understanding of how to use these sources. Perhaps a consolidated migratory bird funding source catalog will become available to managers in the future; this is needed.

Contacts: Primary contacts within the region can be obtained by viewing the web site for the Southeastern Bird Conservation Initiative, National Park Service at http://southeast.fws.gov/birds/npsbirds.htm. This web site will provide contact information of the appropriate bird conservation coordinator in the region for park personnel Primary contacts for EVER are:

US Fish and Wildlife Service

Keith Watson
Asheville, NC 28801
828-350-8228
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Dean Demarest
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National Park Service

South Florida/Caribbean
Inventory & Monitoring Network
Coordinator
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APPENDIX A

HIGH PRIORITY SPECIES IN PENINSULAR FLORIDA BIRD CONSERVATION REGION (from Table 1, Peninsular Florida Priority Bird Species)

Table 1. Priority bird species for Peninsular Florida: Entry criteria and selection rationale

Priority Entry Criteria[1]	Species	Total PIF Priority Species Score	Conservation Score		Percent of BBS Population	Migratory Status[2]	Local Geographical or Historical Notes
			Area Importance	Population Trend			
Ia.	Florida Scrub-Jay[5]	35	5[4]	5[4]	100	R	
	Grasshopper Sparrow[5] (Florida)	35	5[4]	5[4]	100	R	
	Snail Kite[5] (Everglade)	34	5	4[4]	100?	D	
	Crested Caracara[5] (Florida pop.)	34	5[4]	4[4]		D	
	Snowy Plover (SE US)	34	5	5		D	Gulf side only
	Red Knot (SE US)	32	5	5		C	
	Piping Plover[5]	31	4	5		C	
	Prairie Warbler (Florida)	31	5[4]	5[4]		D	
	Wood Stork[5] (SE US pop.)	30	5	4		D	
	Short-tailed Hawk (Florida pop.)	30	5[4]	3		D	
	Swallow-tailed Kite (SE US)	29	5	3	61.7	B	
	Red-cockaded Woodpecker[5]	29	3[4]	3		R	

Table 1 (cont.).

Priority Entry Criteria[1]	Species	Total PIF Priority Species Score	Conservation Score		Percent of BBS Population	Migratory Status[2]	Local Geographical or Historical Notes
			Area Importance	Population Trend			
	Mottled Duck	29	5	4[4]	11.3?	D	
	American Kestrel (SE US)	28	5[4]	4[4]		R	
	Burrowing Owl (Florida)	28	5[4]	3		D	
	Bachman=s Sparrow	28	5	3	18.9	D	
	Saltmarsh Sharp-tailed Sparrow	28	3	3		C	
	Painted Bunting (Eastern)	28	3[4]	3	D		
	American Oystercatcher (Eastern NA pops.)	28	5	3		D	
Ib.	Wilson=s Plover	27	4	3		D	
	Nelson=s Sharp-tailed Sparrow	27	3	3		C	
	Henslow=s Sparrow	27	3	4		C	
	Black Rail	27	4	3		D	
	Sandhill Crane (Florida)	26	5[4]	1		R	
	Audubon=s Shearwater (Caribbean)	26	5	3		P	
	Reddish Egret	26	4	3		D	
	Least Tern	26	5	4[4]	4.6?	B	
	Black Skimmer	26	5	5		D	
	Bicknell=s Thrush	26	5	3		A	

Table 1 (cont.).

Priority Entry Criteria[1]	Species	Total PIF Priority Species Score	Conservation Score: Area Importance	Conservation Score: Population Trend	Percent of BBS Population	Migratory Status[2]	Local Geographical or Historical Notes
	Yellow Rail	26	4	3		C	
	Buff-breasted Sandpiper	25	3	4		A	Most southbound migration
	Black-throated Blue Warbler	25	5	3		A	
	Seaside Sparrow	25	4[4]	3		D	Gulf populations
	Brown Pelican (SE US)	24	5	1[4]		D	
	Marbled Godwit	24	3	4		C	
	Bobolink	24	5	5		A	
	Tricolored Heron	23	4	3	17.3?	D	
	White Ibis	23	4	4		D	
	King Rail	23	4	3		D	
	Sandhill Crane (Greater)	23	5	3		C	
	Solitary Sandpiper	23	5	3		A	
	Whimbrel	23	3	5		A	
	Stilt Sandpiper	23	4	3		A	
	Brown-headed Nuthatch	23	3	3		R	
	Cape May Warbler	23	5	3		A	
	Connecticut Warbler	23	5	3		A	
	Cory=s Shearwater	22	5	3		P	
	Clapper Rail	22	3	3		R	
	Limpkin	22	3[4]	4[4]	33.2?	R	
	Semipalmated Sandpiper	22	5	5		A	
	Short-billed Dowitcher	22	5	5		C	
	Gull-billed Tern	22	3	4		D	
	Royal Tern	22	4	3		D	
	Sandwich Tern	22	5	3		D	
	Black Tern	22	5	5		A	
	Mangrove Cuckoo	22	3[4]	3		E	

Table 1 (cont.).

Priority Entry Criteria[1]	Species	Total PIF Priority Species Score	Conservation Score		Percent of BBS Population	Migratory Status[2]	Local Geographical or Historical Notes
			Area Importance	Population Trend			
	Gray Kingbird	22	3[4]	3	4.5?	B	
	Black-whiskered Vireo	22	3[4]	3		B	
	Loggerhead Shrike	22	5	5	4.1	D	
	Sedge Wren	22	4	2		C	
	Palm Warbler	22	5	5		C	
II a.	Anhinga	21	5	3		D	
	American Bittern	21	4	5		C	
	Northern Bobwhite	21	4	5		R	
	Black-bellied Plover	21	4	5		D	
	Willet	21	5	3		D	
	Western Sandpiper	21	5	3		C	
	Common Ground-Dove	21	5	5	23.8?	R	
	Red-headed Woodpecker	21	3	5	1.0	D	
	Veery	21	4	5		A	
	Pine Warbler	21	4	5		D	
	Grasshopper Sparrow (Eastern)	21	5	5		C	
	Green Heron	20	5	3		D	
	Northern Harrie r	20	4	4		C	
	Ruddy Turnstone	20	3	4		D	
	Least Sandpiper	20	5	5		C	
	Dunlin	20	4	5		C	
	Yellow-billed Cuckoo	20	3	5		B	
	Gray Catbird	20	5	5		C	
	Eastern Towhee	20	5	5	7.9	D	
	American Avocet	19	3	3		C	
	Greater Yellowlegs	19	5	3		C	

Table 1 (cont.).

Priority Entry Criteria[1]	Species	Total PIF Priority Species Score	Conservation Score: Area Importance	Conservation Score: Population Trend	Percent of BBS Population	Migratory Status[2]	Local Geographical or Historical Notes
	Sanderling	19	3	5		C	
	Pectoral Sandpiper	19	5	3		A	
	Common Nighthawk	19	5	5	3.6	B	
II b.	Chuck-will=s-widow	21	5	3	7.0	B	
	White-eyed Vireo	20	5	2	5.4	D	
II c.	Snowy Egret	19	4	3		D	
	Little Blue Heron	20	3	4	5.1	D	
Local or Regional Interest	Prothonotary Warbler	21	2	3	B		(AA@ Merritt Island)
	American White Pelican	20	4	1		C	
	Redhead	20	2	4		C	
	American Woodcock	20	2	4		D	
	Acadian Flycatcher	20	2	3		B	(AA@ Merritt Island)
	Yellow-throated Vireo	20	3	3		B	(AA@ Merritt Island)
	Yellow-throated Warbler	20	3	3		C	
	Hooded Warbler	20	2	3		B	(AA@ Merritt Island)
	Peregrine Falcon	19	5	1		A	Winters in small numbers
	Northern Parula	19	5	2		C	
	Common Loon	18	4	3		C	
	Least Bittern	18	2	3	7.0?	D	
	Wood Duck	18	4	2		D	
	Ring-necked Duck	18	3	2		C	
	Lesser Scaup	18	3	5		C	
	Red-shouldered Hawk	18	5	2		D	
	Eastern Kingbird	18	3	5		B	
	Summer Tanager	18	3	3		B	
	Eastern Meadowlark	18	4	5		D	

Table 1 (cont.).

Priority Entry Criteria[1]	Species	Total PIF Priority Species Score	Conservation Score		Percent of BBS Population	Migratory Status[2]	Local Geographical or Historical Notes
			Area Importance	Population Trend			
	Rusty Blackbird	18	2	5		C	
	Bald Eagle[5]	17	4[4]	1		D	
	Blue-winged Teal	17	5	3		A	
	Barn Owl	17	3	3		D	
	Northern Flicker	17	4	5		D	
	Eastern Wood-Pewee	17	2	3		B	(AA@ Merritt Island)
	Yellow-crowned Night-Heron	16	2	3		D	
	Roseate Spoonbill	16	2	3		D	
	Northern Pintail	16	3	5		C	
	Brown Thrasher	16	2	3		D	
	Black-and-white Warbler	17	3	3		C	
	Smooth-billed Ani	15	2	3		R	
	Blue-gray Gnatcatcher	14	3	2		C	

[1]Entry criteria (Area Importance [AI] scores roughly mean A1" irregular and unpredictable occurrence, A2" rare to uncommon but regular occurrence, A3" low relative abundance, A4" moderate to high relative abundance, A5" highest relative abundance; Population Trend [PT] scores roughly mean A1" definite increase, A2" stable or possible increase, A3" trend unknown, A4" possible decrease, A5" definite decrease):

Ia. <u>Overall Highest Priority Species.</u> Species with total score 28-35. Ordered by total score. Consider deleting species with AI $\leq$ 2 confirmed to be of peripheral occurrence and not of local conservation interest, but retain species potentially undersampled by BBS or known to have greatly declined during this century.

Ib. **<u>Overall High Priority Species.</u> Species with total score 22-27. Ordered by total score. Consider deleting species with AI <u>≤</u> 2 confirmed to be of peripheral occurrence and not of local conservation interest, but retain species potentially undersampled by BBS or known to have greatly declined during this century.**

II. **<u>Area Priority Species.</u> Species with slightly lower score total 19-21 with PT+AI=8+(a), with high percent BBS population (b), or high level of threats identified (TB+TN=7+, TB or TN=5). Ordered by total score. These are <u>overall moderate priority species</u>.**

III. **<u>Additional Species of Global Priority.</u> Add WatchList species (Partners in Flight-National Audubon Society priority species at national level), not already listed in either I or II, with AI=2+. Order by total score. Consider deleting species with AI=2 if confirmed to be of peripheral occurrence and not of local conservation interest, but retain if a local population is viable and/or manageable. These are also <u>overall moderate priority species</u>.**

LORI **<u>Local or Regional Interest Species.</u> Includes game or nongame species identified by State Working Groups. Also, may include species often meeting criteria for I or II within other physiographic areas and therefore of regional interest for monitoring throughout the Southeast. These are <u>overall low priority species</u> within physiographic area, but may be more important within one or more States (especially where multiple states have designated some special protective status on the species).**

[2] Local Migratory Status, codes adapted from Texas Partners in Flight as follows:

A = Breeds in temperate or tropical areas outside of region, and winters in temperate or tropics outside of region (*i.e.*, passage migrant).

B = Breeds in temperate or tropical areas including the region, and winters exclusively in temperate or tropics outside the region (*i.e.*, includes both breeding and transient populations).

C = Breeds in temperate or tropical areas outside of region, and winters in both the region and in temperate or tropical areas beyond area (*i.e.*, includes both transient and wintering populations).

D = Breeds and winters in the region, with perhaps different populations involved, including populations moving through to winter beyond the region in temperate or tropical areas (*i.e.*, populations may be present throughout year, but may include a large number of passage migrants).

E = Species reaching distributional limits within the region, either as short-distance or long-distance breeding migrants, but at population levels above peripheral status.

F = Same as E except for wintering (non-breeding) migrants.

R = Resident, generally non-migratory species (though there may be local movements).

RP= Resident, non-migratory species, reaching distributional limits within the region, but at population levels above peripheral status.

P = Pelagic, breeding grounds outside of region, but can occur during breeding season.

PB = Post-breeding dispersal or non-breeding resident; species present during breeding season, but not known to be breeding in the region proper.

[3]Highest percent of breeding population recorded in temperate North America; numbers in A @ are likely projections; ? indicates species widespread outside of temperate North America and/or waterbirds poorly sampled by Breeding Bird Survey within physio. area.

[4]AI or PT score revised from what was derived by BBS data, or lack thereof, based on better local information.

[5]Species listed as either Federal Endangered or Threatened.

APPENDIX B

Wildlife Conservation Commission

FLORIDA'S ENDANGERED SPECIES, THREATENED SPECIES AND SPECIES OF SPECIAL CONCERN

Official Lists

Publication Date: 1 August 1997

This document consolidates the state and federal official lists of endangered species, threatened species, and other species categorized in some way by the respective jurisdictional agencies as meriting special protection or consideration. The state lists of animals are maintained by the Florida Game and Fresh Water Fish Commission and categorized as endangered, threatened and of special concern, and constitute Rules 39-27.003, 39-27.004 and 39-27.005, respectively, Florida Administrative Code (F.A.C.). The state lists of plants are categorized into endangered, threatened and commercially exploited, and are administered and maintained by the Florida Department of Agriculture and Consumer Services via Chapter 5B-40, F.A.C. The federal lists of animals and plants are administered by the U.S. Fish and Wildlife Service and categorized into endangered and threatened, and are published in 50 CFR 17 (animals) and 50 CFR 23 (plants). The abbreviations used in part one are:

GFC = Florida Fish and Wildlife Conservation Commission

FDA = Florida Department of Agriculture and Consumer Services

FWS = United States Fish and Wildlife Service

E = Endangered

T = Threatened

T(S/A) = Threatened/Similarity of Appearance

T(E/P) = Threatened/Experimental Population

SSC = Species of Special Concern

C = Commercially Exploited

		Designated Status	
Scientific Name	**Common Name(s)**	**GFC**	**FWS**
Birds			
Ajaia ajaja	Roseate spoonbill	SSC	
Ammodramus maritimus juncicolus	Wakulla seaside sparrow	SSC	

		Designated Status	
Scientific Name	**Common Name(s)**	**GFC**	**FWS**
Ammodramus maritimus mirabilis	Cape Sable seaside sparrow	E	E
Ammodramus maritimus peninsulae	Scott's seaside sparrow	SSC	
Ammodramus savannarum floridanus	Florida grasshopper sparrow	E	
Aphelocoma coerulescens	Florida scrub-jay	T	T
Aramus guarauna	Limpkin	SSC	
Campephilus principalis	Ivory-billed woodpecker	E	E
Charadrius alexandrinus tenuirostris	Southeastern snowy plover	T	
Charadrius melodus	Piping plover	T	T
Cistothorus palustris griseus	Worthington's marsh wren	SSC	
Cistothorus palustris marianae	Marian's marsh wren	SSC	
Columba leucocephala	White-crowned pigeon	T	
Dendroica kirtlandii	Kirtland's warbler	E	E
Egretta caerulea	Little blue heron	SSC	
Egretta rufescens	Reddish egret	SSC	
Egretta thula	Snowy egret	SSC	
Egretta tricolor	Tricolored (=Louisiana) heron	SSC	
Eudocimus albus	White ibis	SSC	
Falco peregrinus tundrius	Arctic peregrine falcon	E	
Falco sparverius paulus	Southeastern American kestrel	T	
Grus americana	Whooping crane	SSC	T(E/P)
Grus canadensis pratensis	Florida Sandhill crane	T	
Haematopus palliatus	American oystercatcher	SSC	
Haliaeetus leucocephalus	Bald eagle	T	T
Mycteria americana	Wood stork	E	E

		Designated Status	
Scientific Name	**Common Name(s)**	**GFC**	**FWS**
Pandion haliaetus	Osprey	SSC*	
Pelecanus occidentalis	Brown pelican	SSC	
Picoides borealis	Red-cockaded woodpecker	T	E
Polyborus plancus audubonii	Audubon's crested caracara	T	T
Rostrhamus sociabilis	Snail kite	E	E
Rynchops niger	Black skimmer	SSC	
Speotyto cunicularia	Burrowing owl	SSC	
Sterna antillarum	Least tern	T	
Sterna dougallii	Roseate tern	T	T
Vermivora bachmanii	Bachman's warbler	E	E
*Applicable in Monroe County only			

APPENDIX C

US FISH AND WILDLIFE SERVICE SPECIES OF CONSERVATION CONCERN IN PENINSULAR FLORIDA (BCR 31)

Black-capped Petrel
Audubon's Shearwater
Magnificent Frigatebird
American Bittern
Little Blue Heron
Reddish Egret
White Ibis
Swallow-tailed Kite
Short-tailed Hawk
American Kestrel (resident *paulus* ssp. only)
Peregrine Falcon
Yellow Rail
Black Rail
Limpkin
Snowy Plover
Wilson's Plover
American Oystercatcher
Whimbrel
Marbled Godwit
Red Knot
Semipalmated Sandpiper
Stilt Sandpiper
Buff-breasted Sandpiper
Short-billed Dowitcher
Gull-billed Tern
Common Tern
Least Tern
Black Tern
Black Skimmer
White-crowned Pigeon
Common Ground-Dove
Mangrove Cuckoo
Smooth-billed Ani
Burrowing Owl
Chuck-will's-widow
Red-headed Woodpecker
Loggerhead Shrike
Black-whiskered Vireo
Brown-headed Nuthatch
Yellow Warbler (resident *gundlachi* ssp. only)
Yellow-throated Warbler
Prairie Warbler
Bachman's Sparrow
Henslow's Sparrow
Nelson's Sharp-tailed Sparrow
Saltmarsh Sharp-tailed Sparrow
Seaside Sparrow
Painted Bunting

APPENDIX L.6

SALT RIVER BAY NATIONAL HISTORICAL PARK AND ECOLOGICAL RESERVE

DRAFT

Avian Conservation Implementation Plan
Salt River Bay National Historic Park and Ecological Preserve

National Park Service
Southeast Region



Compiled by J. Keith Watson
U.S. Fish and Wildlife Service
In cooperation with

SARI Resource Management Staff, National Park Service
And Bird Conservation Partners
November 2003

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Introduction

This Avian Conservation Implementation Plan (ACIP) is provided to the staff at Salt River Bay National Historic Park and Ecological Preserve (SARI) to serve as guidance to identify, document, and undertake bird conservation activities in the park and with neighboring communities, organizations, and adjacent landowners. This plan may identify goals, strategies, partnerships, and perhaps specific projects for the park to participate in existing bird conservation planning and implementation efforts associated with the North American Bird Conservation Initiative (NABCI). Under the auspice of NABCI, appropriate bird and habitat conservation goals may be recommended as identified in the appropriate existing national or regional bird conservation efforts aligned with this initiative: Partners In Flight (PIF), North American Waterfowl Management Plan (NAWMP), US Shorebird Conservation Plan (USSCP), and Waterbird Conservation for the Americas (WCA). For example, parks in the Appalachians and the Cumberland Plateau will have few if any high priority waterbird conservation issues at a regional landscape or greater scale. As such, little information regarding waterbird conservation will be presented in the ACIP, unless there is an identified park need for this species group, or other mandates, such as federal laws. Similarly, because SARI has both coastal and upland habitat, recommendations will be provided in the ACIP for landbirds, waterbirds, and habitat conservation derived from the appropriate PIF bird conservation plans. However, all high priority bird conservation issues for SARI will be discussed and integrated as appropriate.

Information and data presented in the ACIP have been obtained from several sources: 1) interviews with SARI staff 2) SARI bird conservation partners 3) the Puerto Rico and US Virgin Islands Bird Conservation Plan (Nunez-Garcia and Hunter 2000), 4) NPS databases, and 5) personal communications with bird conservation specialists in the region. This plan has been reviewed by SARI resource management staff and managers, South Florida/Caribbean Inventory and Monitoring (SF/C I&M) Network staff, and bird conservation partners and approved by SARI management. Optimally, this plan will be incorporated into the park's Resource Management Plan (RMP) and updated annually to reflect completed projects, newly identified needs, and shifts in bird conservation priorities in the region.

SARI is not obligated to undertake any of the proposed actions in this plan. The plan is provided to offer guidance to SARI to voluntarily support important park, regional, and perhaps national and international bird conservation projects for which SARI is a primary participant in the proposed actions.

Background

During the past thirty years, monitoring programs across North America have documented declines of certain bird species populations and their habitats, often severe (Sauer et al. 2000). The decline has caused great concern among scientists, biologists, biodiversity proponents, ecologists, land managers, etc., and the bird conservation community in

general. Birds are recognized as critical components of local and global genetic, species, and population diversity, providing important and often critical ecological, social, and cultural values. Their overall decline has stimulated a worldwide focus on conservation efforts and North American interest in bird conservation is rapidly becoming a focus of government, non-government, industry, and private interests and expenditures.

Many state, federal, and non-governmental wildlife agencies and organizations (NGO's) have recognized this alarming bird decline trend and have joined forces in several extensive partnerships to address the conservation needs of various bird groups and their habitats. The primary initiatives are:

- North American Waterfowl Management Plan
- Partners in Flight
- U.S. Shorebird Conservation Plan
- Waterbird Conservation for the Americas

While efforts associated with these plans have generated some successes, it has been increasingly recognized that the overlapping conservation interests of these initiatives can be better served through more integrated planning and delivery of bird conservation. The *North American Bird Conservation Initiative (NABCI;* http://www.nabci-us.org/main2.html) arose out of this realization. The vision of NABCI is simply to see ***"populations and habitats of North America's birds protected, restored and enhanced through coordinated efforts at international, national, regional, state and local levels, guided by sound science and effective management."*** NABCI seeks to accomplish this vision through (1) broadening bird conservation partnerships, (2) working to increase the financial resources available for bird conservation in the U.S., and (3) enhancing the effectiveness of those resources and partnerships by facilitating integrated bird conservation (U.S. NABCI Committee 2000). Together, the four bird conservation initiatives mentioned above, as well as several other local and regional partnerships, work collectively to pursue this vision.

NABCI is guided by a set of principles that establish an operational framework within which the Initiative and its partners may conduct integrated bird conservation in the U.S. These will articulate a common understanding of the relationship between NABCI, the individual bird conservation initiatives, and all partner entities to ensure recognition of existing federal legislative and international treaty obligations, state authorities, and respect for the identity and autonomy of each initiative. The fundamental components of the conservation approach to be used by NABCI are expressed within its goal:

> ***To deliver the full spectrum of bird conservation through regionally-based, biologically-driven, landscape-oriented partnerships.***

The Southeastern Bird Conservation Initiative: National Park Service: In 1999, the Southeast Region of the National Park Service (NPS) recognized the importance of coordinating existing bird conservation goals into planning and operations of national park

units in the southeast, that is, integration of NABCI. In support of this recognition, the Southeast Regional Office NPS approved and allocated eighty-eight thousand dollars, cost sharing 1:1 with the US Fish and Wildlife Service (FWS) Region 4 (Southeast) to hire a biologist to conduct this two-year project (Interagency Agreement FS028 01 0368). This project is unique in the NPS, and perhaps the nation, and represents a potential model for better coordinating regional bird conservation programs and activities within and outside the NPS. It further represents a progressive action toward institutionalizing bird conservation as a programmatic priority in the Southeast Region of NPS, and potentially the nation.

As envisioned, the integration of NABCI into the Southeastern NPS involves:

1) Development and delivery of Avian Conservation Implementation Plans (ACIP),
2) Coordination with NPS Inventory and Monitoring Program,
3) Development of a web based project site,
4) Establishment or enhancement of bird conservation partnerships,
5) Identification and exploration of potential funding opportunities, and
6) Technical guidance and assistance as needed or requested.

This ACIP fulfills one aspect of the plan outlined above, and serves as a basis for future bird conservation actions in SARI and with adjacent partners or landowners.

Concurrently, the development of a Memorandum of Understanding (MOU) between the FWS and the NPS to implement Presidential Executive Order (EO) 13186, **Responsibilities of Federal Agencies To Protect Migratory Birds**, calls for integration of programs and recommendations of existing bird conservation efforts into park planning and operations. Complementing each other, the MOU and the Southeastern Bird Conservation Initiative will advance bird conservation in the Southeast Region of the NPS beyond current regional NPS efforts.

Role of NPS in Avian Conservation

The interagency agreement that facilitates this partnership supports both FWS and NPS management policies. Specifically for the NPS, the agreement supports and advances the **Strategy for Collaboration** (March 2000), a visionary document developed and signed by the Southeast Natural Resource Leaders Advisory Group (SENRLAG), a consortium of 13 land and resource management agencies in the Southeastern United States whose vision is to encourage and support cooperation in planning and managing the region's natural resources. Furthermore, the agreement is aligned with and implements a variety of NPS Management Polices (2001) including but not limited to External Threats and Opportunities (Chapter 1.5), Environmental Leadership (Chapter 1.6), Cooperative Planning (Chapter 2.3.1.9), Land Protection (Chapter 3), and especially Natural Resource Management (Chapter 4) that details

policy and management guidelines which apply to bird conservation. Important policies in this chapter includes:

- Planning for Natural Resource Management (4.1.1)
- Partnerships (4.1.4)
- Restoration of Natural Systems (4.1.5)
- Studies and Collection (4.2)
- General Principles for Managing Biological Resources (4.4.1)
- Plant and Animal Population Management Principles (4.4.1.1)
- Management of Native Plants and Animals (4.4.2)
- Management of Endangered Plants and Animals (4.4.2.3)
- Management of Natural Landscapes (4.4.2.4)
- Management of Exotic Species (4.4.4)
- Pest Management (4.4.5)
- Fire Management (4.5) and
- Water Resource Management (4.6)

The NPS is the fourth largest landowner in the United States, consisting of over 380 national park units covering 83 million acres of land and water with associated biotic resources (www.nps.gov). The 64 units in the Southeast Region of the NPS represent 16% of the total number of park units in the national park system and cover approximately 5% of the total land base in the entire system. Park units in the Southeast Region include national seashores (Canaveral National Seashore, Cape Hatteras National Seashore), national parks (Great Smoky Mountains National Park, Everglades National Park), national recreation areas (Big South Fork National River and Recreation Area), national preserves (Big Cypress National Preserve, Salt River Bay National Historic Park and Ecological Preserve), national battlefields (Cowpens National Battlefield, Fort Donelson National Battlefield), national monuments (Congaree Swamp National Monument, Ocmulgee National Monument), and others such as the Blue Ridge Parkway, Obed Wild and Scenic River, and Timicuan Ecological and Historic Preserve.

Southeast NPS units provide habitat for over 400 species of migrating, breeding, and wintering birds and include a wide range of Federal and State listed threatened and endangered species. Likewise, these units also provide nest, migration, and winter habitat for most of the eastern species identified in the national bird conservation plans in need of conservation attention.

Additionally, the NPS attracts over 280 million visitors to the parks each year, 120 million of these in the Southeast Region, affording excellent recreational bird watching and opportunities to strengthen bird conservation interpretation, outreach, and education programs. These opportunities, the NPS mission, policies, and organization all lead to the conclusion that the NPS is an extremely valuable partner and contributor to bird conservation in the region.

Nationally, the status of birds in national parks is largely unknown, although many parks have adequate knowledge regarding bird occurrence in the parks (http://www.npwrc.usgs.gov/resource/othrdata/chekbird/chekbird.htm). Parks often play a role in ongoing regional bird conservation efforts. Indeed many of these parks are often important to regional, national, or international bird conservation, and many have been designated as Important Bird Areas (IBA's) by the National Audubon Society. To date, there are approximately 64 NPS units that are designated IBA's, 35 of which are considered of global importance (http://abcbirds.org/iba/aboutiba.htm). In the Southeast Region, the NPS has 13 IBA's.

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The **NPS Inventory and Monitoring (I&M) Program** has been developed to provide management driven scientific information to national park managers so that resources can be adequately protected within national parks. One of the first phases of this program is to inventory vertebrates, including birds, within the 260 national park units in the program. Once completed, data from the inventories will provide an account of the occurrence and abundance of birds in all the national parks in the program. These records will be stored in the NPS I&M NPSpecies database http://www.nature.nps.gov/im/apps/npspp/). Coordination with I&M network staff is important to developing long-term bird monitoring programs that fulfill both park and NABCI objectives.

Park Flight is a NPS international partnership initiative that directs funding toward a variety of NPS programs that involve conservation of Neotropical migratory birds whose life history range covers a US national park and a Latin American protected area. A relatively new program, Park Flight offers parks the opportunity to partner with a Latin American national park or protected area to cooperate on developing bird conservation and education projects (NPS 2002).

Recent increases in NPS base funded programs such as inventory and monitoring, exotic species management, habitat restoration, and fire management all indicate that national park managers recognize that park lands are increasingly subject to a variety of threats and conditions that must be improved to provide the quality of national park experience articulated in the NPS Organic Act (1916). Programmatic funding in these areas will increase the ability of national parks to provide quality habitat and conditions for increased wildlife conservation, including birds. Furthermore, private interests and non-profit conservation organizations have initiated programs, including grant programs, to provide much needed funding to national parks to meet backlogs of identified yet unfunded needs.

Park Description

SARI is the only known site where members of the Columbus expedition set foot on what is now U.S. territory. The park contains the only ceremonial prehistoric ball court ever

discovered in the Lesser Antilles, village middens, and burial grounds. The area was a focal point of various European attempts to colonize the area during the post-Columbian period by the Spaniards, French, Dutch, English, and Danish. The site is marked by Fort Sale, a remaining earthworks fortification from the Dutch period of occupation. Salt River's natural significance and beauty derive from the association of upland terrestrial, estuarine, and marine environments within a relatively small geographic area. It encompasses the single largest mangrove system remaining in the Virgin Islands. The mangroves and the bay's seagrass beds provide some of the most important foraging and nesting habitats for resident and migratory wildlife in the territory. The submarine canyon at the entrance to Salt River Bay, together with the sheer outer wall (with its diversity of deep water corals, caverns, grottoes, and ledges) descending to almost 2,000 feet, is one of few such features found worldwide (NPS, 2001?)

Avian Resources of Puerto Rico and the US Virgin Islands

Puerto Rico and the Virgin Islands are part of the West Indies, a chain of islands that extends from Florida to Venezuela and separate the Caribbean Sea from the Atlantic Ocean. These tropical Islands are located within 17-19° latitude North and 64-68° longitude West about 1,609 kilometers from Florida and 805 kilometers from Venezuela.

The U.S. Virgin Islands are located about 64 kilometers east of the Puerto Rico. These Islands comprise another archipelago that includes St. Thomas, St. John, St. Croix, and numerous uninhabited small islets and cays. The three main Islands were bought by the U.S.A. from Denmark in 1917 and are now U.S. Territory with a total area of 340 km^{2}.

The number, size and shape of the islands comprised within this region combined with climate, topography, geological processes, and human activities have produced a tremendous diversity of habitats. Historically different types of forest covered most of the land area of Puerto Rico and the Virgin Islands. However, forest conversion caused by agricultural and other land use practices have shaped the present landscape. Forested landscape in the U.S. Virgin Islands is typified by sub-tropical dry forest and littoral shrubs.

Including vagrants, exotics and fossils, the total number of bird species in the region sums to 364. Presently, 276 species are known to occur in Puerto Rico and 210 in the Virgin Islands for a total of 284 species in the region (Raffaele 1989). Recent studies indicate that these numbers may change as many native forms may be reclassified as species or subspecies on their own. Raffaele (1989) categorized the regional birds species as follows: 97 breeding permanent residents (94 in Puerto Rico and 60 in the Virgin Islands), 11 breed and leave (11 in Puerto Rico and 10 in the Virgin Islands), 134 non-breeding migrants and visitors (134 Puerto Rico and 129 the Virgin Islands), 31 introduced probable breeders (31 in Puerto Rico and 6 in the Virgin Islands), five introduced possible breeders (same species for both Puerto Rico and the Virgin Islands), and one species recently extirpated from Puerto Rico. As the numbers indicate, migrant species comprise almost half of the species playing a major role in the ecology of the region. Also noteworthy is the

establishment of a high number of exotic species. As a result of combining both native and exotic species, Puerto Rico supports 85 species of breeding land birds, the greatest number of any West Indian island and except for Cuba, harbors the second largest total number of species in the region (Raffaele 1989).

The oceanic nature of the islands in the region has resulted in increased endemism. Puerto Rico harbors **16 endemic** bird species including one endemic genus (*Nesospingus*) represented by a single species, the Puerto Rican Tanager (*Nesospingus speculiferus*) and one family (Todidae) shared with the rest of the West Indian islands but found nowhere else. Rafaele (1989) considered 51 species to be threatened in the region mostly because of the detrimental effects of habitat alteration.

Avian Conservation in SARI

Avian Biodiversity: SARI has an avian inventory and two checklists; one is a Christmas Bird Count list and the other is a compilation from work conducted by Bill Knowles (Knowles 1993). Staff has identified the need to update and combine the two existing checklists and make available to the public.

Verified records of birds in SARI have been entered into the NPS I&M program's database, NPSpecies, and may be viewed via the internet at http://www.nature.nps.gov/im/app/npspp with a user identification and password combination authorized by the NPS for NPS personnel and NPS cooperators.

Threatened and Endangered Species: The Brown Pelican is the only federally listed species known to regularly occur in SARI. Here the Brown Pelican forages and may possibly nest. The recently delisted American Peregrine Falcon occurs as a rare but regular winter visitor in the park and vicinity.

Several USVI Territory **Listed** species occur in SARI including Brown Pelican, Roseate Tern, White-crowned Pigeon, White-cheeked Pintail, Great Blue Heron, Great Egret, Snowy Egret, Black-crowned Night Heron, Least Bittern, Clapper Rail, and Least Tern.

Several high priority PIF species for the Caribbean occur in SARI (see Appendix A). Prominent among these species are White-crowned Pigeon, Yellow Warbler, White-cheeked Pintail, Brown Pelican, Scaly-naped Pigeon, Antillean Crested Hummingbird, Puerto Rican Flycatcher, Lesser Antillean Bullfinch, and several Neotropical migrants including Northern Waterthrush and Northern Parula.

Park Priorities: Park staff and consultants have not identified any particular species that is a park management concern or high priority for conservation. Rather, park staff is concerned about conserving all birds and their habitats in SARI. However, several species that occur in SARI are high priority in the Caribbean and conservation efforts in the park could focus on these species or groups of species.

Inventory: A complete inventory has been recognized as important information for park managers and is being conducted within the framework of the NPS I&M Program. SARI is one of seven parks in the NPS South Florida/Caribbean I&M Network for which a plan to conduct high priority inventory projects has been prepared (Sasso and Patterson 2000). Although SARI was not originally included in development of the plan, avian inventory is desired for this park, including presence/absence surveys and a determination of breeding bird distribution and abundance throughout the park. Currently, ongoing inventory efforts are:

- bird census being conducted by VIDPNR
- basic inventory being conducted by volunteer (Roland Wauer)

Monitoring: Currently, the following avian monitoring projects are being conducted at SARI. They are:

- a Christmas Bird Count (CBC)
- VIDPNR) based bird census
- White-crowned Pigeon and Least Tern monitoring by Bill Knowles

Research: Scientific research is permitted within the park. Currently, no research other than ongoing inventory and monitoring is underway.

- **Outreach:** The park does not have interpretive and outreach program related to birds and bird conservation.

Park Identified Needs for Avian Conservation

SARI has identified several projects that would increase the avian knowledge of the park. These are:

Inventory

- Complete a thorough inventory, including distribution and abundance of birds year around

Monitoring

- Identification of priority species and monitoring needs
- Establish a monitoring program for federal and territorial listed species
- Establish a monitoring program for species that nest and roost in SARI, with a emphasis on priority species

Research

- Compare pre-Hugo mangrove bird data with current mangrove bird demography

Coordination with Regional Conservation Initiatives

North American Bird Conservation Initiative

NABCI bird conservation planning units, referred to as Bird Conservation Regions (BCR), are often larger than other planning units associated with other plans, such as Partners In Flight. For example, SARI is within the NABCI BCR 69 that includes all of the Commonwealth of Puerto Rico, the US Virgin Islands and the British Virgin Islands and includes the physiographic region designated by Partners in Flight as Puerto Rico/Virgin Islands (Figure 2; compare to Figure 1).

Several NABCI BCR's have coordinators whose primary responsibility is to coordinate all bird conservation planning in the BCR, across all agencies and organizations. Currently, the Caribbean BCR does not have a designated coordinator; however, the assistant coordinator for the Atlantic Coast Joint Venture (ACJV) can provide valuable assistance to SARI with implementation of aspects of this ACIP.

North American Waterfowl Management Plan (NAWMP)

The NAWMP (http://northamerican.fws.gov/NAWMP/nawmphp.htm) is completed and has been revised several times, incorporating updated goals and strategies based on new information. This plan is one of the most successful bird conservation delivery programs in the United States, being monetarily supported by the North American Wetlands Conservation Act (NAWCA). This plan can be consulted for priority waterfowl conservation needs in the Virgin Islands. The ACJV assistant coordinator has coordination responsibility for the USVI.

Partners In Flight

Goals and strategies for the Caribbean can be found in the draft bird conservation plan, previously submitted to the park (Nunez-Garcia and Hunter 2000). The park will receive updates of the plan as they are completed. The current plan identifies priority bird and habitat conservation goals that must be implemented in order to achieve bird conservation success in this region. Because the Partners In Flight bird conservation plan for this region is better developed than other plans, and includes all species, SARI will utilize this plan more than any other plan to participate in NABCI implementation.

Similar to NABCI BCR's, PIF physiographic areas often do not have designated coordinators. However, state level non-game agencies with investment in PIF will establish key personnel to develop partnerships among cooperators in the physiographic area. The VI territorial government, Department of Planning and Natural Resources (VIDPNR) has prime responsibility for implementation of the Puerto Rico/US Virgin Islands Partners in Flight bird conservation plan and can be instrumental in implementing recommendations

identified in this ACIP and projects important to bird conservation relative to the VI's role in Caribbean bird conservation.

United States Shorebird Conservation Plan (USSCP)

The USSCP has been completed and is available on the world wide web (http://shorebirdplan.fws.gov/). A regional step down plan is in preparation by FWS personnel and should be available in 2003.

Waterbird Conservation for the Americas (WCA)

The WCA plan has been completed and is available on the World Wide Web or can be ordered from the US Fish and Wildlife Service National Conservation Training Center (http://www.waterbirdconservation.org/).

Integration of NABCI Goals and Objectives into Park Planning and Operations

NABCI Implementation Recommendations

To successfully achieve park-established goals and actively participate in NABCI, the park could implement a variety of projects in different NPS programs. Most of these projects would require some level of participation by many existing park programs and could either be achieved through NPS funding, or more likely, through establishing or improving partnerships with agencies and organizations that already have the necessary expertise to provide guidance, funding, and execution of these programs. Programmatic areas where bird conservation actions are likely to be focused are:

- Inventory
- Monitoring
- Habitat Restoration
- Threat Management (includes exotic species, air quality, water quality, etc.)
- Research
- Compliance
- Outreach
- Partnerships

To the extent appropriate, each of these program areas will be discussed separately and within each, specific opportunities identified that, when implemented, will enable to park to meet its mandates (current and expected) as well as integrate NABCI into its planning and operations. With emphasis added, the park is not expected to implement any of these recommendations or be obligated to pursue any opportunity other than those the park is required to do by law or NPS program or policy. In other words, participation in this effort

is currently voluntary. However, participation in these efforts at some level could become mandatory with the completion of an MOU with the FWS regarding EO 13186, **Responsibilities of Federal Agencies to Protect Migratory Birds**. The MOU will establish a formal agreement between the FWS and the NPS to promote bird conservation within the agency by incorporating goals and strategies of existing bird conservation initiatives, plans, and goals into park planning and operations.
Should the park decide to implement any of these projects, further consultation with bird conservation contacts is encouraged to obtain updated information on the relevance of these opportunities in regional bird conservation.

High priority projects are identified in **bold** print. Priorities that the park is encouraged to seek NPS funding for are marked with and asterisk (*****). These projects are those that are critical to the stabilization or improvement of a bird population in the planning region.

Inventory

The park has identified the need to better characterize its bird fauna. Distribution and abundance data are desired to fully understand the status of birds in the park so that conservation actions for birds can be implemented, especially for federally and territorially listed species. Status of high priority species as identified in the Puerto Rico/US Virgin Islands bird conservation plan and the USVI territorial watchlist is needed to effectively structure park management for the continued preservation and enhancement of the park's avifauna.

Abundance and distribution data are needed

- **for resident breeding birds in mangroves***
- **for resident breeding birds in the subtropical dry forests**
- **for birds that forage and roost in the park**
- **for wintering birds in the mangroves and subtropical dry forests, particularly migrant warblers**

Additionally, the park is encouraged to:

- **continue to partner with the VIDPNR and USFWS to coordinate area inventory efforts**
- **verify other avian observational data collected in the park and enter into the appropriate database (NPSpecies, eBird Monitoring Program of Cornell's Laboratory of Ornithology, Columbid Database, etc.)**

- **standardize inventory and monitoring methodology to conform to NPS and/or FWS recommended standards (Fancy and Sauer 2000, Hunter 2000).**

Monitoring

Efforts should be made to continue existing monitoring programs while developing other programs based on inventory results, striving to conform to established NPS or FWS surveys and monitoring protocols. Close coordination with VIDPNR bird conservation initiatives are needed to identify and implement high priority projects on park lands and to ensure that park efforts contribute to park or regional bird conservation rather than undertake an action or actions that are not needed or are better conducted in other areas. Specific recommendations are to:

- **continue to conduct existing monitoring programs (CBC, Least Tern and White-crowned Pigeon) and enter data into the appropriate database (NPSpecies, eBird, or National Point Count Database (USGS 2001) (http://www.mp2-pwrc.usgs.gov/point/)**

- **establish mangrove bird monitoring program throughout the park***

- **compare mangrove bird distribution and abundance to mangrove restoration efforts**

- **monitor resident and migrant birds at established forest point counts along ecologically distinct or vegetative/habitat types ***

- **establish monitoring programs based on results of inventory data for High Priority species and with potential for high conservation role for any of these species**

- **standardize inventory and monitoring methodology to conform to NPS and/or FWS recommended standards (Fancy and Sauer 2000, Hunter 2000).**

- **partner with VIDPNR and USFWS staff to coordinate area monitoring efforts**

Habitat Restoration/Management

Recently, habitat restoration efforts have increased on NPS lands; NPS receiving restoration emphasis and guidance in the 2001 Management Policies (NPS 2001). Habitat restoration efforts that parks may undertake are wetland restoration, grassland restoration, woodland restoration, etc. utilizing a wide range of tools to accomplish the

restoration. Some of these tools may be but not limited to forest management practices, exotic species management, public use and recreation management, infrastructure development management, and prescribed fire.

Due to the protected nature of SARI lands, and generally those in the national park system, the condition of habitats for bird use may be of higher quality than other natural, developed, agricultural, or forest lands under other management regimes. However, national park lands can be greatly improved for wildlife, and particularly bird use, by restoring processes important for habitat formation, succession, and structural development. Largely, these processes have not been managed historically in the national park system but current policy allows for active management of species, populations, and lands to provide for long-term conservation of park resources.
Protection, restoration, and enhancement of habitats in SARI can greatly contribute to established habitat goals identified in the Puerto Rico/US Virgin Islands bird conservation plan.

Specific recommendations are to:

- **continue mangrove restoration in SARI and protect remaining mangroves throughout the park***

- **identify any inholdings of high value and work with landowner to acquire conservation easement or fee title to land***

- **avoid or minimize park developments**

- **restore and/or improve hydrological quality and processes where needed, especially where non-point source pollution may affect water quality and in marina where boat discharge may affect water quality**

Threat Management

Although largely unquantified, several threats exist in SARI that may affect bird conservation. Feral and wild animals such as cats, dogs, and mongoose may damage birds directly through predation or disturbance to nesting, foraging, and roosting opportunities. Additionally, human disturbances associated with vehicles, jet-skis, boats, and helicopters may disturb nesting, foraging, and roosting birds. The park is encouraged to:

- **protect water quality in SARI and marina waters through protection of upland habitats in watershed**

- **protect water quality in SARI and marina waters through implementation of**

best marina practices, such as elimination of boat sewage disposal, elimination of fuel spills, and elimination of other boat or business discharge into water

- **protect Least Tern colony by reducing non-native predators and eliminating disturbance from vehicles**

- **develop aggressive reduction program for rats, cats, and mongoose**

- **assess disturbance from kayak touring and work with kayak tour operators to eliminate potential disturbances to birds**

- **work with adjacent landowners and neighbors, the local community, and pubic officials to curb unregulated and free roaming feral and domestic dogs and cats in the park***

- assess potential impact form helicopter overflights

- assess potential impacts from human uses such as camping, harvesting of mangrove for firewood use, and crabbing

- remove derelict boats that may be discharging pollutants

- provide monofilament dispenser at marina

- identify potential bird injury or mortality associated with fishing gear and fishing practices in the park and nearby waters, especially for Brown Pelican

If necessary, consult with regional Exotic Plant Management Team (EPMT) to identify and remove exotic plant species that may negatively affect habitats. Currently, no EPMT provides service the SARI area. Until an EPMT is established that can provide assistance to SARI, staff is directed to consult with the regional pest management specialist (see contacts).

Additionally, the park is encouraged to:

- **hire additional protection staff to better manage threats and implement projects identified in this plan***

- **develop close working relationship with VIDPNR Coastal Zone Management to promote protection of islands natural resources and the Salt River watershed**

Research

- **list park needs and projects on Research Permit and Reporting System web site (RPRS)**

- develop contact with South Florida/Caribbean Cooperative Ecosystem Studies Unit (CESU) at the University of Miami, Miami, FL

Compliance

Park compliance with the Migratory Bird Treaty Act and the Executive Order 13186, **Responsibilities of Federal Agencies to Protect Migratory Birds,** is necessary to assure that park activities incorporate bird conservation into park planning and operations. Further, to ensure that migratory birds are considered in all phases of park planning processes, especially during the National Environmental Policy Act (NEPA) and the Director's Order #12 Compliance processes, the park should consider adding specific language in project evaluations that requires consideration and implications of park projects on migratory birds. The MOU being developed between the NPS and the FWS will likely contain specific language requiring a park to consider implications of park projects on migratory birds. Additional considerations are to encourage:

- **park staff to begin specific consideration of migratory birds during park planning processes***

- park staff to attend USFWS training on implementation of EO 13186 at the National Conservation Training Center (NCTC) (when available) or other training on migratory bird conservation in North America. NCTC has several courses and training related to conservation of migratory birds (http://training.fws.gov/courses.html).

The USFWS NCTC offers and reserves two tuition free slots for National Park Service employees wishing to attend NCTC courses on a first come, first served basis. Additionally, discount lodging is also available while attending a NCTC course.

Outreach

- **participate in International Migratory Bird Day (IMBD) events with a local partner (http://birds.fws.gov/imbd.html)***

- **update the bird checklist for public availability***

- **nominate SARI as an Important Bird Area**

(http://www.abcbirds.org/iba/nominstr.htm)

- **develop public outreach regarding efforts of the Salt River Marine Reserve and Wildlife Sanctuary**

- **continue to develop and implement outreach and educational programs to enhance visibility of bird conservation issues**

- **encourage Virgin Islands Audubon Society to participate in ongoing and new inventory and monitoring programs**

- **encourage accurate documentation and reporting from these and random outings by visitors (see Cornell University's eBird monitoring program (Cornell Lab. Ornith. 2002 (http://www.ebird.org/about/index.jsp)**

- **work with adjacent landowners and neighbors, the local community, and pubic officials to curb unregulated and free roaming feral and domestic dogs and cats in the park**

- park interpretation/education staff are encouraged to attend USFWS training on Migratory Bird Education at NCTC

- consider adding links to bird conservation information, data, etc. to the park's web site home page

- support bird conservation by serving shade-grown coffees at meetings, events, and the office buildings in the park (http://www.americanbirding.org/programs/conssbcof3.htm)

- participate in bird conservation efforts of the Society for the Conservation and Study of Caribbean Birds (SCSCB), including subscribing to this organization's electronic information forum

- explore cultural affiliation of landscape to inhabitants, both historical and contemporary. Cultures are strongly tied to the landscape they inhabit and birds often play a role in a cultural tie to the landscape. When these connections are discovered and preserved, a greater appreciation for the landscape and it's value to the culture can be achieved

Partners and Partnerships

Partnerships for land conservation and protection will perhaps have the greatest positive influence on bird conservation above all other landscape scale planning. Specific

recommendations are to:

- **keep abreast of USVI territorial initiatives that could impact park resources, particularly with Coastal Zone Management**

- **continue to identify priority acquisition areas in cooperation with Salt River Commission to protect SARI from adjacent developments**

- **cooperate and VIDPNR in the preparation and implementation of the USVI Comprehensive Wildlife Conservation Plan**

- **continue to cooperate and develop protection measures with the Salt River Marine Reserve and Wildlife Sanctuary program**

- **work with the White-crowned Pigeon Working Group of the SCSCB to determine appropriate conservation actions for this species in the park**

- **become a contributing member of the Caribbean Columbid Population Data Center, a cooperative effort of the Puerto Rico Department of Natural Resources, USFWS, and other Caribbean interests to assess populations status and implement conservation actions necessary for these species**

- **contact the nearest Joint Venture office (see Funding section for explanation of Joint Ventures) or BCR coordinator to develop partnerships and funding proposals tiered to priorities established by the park, this ACIP, and the Puerto Rico and US Virgin Islands Bird conservation plan**

- **encourage the USVI territorial government to become a member of the Atlantic Coast Joint Venture, increasing USVI partners chances to utilize NAWCA funds for bird and habitat conservation projects**

- continue to maintain productive relationship with local Audubon Society

Funding Opportunities

Internal NPS funding is often an effective source to obtain funding; however, the project will have to be a fairly high priority among the park's natural resource program to successfully compete for the limited funding available in the NPS. Therefore, partnerships and outside funding programs are often more productive for securing bird conservation funding. Within this ACIP, identified priority projects that are considered to be high park priorities as well as NABCI priorities are marked with and asterisk (*). SARI is encouraged to enter all high priority projects into the NPS Performance Management Information System (PMIS) database.

Funding for conservation projects for Neotropical migrants is also available through the Park Flight program.

With the exception of the North American Waterfowl Management Plan (NAWMP and its associated funding legislation, the North American Wetland Conservation Act), funding opportunities for bird conservation programs, plans, and initiatives have been lacking. Only within the last decade have other appropriate and specific sources for bird conservation funding been created and used. The NAWMP has been supported for approximately 14 years by the North American Wetlands Conservation Act (NAWCA 1989). This program has provided $487 million in appropriated funds matched with $1.7 billion for wetland and bird conservation projects since its inception. In 2002 alone, over $70 million US dollars were awarded to US and Canadian agencies and organizations to enhance waterfowl populations by improving, restoring, or protecting wetland habitats. To adequately evaluate projects and distribute these funds, partnerships called Joint Ventures were established. Nationally, 14 (11 US, 3 Canada)
Joint Ventures have been established, several which are funded and staffed. Internet links to Joint Ventures are:

(http://southwest.fws.gov/gulfcoastjv/ojvcontact.html) and
(http://northamerican.fws.gov/NAWMP/jv.htm).

Funding through NAWCA is highly underutilized by the NPS and any park unit that has wetland, water, or bird conservation needs associated with wetland are encouraged to investigate using this funding source. Naturally, there are certain requirements to be eligible for all grants and park managers are encouraged to consult with the nearest Joint Venture, BCR, PIF Coordinator, to learn how this program might be applicable to implementation of this plan, and other park wetland issues. SARI is not within a region which has an operational Joint Venture, but contact with the Atlantic Coast Joint Venture will provide opportunity to investigate use of this funding source and developing proposals.

Internal FWS funding programs may be used to support projects, but no effective method of project proposal delivery to these sources is currently in place for the NPS. Current funding in these programs may result from FWS familiarity with NPS needs, or

NPS participation in one of the area FWS Ecosystem Teams, where a project has been identified and proposed to be funded through the Ecosystem Team.

One unexplored yet potentially fruitful funding source for national parks is the myriad of grants through the FWS State Programs, where grants are awarded to private individuals engaged in habitat conservation projects. No funding is directly available to national parks, but identified projects with important or critical adjacent landowners can sometimes be funded through these sources. Similar programs are available if the adjacent landowner is

a federally recognized American Indian tribe.

Specific congressional appropriations to protect migratory birds has recently been authorized under the Neotropical Migratory Bird Conservation Act (2000) (http://www.nfwf.org/programs/nmbcapp.htm). Appropriations through this Act are authorized up to $5 million per year. However, in 2000, appropriation was approximately $3.75 million and a majority of this funding was directed toward projects in Central and South America.

Many of the identified projects are eligible for funding under various grant programs of the National Fish and Wildlife Foundation (http://www.nfwf.org/programs/programs.htm).

Other prominent funding sources available to NPS managers for bird conservation are listed on this projects web site at:

http://southeast.fws.gov/birds/NPSHighlits.htm.

Funding opportunities for migratory bird conservation are available yet most natural resource agencies are not fully aware of and/or understanding of how to use these sources. Perhaps a consolidated migratory bird funding source catalog will become available to managers in the future; this is needed.

Contacts

Primary contacts within the region can be obtained by viewing the web site for the Southeastern Bird Conservation Initiative, National Park Service at http://southeast.fws.gov/birds/npsbirds.htm. This web site will provide contact information of the appropriate bird conservation coordinator in the region for park personnel. Park staff are encouraged to view the web site and obtain contact information. Primary contacts for SARI are:

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APPENDIX A

PUERTO RICO AND VIRGIN ISLANDS (BCR 69) BASED ON CONTINENTAL AND REGIONAL WATCH LIST AMONG ALL BIRDS WITHIN SOUTHEAST U.S., AND THE WEST INDIES*

(Action Levels: IM=Immediate Management; MA=Management Attention; PR=Long-Term Planning and Responsibility) (subspecies/populations of interest noted; all species breed or are resident unless otherwise indicated; ba=number of breeding adults)

Tier I. Continental Conservation Interest

a. Multiple Causes for concern across entire range

White-tailed Tropicbird	(500-600 pairs, 14-19% in West Indies)	IM
Red-billed Tropicbird	(375-450 pairs, 14-22% in West Indies)	IM
West Indian Whistling-Duck	(<100 ba, 1-5% globally)	IM
Black Rail	(Extirpated?)	IM
Snowy Plover	(Threatened Pacific Coast; West Indies subspecies)	IM
Piping Plover	(Endangered, winter)	IM
Plain Pigeon	(Endangered; <5,000 ba, <10% globally)	IM
Puerto Rican Parrot	(Endangered; <100 ba in the wild, 100% globally)	IM
Puerto Rican Nightjar	(Endangered; <2,000 ba, 100% globally)	IM
White-necked Crow	(Endangered/Extirpated from Puerto Rico)	IM
Bicknell's Thrush	(Possible rare winter in Puerto Rico)	PR
Golden-winged Warbler	(Rare winter)	PR
Elfin-Woods Warbler	(Candidate for Listing; <1,000 ba, 100% globally	IM
Yellow-shouldered Blackbird	(Endangered; <500 ba, 100% globally)	IM

b. Moderately abundant or widespread with declines and/or high threats

Audubon's Shearwater	(~150 pairs, 2-4% in West Indies)	IM
Masked Booby	(300 pairs, 50% in West Indies)	IM
Red-footed Booby	(1,450-2,650 pairs, 15-33% in West Indies)	IM
Brown Booby	(2,075-2,300 pairs, 22-36% in West Indies)	MA
Little Blue Heron		MA
American Golden-Plover	(Rare southbound transient)	PR
Lesser Yellowlegs	(non-breeding)	MA
Solitary Sandpiper	(transient)	MA
Upland Sandpiper	(Rare transient)	PR
Whimbrel	(non-breeding)	MA
Sanderling	(non-breeding)	MA
Semipalmated Sandpiper	(non-breeding)	MA
Western Sandpiper	(non-breeding)	MA
Stilt Sandpiper	(non-breeding)	MA
Wilson's Snipe	(winter)	MA
Gull-billed Tern	(non-breeding?)	PR
Roseate Tern	(North Atl. Endangered, West Indies Threatened; 1,200-3,600 pairs, >25% in West Indies)	IM
Least Tern	(Calif. & interior subspecies Endangered; 300-450 pairs, 8-25% in West Indies)	IM
White-crowned Pigeon		MA
Mangrove Cuckoo		MA
Short-eared Owl	(Greater Antillean subspecies)	MA

Puerto Rican Vireo	(100 % globally)	MA
Prairie Warbler	(winter)	MA
Prothonotary Warbler	(winter)	MA
Worm-eating Warbler	(winter)	MA
Kentucky Warbler	(Rare winter)	PR
Greater Antillean Oriole	(10-20% globally)	MA

c. Restricted distributions and/or low population size

Magnificent Frigatebird	(700-900 pairs, 13-21% in West Indies)	IM
Reddish Egret	(Rare, non-breeding)	PR
Caribbean Coot	(1,000 ba, <50,000 West Indies)	IM
Wilson's Plover		MA
American Oystercatcher	(Eastern North American subspecies)	IM
Red Knot	(non-breeding; presumably Alaskan subspecies)	PR
Bridled Tern	(900-1,700 pairs, 15-40% in West Indies)	MA
Antillean Nighthawk		PR
Black Swift	(West Indian subspecies)	MA
Lesser Antillean Pewee	(Puerto Rican subspecies)	PR
Blue-winged Warbler	(Rare, winter)	PR
Adelaide's Warbler	(100% globally)	PR
Swainsons's Warbler	(Rare, winter)	PR

Tier II. Regional Conservation Interest

a. High Concern

Brown Pelican	(West Indies, Endangered; 520-850 pairs, 25-40% in West Indies)	IM
Green Heron		MA
Yellow-crowned Night-Heron		PR
Black-bellied Plover	(non-breeding)	MA
Ruddy Turnstone	(non-breeding)	MA
Least Sandpiper	(non-breeding)	MA
Antillean Mango	(nearly extirpated on Virgin Islands)	MA
Black-whiskered Vireo		PR

b. High Threats

Pied-billed Grebe	(breeding populations only)	MA
Least Bittern		MA
Black-crowned Night-Heron		MA
Greater Flamingo	(Extirpated as a resident, may be recolonizing)	MA
White-cheeked Pintail	(Lesser subspecies; <5,000 ba Puerto Rico-Virgin Islands; ~60,000 ba in West Indies)	MA
Ruddy Duck	(West Indian subspecies; ~1,500 ba Puerto Rico; <<50,000 ba West Indies)	MA
Masked Duck	(West Indian populations; <100 ba Puerto Rico; <<50,000 ba West Indies)	MA
Sharp-shinned Hawk	(Puerto Rican subspecies, Endangered; <100 ba)	IM
Broad-winged Hawk	(Puerto Rican subspecies, Endangered; <100 ba)	IM
American Kestrel	(Eastern Caribbean subspecies)	MA
Clapper Rail		MA

Yellow-breasted Crake	(Hispaniolan-Puerto Rican subspecies)	MA
Purple Gallinule		MA
Limpkin	(Hispaniolan-Puerto Rican subspecies)	IM
Willet		MA
Key West Quail-Dove		MA
Bridled Quail-Dove		MA
Puerto Rican Screech-Owl	(Virgin Islands subspecies, extirpated except on Culebra?)	IM
Yellow Warbler	(West Indian "Golden" subspecies)	MA
Louisiana Waterthrush	(winter)	MA

c. High Responsibility

Tricolored Heron		PR	
Black-necked Stilt			PR
Pectoral Sandpiper	(transient)		PR
Sooty Tern	(55,000-80,000 pairs, 20-40% in West Indies)		PR
Black Tern	(transient)		PR
Brown Noddy	(1,300-2,100 pairs, 7-18% in West Indies)		PR
Scaly-naped Pigeon			PR
Zenaida Dove			PR
Puerto Rican Lizard-Cuckoo	(100% global)		PR
Puerto Rican Screech-Owl	(Puerto Rican subspecies; 100% globally)		PR
Green Mango	(100% globally)		PR
Antillean Crested Hummingbird			PR
Puerto Rican Emerald	(100% globally)		PR
Puerto Rican Tody	(100% globally)		PR
Puerto Rican Woodpecker	(100% globally)		PR
Caribbean Elaenia			PR
Puerto Rican Flycatcher	(100% global, nearly extirpated Virgin Islands)		PR
Gray Kingbird			PR
Loggerhead Kingbird	(Puerto Rican-Vieques subspecies)		PR
Caribbean Martin			PR
Cave Swallow			PR
Red-legged Thrush	(Hispaniolan-Puerto Rican subspecies)		PR
Northern Parula	(winter)		PR
Cape May Warbler	(winter)		PR
Black-throated Blue Warbler	(winter)		PR
Puerto Rican Tanager			PR
Puerto Rican Spindalis			PR
Antillean Euphonia			PR
Puerto Rican Bullfinch	(Puerto Rican subspecies; 100% globally)		PR
Grasshopper Sparrow	(Puerto Rican subspecies)		PR

Tier III. Additional State, Territorial Listed Species (drawn from species in Tier IV)

Least Grebe	PR
Great Blue Heron	PR
Great Egret	PR
Snowy Egret	PR

Tier IV. Additional Local or Regional Interest Species (also Stewardship Species identified

by Avifaunal Biome supporting vast majority of breeding population)

Glossy Ibis				PR
Northern Pintail		(winter)		MA
Blue-winged Teal		(winter)		MA
Lesser Scaup		(winter)		MA
Northern Harrier	(winter)		PR	
Osprey				PR
Merlin		(mostly transient)		PR
Peregrine Falcon		(mostly transient)		PR
Sora		(winter)		PR
Common Moorhen				PR
Semipalmated Plover		(non-breeding)		PR
Killdeer				PR
Greater Yellowlegs		(non-breeding)		PR
Spotted Sandpiper		(non-breeding)		PR
White-rumped Sandpiper		(transient)		PR
Royal Tern		(115-315 pairs, >25% in West Indies)		PR
Sandwich Tern		(800-3,600 pairs, 28-71% in West Indies)	PR	
White-winged Dove				PR
Mourning Dove				PR
Yellow-billed Cuckoo				PR
Common Nighthawk				PR
Chuck-will's-widow		(Rare, winter)		PR
White-eyed Vireo		(Rare, winter)		PR
Yellow-throated Vireo		(Rare, winter)		PR
Magnolia Warbler		(Northern Forest Biome, winter)		PR
Yellow-throated Warbler		(winter)		PR
Palm Warbler		(Northern Forest Biome, winter)		PR
Blackpoll Warbler		(transient)		PR
Black-and-white Warbler	(winter)		PR	
American Redstart		(winter)		PR
Ovenbird		(winter)		PR
Northern Waterthrush		(winter)		PR
Hooded Warbler	(Rare, winter)		PR	
Indigo Bunting		(non-breeding)		PR
Bobolink		(transient)		PR
Baltimore Oriole		(transient)		PR

*

WL=WatchList score used for Continental Scoring (PIF Approach); species with WL SUBTOT combined scores of (1) 15 or more, (2) 14 with Tmax+PT $\geq$5, or (3) with 13 with PT=5 are identified. using formula:

Combined Score = PT + PS + maximum of (BD or ND) + maximum of (TB or TN)

Tier=

I. Continental Conservation Interest (Continental WatchList): (a) Species with multiple causes for concern across their entire range; (b) Moderately abundant or widespread species with declines or high threats, and (c) Species with restricted distributions or low population size.

Species with multiple causes for concern across their entire range: These species are considered by many to be of highest continental concern and of highest priority for conservation actions at national and international scales. A majority of these are legally listed as Endangered or Threatened in either the U.S. or Canada, and as such have recovery plans in place. Notable in this group, however, are several species without legal status, including Bicknell's Thrush and Saltmarsh Sharp-tailed Sparrow.

Moderately abundant or widespread species with declines or high threats: These species are on the Watch List primarily because they are declining and/or threatened throughout their range, though still fairly widespread or with moderately large populations. Many of these species still number in the millions (e.g. Dickcissel, Wood Thrush), but are threatened with serious reductions in population or geographic range in the future. Several other species (e.g. Swallow-tailed Kite, Mangrove Cuckoo, Elegant Trogon) are fairly widespread outside the U.S. and Canada, but are threatened in the U.S. portion of their range. Five species are afforded U.S. federal legal status in part of their range or for a particular recognized subspecies. This group also includes four resident game bird species with seriously declining populations.
Species with restricted distributions or low population size: These species are on the Watch List because they are restricted to a small range or have small global populations (often both). Many of these species are not known to be declining or seriously threatened at present, but many others are, (e.g. Spotted Owl, Montezuma Quail, Bendire's Thrasher, Rufous-winged Sparrow, Audubon's Oriole). We recognize that these species with small populations and restricted range are particularly vulnerable to relatively minor changes from current conditions, whether or not their populations are currently in decline.

II. Regional Conservation Interest (non-WatchList; TOT$\geq$19): (a) high regional concern (AI+PT$\geq$8); (b) high regional threats (TB+TN$\geq$7, or TB or TN=5) and includes taxa (subspecies and populations) of regional conservation interest not otherwise included in categories above; (c) high regional responsibility (as measured by percent of global, continental, or regional populations).

III Additional Federally and/or State listed.

IV Local or regional concern or interest, including Stewardship Species as defined in the Continental PIF Plan for North America:

Stewardship Species: Stewardship Species, whether on the Watch List or not, are of continental importance because they represent all the large biogeographic regions in North America. They are broadly distributed across Canada and the U.S. during the breeding seasons, in a pattern that mirrors the richness of all landbird species. Winter Stewardship Species are much more heavily concentrated in the southern U.S., particularly the southwest and into Mexico, and along the U.S. west coast. Stewardship actions that preserve healthy populations of these species will address the PIF goal of 'keeping common birds common.' These species, which are both of high overall concern and also largely dependent on a single biogeographic region, merit special attention for conservation action within their core range.

Component Scores to determine Continental WatchList (minus AI) and Regional Scores (and all smaller geographical units, Bird Conservation Regions, Physiographic Areas, States, Provinces, Territories, etc.) are defined as follows:

PT=Population Trend based on a combination of data sources, principally BBS tempered by local and state datasets for breeding species. For non-breeding species usually best professional judgment often based in part on continental trends shown in BBS and/or CBC.

5=Definite decrease
4=Possible decrease
3=Trend uncertain, No data
2=Possible increase, stable
1=Definite increase

Some guidelines based on BBS data, but for waterbirds trends are often dramatic and not linear so an inspection of trend graphs often is required to make a judgment as to trend score, again tempered by local and state data sets if they exist.

Significant increase (BBS trend ≥1.36%/yr, $P \leq 0.10$, df>13)		1
Possible increase (≥0.47 to 1.36%/ yr, $P \leq 0.35$, w/any df)	2a	
Possible increase (≥1.36%/yr, $0.1 < P \leq 0.35$, df>13)		2a
Possible increase (≥1.36%/yr, $P \leq 0.10$, df<13)	2a	
Stable (> -0.54 to < +0.47%/yr, and UCI<0.47 OR LCI>-0.54)	2b	
- except when trend is negative and P≤0.10 and LCI<-0.54, then Possible decrease	4	
Trend uncertain (≤-0.54%/yr or ≥0.47%/yr and $P>0.35$)	3	
Trend uncertain (>-0.54%/yr and <0.47%/yr and UCI>0.47 AND LCI<-0.54)	3	
No data	3	
Possible decrease (either of next 3 options, but based on 6-13 degrees of freedom)	4	
Possible decrease (≤-0.54 to -2.27%/yr, $P=0.0$-0.35)	4	
Possible decrease (≤-2.27%/yr, $0.1 < P \leq 0.35$)		4
Significant decrease (≤-2.27%/yr and $P \leq 0.10$)	5	

PS=Population Size based on best population estimates globally
5=Rare (<50 thousand breeding individuals globally)
4=Uncommon (50-500 thousand breeding individuals globally)
3=Fairly Common (500 thousand-5 million breeding individuals globally)
2=Common (5 million to 50 million breeding individuals globally)
1=Abundant (50 million + breeding individuals globally)

TB and TN=Threats Breeding and Threats Non-breeding

5=Extreme deterioration in the future suitability of breeding/non-breeding conditions is expected; species is in danger of regional extirpation or major range contraction, or has already been extirpated
4=Severe deterioration in the future suitability of breeding/non-breeding conditions is expected
3=Slight to moderate decline in the future suitability of breeding/non-breeding conditions is expected
2=Expected future conditions for breeding/non-breeding populations are expected to remain stable; no known threats
1=Expected future conditions for breeding/non-breeding populations are enhanced by human activities or land-uses; potentially a 'problem' species

BD and ND=Breeding Distribution and Non-breeding Distribution

5=Very Local Distribution (<500,000 km2, or very restricted coastal areas or interior uplands)
4=Local Distribution (>500,000 and <1,000,000 km2, or <1,600 km of coast)
3=Moderate Distribution (>1,000,000 and <2,000,000 km2, or >1,600 to <5,000 km of coast)
2=Widespread (>2,000,000 and <4,000,000 km2, or >5,000 to <8,000 km of coast)
1=Very Widespread (>4,000,000 km2, or >8,000 km of coast)

SUBTOT=Subtotal of six scores (absent AI) used to calculate Combined Score for Continental WatchList

AI=Area Importance, "relative" relative abundance for the species for each area within range scaled against its maximum relative abundance (i.e., the BCR or physiographic area supporting the highest relative abundance)

5=Very High relative abundance (~50+% of maximum relative abundance)
4=High relative abundance (~25-49% of maximum relative abundance)

3=Moderate relative abundance (~10-24% of maximum relative abundance)
2=Low relative abundance (~1-9% of maximum relative abundance)
1=Peripheral, scattered occurrences.

TOT=Total Score of all seven factors used for identifying Tiers for which species best fits for conservation planning at Planning Region/Bird Conservation Region/Physiographic Area.

Act. Level=Action Level at present based on expert opinion, but ultimately rules based on scores would be preferable.

IM=Immediate management needed to reverse or stabilize significant, long-term population declines in species with small populations, or to protect species with the smallest populations for which trends are poorly known. Lack of action may lead to extirpations or extinction.

MA=Management or other on-the-ground conservation actions needed to reverse or stabilize significant, long-term population declines in species that are still relatively abundant.

PR=Long-term Planning and Responsibility needed for species to ensure that sustainable populations are maintained for species for which a region has high responsibility for that species.

PC=Population Control/Suppression needed for species that are otherwise secure and increasing that may come into conflict with other species of higher conservation concern or other resources of interest.

APPENDIX B

Bird-Habitat Relationships for Puerto Rico and Virgin Islands, West Indies.

Conservation Tier	Limestone and montane forests	Mangrove and coastal woodlands	Shrub-scrub	Grassland/ Open lands	Landbird Transients	Marshes/long-legged waders	Open water	Mudflats	Beach front and salt ponds	Nesting seabirds
I a. Multiple concerns continentally	Plain Pigeon	West Indian Whistling-Duck	Yellow-shouldered Blackbird			West Indian Whistling-Duck	West Indian Whistling-Duck		Snowy Plover	White-tailed Tropicbird
	Puerto Rican Parrot	Yellow-shouldered Blackbird				Black Rail			Piping Plover*	Red-billed Tropicbird
	Puerto Rican Nightjar									
	White-necked Crow									
	Bicknell's Thrush*									
	Golden-winged Warbler*									
	Elfin-woods Warbler									
I b. High continental threats and/or declining	Mangrove Cuckoo**	White-crowned Pigeon**	Prairie Warbler*	American Golden-Plover*		Little Blue Heron*		Lesser Yellowlegs*	Sanderling*	Audubon's Shearwater
	Puerto Rican Vireo	Mangrove Cuckoo**		Upland Sandpiper*		Wilson's Snipe		Solitary Sandpiper*	Gull-billed Tern	Masked Booby
	Worm-eating Warbler*	Prothonotary Warbler*		Short-eared Owl				Whimbrel*		Red-footed Booby

	Kentucky Warbler*							Semipalmated Sandpiper*		Brown Booby
	Greater Antillean Oriole							Western Sandpiper*		Roseate Tern
								Stilt Sandpiper*		Least Tern
								Short-billed Dowticher*		
Conservation Tier	**Limestone and montane forests**	**Mangrove and coastal woodlands**	**Shrub-scrub**	**Grassland/ Open lands**	**Landbird Transients**	**Marshes/long-legged waders**	**Open water**	**Mudflats**	**Beach front and salt ponds**	**Nesting seabirds**
I c. Local and/or rare continentally	Black Swift**	Lesser Antillean Pewee	Lesser Antillean Pewee	Antillean Nighthawk**		Caribbean Coot	Caribbean Coot		Reddish Egret	Magnificent Frigatebird
	Lesser Antillean Pewee		Adelaide's Warbler						Wilson's Plover*	Bridled Tern
	Blue-winged Warbler*								American Oystercatcher*	
	Adelaide's Warbler								Red Knot*	
	Swainson's Warbler*									
II a. High concern regionally	Black-whiskered Vireo**	Green Heron*	Antillean Mango			Green Heron*		Black-bellied Plover*	Ruddy Turnstone*	Brown Pelican
		Yellow-crowned Night Heron*				Yellow-crowned Night Heron*		Least Sandpiper*		

II b. High threats regionally	Sharp-shinned Hawk	Clapper Rail	American Kestrel	American Kestrel (w/nest trees)		Pied-billed Grebe	Pied-billed Grebe	Greater Flamingo	Willet*	
	Broad-winged Hawk	Yellow "Golden" Warbler	Key West Quail-Dove			Least Bittern*	White-cheeked Pintail			
	Limpkin					Black-crowned Night-Heron*	Ruddy Duck			
	Bridled Quail-Dove					White-cheeked Pintail	Masked Duck			
	Puerto Rican Screech- Owl (VI)					Ruddy Duck				
	Louisiana Waterthrush*					Masked Duck				
						Yellow-breasted Crake				
						Purple Gallinule*				
Conservation Tier	**Limestone and montane forests**	**Mangrove and coastal woodlands**	**Shrub-scrub**	**Grassland/ Open lands**	**Landbird Transients**	**Marshes/long-legged waders**	**Open water**	**Mudflats**	**Beach front and salt ponds**	**Nesting seabirds**
II c. High responsibility regionally	Scaly-naped Pigeon	Puerto Rican Flycatcher	Antillean Crested Hummingbird	Zenaida Dove		Tricolored Heron*		Black-necked Stilt*	Black-necked Stilt*	Sooty Tern
	Puerto Rican Lizard-Cuckoo	Northern Parula*	Caribbean Elaenia	Gray Kingbird**				Pectoral Sandpiper*	Black Tern*	Brown Noddy
	Puerto Rican Screech-Owl (PR subsp.)	Cape May Warbler*	Puerto Rican Flycatcher	Caribbean Martin**						
	Green Mango		Gray Kingbird**	Cave Swallow						
	Puerto Rican Emerald		Northern Parula*	Grasshopper Sparrow						
	Puerto Rican Tody		Puerto Rican Bullfinch							

	Puerto Rican Woodpecker									
	Puerto Rican Flycatcher									
	Loggerhead Kingbird									
	Red-legged Thrush									
	Northern Parula*									
	Cape May Warbler*									
	Black-throated Blue Warbler*									
	Puerto Rican Tanager									
	Puerto Rican Spindalis									
	Antillean Euphonia									
	Puerto Rican Bullfinch									
Conservation Tier	**Limestone and montane forests**	**Mangrove and coastal woodlands**	**Shrub-scrub**	**Grassland/ Open lands**	**Landbird Transients**	**Marshes/long-legged waders**	**Open water**	**Mudflats**	**Beach front and salt ponds**	**Nesting seabirds**
III. Additional State Listed						Least Grebe (USVI)	Least Grebe (USVI)			
						Great Blue Heron (USVI)				
						Great Egret* (USVI)				

						Snowy Egret* (USVI)				
IV. Local or regional interest	Chuck-will's-widow*	White-winged Dove	White-winged Dove	Northern Harrier	Merlin*	Glossy Ibis	Northern Pintail	Semipalmated Plover*		Royal Tern
	Yellow-throated Vireo*	Yellow-billed Cuckoo*	Yellow-billed Cuckoo*	Killdeer	Peregrine Falcon*	Sora	Blue-winged Teal*	Greater Yellowlegs*		Sandwich Tern
	Magnolia Warbler*	Yellow-throated Warbler*	White-eyed Vireo*	Mourning Dove	Common Nighthawk*	Common Moorhen*	Lesser Scaup	Spotted Sandpiper*		
	Blackpoll Warbler*	Palm Warbler*	Indigo Bunting*	Indigo Bunting*	Bobolink*		Osprey*	White-rumped Sandpiper*		
	Black-and-white Warbler*	Blackpoll Warbler*			Baltimore Oriole*					
	American Redstart*	Black-and-white Warbler*								
	Ovenbird*	American Redstart*								
	Hooded Warbler*	Northern Waterthrush*								
		Hooded Warbler*								

*Nearctic-Neotropical Migrant species, those species with populations principally breeding in temperate North American areas that winter principally in tropical North American and/or South America areas.

**Intratropical Migrants species, those species breeding in the northern tropical areas of North America that winter principally further south in tropical North America and/or South America areas.

APPENDIX 7

VIRGIN ISLANDS NATIONAL PARK AND CORAL REEF

NATIONAL MONUMENT

DRAFT

Avian Conservation Implementation Plan
Virgin Islands National Park

National Park Service
Southeast Region



Compiled by J. Keith Watson
U.S. Fish and Wildlife Service

In cooperation with
VIIS Resource Management Staff, National Park Service
and Bird Conservation Partners

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Introduction

This Avian Conservation Implementation Plan (ACIP) is provided to the staff at Virgin Islands National Park (VIIS) to serve as guidance to identify, document, and undertake bird conservation activities in the park and with neighboring communities, organizations, and adjacent landowners. This plan may identify goals, strategies, partnerships, and perhaps specific projects for the park to participate in existing bird conservation planning and implementation efforts associated with the North American Bird Conservation Initiative. Under the auspice of NABCI, appropriate bird and habitat conservation goals may be recommended as identified in the appropriate existing national or regional bird conservation efforts aligned with this initiative: Partners In Flight (PIF), North American Waterfowl Management Plan (NAWMP), US Shorebird Conservation Plan (USSCP), and Waterbird Conservation for the Americas (WCA). For example, parks in the Appalachians and the Cumberland Plateau will have few if any high priority waterbird conservation issues at a regional landscape or greater scale. As such, little information regarding waterbird conservation will be presented in the ACIP, unless there is an identified park need for this species group, or other mandates, such as federal laws. Similarly, because most of the parks in the Caribbean are located in and are primarily coastal with some upland landscapes, recommendations will be provided in the ACIP for waterbird, landbird and habitat conservation and will be derived from the appropriate PIF bird conservation plans and regional shorebird and waterbird plans. However, all high priority bird conservation issues for VIIS will be discussed and integrated as appropriate.

Information and data presented in the ACIP have been obtained from several sources: 1) interviews with VIIS staff 2) VIIS bird conservation partners 3) the PIF Puerto Rico and US Virgin Islands Bird Conservation Plan (Nunez-Garcia and Hunter 2000), 4) NPS databases, and 5) personal communications with bird conservation specialists throughout North America, especially in the Caribbean. This plan has been reviewed by VIIS resource management staff and managers, and bird conservation partners and approved by VIIS management. Optimally, this plan will be incorporated into the park's Resource Management Plan (RMP) and updated annually to reflect completed projects, newly identified needs, and shifts in bird conservation priorities in the region.

VIIS is not obligated to undertake any of the proposed actions in this plan. The plan is provided to offer guidance to VIIS to voluntarily support important park, regional, and perhaps national and international bird conservation projects for which VIIS is a primary participant in the proposed actions.

Background

During the past thirty years, monitoring programs across North America have documented declines of certain bird species populations and their habitats, often severe (Sauer et al. 2000). Although these declines were typically for North American continental birds, similar declines have occurred in the Caribbean for many of the same reasons (Raffaele 1989).

The decline has caused great concern among scientists, biologists, biodiversity proponents, ecologists, land managers, etc., and the bird conservation community in general. Birds are recognized as critical components of local and global genetic, species, and population diversity, providing important and often critical ecological, social, and cultural values. Their overall decline has stimulated a worldwide focus on conservation efforts and North American interest in bird conservation is rapidly becoming a focus of government, non-government, industry, and private interests and expenditures.

Many state, federal, and non-governmental wildlife agencies and organizations (NGO's) have recognized this alarming bird decline trend and have joined forces in several extensive partnerships to address the conservation needs of various bird groups and their habitats. The primary initiatives are:

- North American Waterfowl Management Plan
- Partners in Flight
- U.S. Shorebird Conservation Plan
- Waterbird Conservation for the Americas

While efforts associated with these plans have generated some successes, it has been increasingly recognized that the overlapping conservation interests of these initiatives can be better served through more integrated planning and delivery of bird conservation. The *North American Bird Conservation Initiative* (NABCI; http://www.nabci-us.org/main2.html) arose out of this realization. The vision of NABCI is simply to see ***"populations and habitats of North America's birds protected, restored and enhanced through coordinated efforts at international, national, regional, state and local levels, guided by sound science and effective management."*** NABCI seeks to accomplish this vision through (1) broadening bird conservation partnerships, (2) working to increase the financial resources available for bird conservation in the U.S., and (3) enhancing the effectiveness of those resources and partnerships by facilitating integrated bird conservation (U.S. NABCI Committee 2000). Together, the four bird conservation initiatives mentioned above, as well as several other local and regional partnerships, work collectively to pursue this vision.

NABCI is guided by a set of principles that establish an operational framework within which the Initiative and its partners may conduct integrated bird conservation in the U.S. These will articulate a common understanding of the relationship between NABCI, the individual bird conservation initiatives, and all partner entities to ensure recognition of existing federal legislative and international treaty obligations, state authorities, and respect for the identity and autonomy of each initiative. The fundamental components of the conservation approach to be used by NABCI are expressed within its goal:

> ***To deliver the full spectrum of bird conservation through regionally-based, biologically-driven, landscape-oriented partnerships.***

The Southeastern Bird Conservation Initiative: National Park Service: In 1999, the Southeast Region of the National Park Service (NPS) recognized the importance of coordinating existing bird conservation goals into planning and operations of national park units in the southeast, that is, integration of NABCI. In support of this recognition, the Southeast Regional Office NPS approved and allocated eighty-eight thousand dollars, cost sharing 1:1 with the US Fish and Wildlife Service (FWS) Region 4 (Southeast) to hire a biologist to conduct this two-year project (Interagency Agreement FS028 01 0368). This project is unique in the NPS, and perhaps the nation, and represents a potential model for better coordinating regional bird conservation programs and activities within and outside the NPS. It further represents a progressive action toward institutionalizing bird conservation as a programmatic priority in the Southeast Region of NPS, and potentially the nation.

As envisioned, the integration of NABCI into the Southeastern NPS involves:

1) Development and delivery of Avian Conservation Implementation Plans (ACIP),
2) Coordination with NPS Inventory and Monitoring Program,
3) Development of a web based project site,
4) Establishment or enhancement of bird conservation partnerships,
5) Identification and exploration of potential funding opportunities, and
6) Technical guidance and assistance as needed or requested.

This ACIP fulfills one aspect of the plan outlined above, and serves as a basis for future bird conservation actions in VIIS and with adjacent partners or landowners. Concurrently, the development of a Memorandum of Understanding (MOU) between the FWS and the NPS to implement Presidential Executive Order (EO) 13186, **Responsibilities of Federal Agencies to Protect Migratory Birds**, calls for integration of programs and recommendations of existing bird conservation efforts into park planning and operations. Complementing each other, the MOU and the Southeastern Bird Conservation Initiative will advance bird conservation in the Southeast Region of the NPS beyond current regional NPS efforts.

Role of NPS in Avian Conservation

The interagency agreement that facilitates this partnership supports both FWS and NPS management policies. Specifically for the NPS, the agreement supports and advances the **Strategy for Collaboration** (March 2000), a visionary document developed and signed by the Southeast Natural Resource Leaders Advisory Group (SENRLAG), a consortium of 13 land and resource management agencies in the Southeastern United States whose vision is to encourage and support cooperation in planning and managing the region's natural resources. Furthermore, the agreement is aligned with and implements a variety of NPS Management Polices (2001) including but not limited to External Threats and Opportunities (Chapter 1.5), Environmental Leadership (Chapter 1.6), Cooperative

Planning (Chapter 2.3.1.9), Land Protection (Chapter 3), and especially Natural Resource Management (Chapter 4) that details policy and management guidelines which apply to bird conservation. Important policies in this chapter includes:

- Planning for Natural Resource Management (4.1.1)
- Partnerships (4.1.4)
- Restoration of Natural Systems (4.1.5)
- Studies and Collection (4.2)
- General Principles for Managing Biological Resources (4.4.1)
- Plant and Animal Population Management Principles (4.4.1.1)
- Management of Native Plants and Animals (4.4.2)
- Management of Endangered Plants and Animals (4.4.2.3)
- Management of Natural Landscapes (4.4.2.4)
- Management of Exotic Species (4.4.4)
- Pest Management (4.4.5)
- Fire Management (4.5) and
- Water Resource Management (4.6)

The NPS is the fourth largest landowner in the United States, consisting of over 380 national park units covering 33.6 million ha (83 million acres) of land and water with associated biotic resources (www.nps.gov). The 64 units in the Southeast Region of the NPS represent 16% of the total number of park units in the national park system and cover approximately 5% of the total land base in the entire system. Park units in the Southeast Region include national seashores (Canaveral National Seashore, Cape Hatteras National Seashore), national parks (Great Smoky Mountains National Park, Virgin Islands National Park), national recreation areas (Big South Fork National River and Recreation Area), national preserves (Big Cypress National Preserve), national battlefields (Cowpens National Battlefield, Fort Donelson National Battlefield), national monuments (Congaree Swamp National Monument, Ocmulgee National Monument), and others such as the Blue Ridge Parkway, Obed Wild and Scenic River, and Timicuan Ecological and Historic Preserve.

Southeast NPS units provide habitat for over 400 species of migrating, breeding, and wintering birds and include a wide range of Federal and State listed threatened and endangered species. Likewise, these units also provide nest, migration, and winter habitat for most of the eastern species identified in the national bird conservation plans in need of conservation attention.

Additionally, the NPS attracts over 280 million visitors to the parks each year, 120 million of these in the Southeast Region, affording excellent recreational bird watching and opportunities to strengthen bird conservation interpretation, outreach, and education programs. These opportunities, the NPS mission, policies, and organization all lead to the conclusion that the NPS is an extremely valuable partner and contributor to bird conservation in the region.

Nationally, the status of birds in national parks is largely unknown, although many parks have adequate knowledge regarding bird occurrence in the parks (http://www.npwrc.usgs.gov/resource/othrdata/chekbird/chekbird.htm). Parks often play a role in ongoing regional bird conservation efforts. Indeed many of these parks are often important to regional, national, or international bird conservation, and many have been designated as Important Bird Areas (IBA's) by the National Audubon Society. To date, there are approximately 64 NPS units that are designated IBA's, 35 of which are considered of global importance (http://abcbirds.org/iba/aboutiba.htm). In the Southeast Region, the NPS has 13 globally recognized IBA's.

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The **NPS Inventory and Monitoring (I&M) Program** has been developed to provide management driven scientific information to national park managers so that resources can be adequately protected within national parks. One of the first phases of this program is to inventory vertebrates, including birds, within the 260 national park units in the program. Once completed, data from the inventories will provide an account of the occurrence and abundance of birds in all the national parks in the program. These records will be stored in the NPS I&M NPSpecies database http://www.nature.nps.gov/im/apps/npspp/). Coordination with I&M network staff is important to developing long-term bird monitoring programs that fulfill both park and NABCI objectives.

Park Flight is a NPS international partnership initiative that directs funding toward a variety of NPS programs that involve conservation of neotropical migratory birds whose life history range covers a US national park and a Latin American protected area. A relatively new program, Park Flight offers parks the opportunity to partner with a Latin American national park or protected area to cooperate on developing bird conservation and education projects (NPS 2002).

Recent increases in NPS base funded programs such as inventory and monitoring, exotic species management, habitat restoration, and fire management all indicate that national park managers recognize that park lands are increasingly subject to a variety of threats and conditions that must be improved to provide the quality of national park experience articulated in the NPS Organic Act (1916). Programmatic funding in these areas will increase the ability of national parks to provide quality habitat and conditions for increased wildlife conservation, including birds. Furthermore, private interests and non-profit conservation organizations have initiated programs, including grant programs, to provide much needed funding to national parks to meet backlogs of identified yet unfunded needs.

Park Description

Virgin Islands National Park was established in 1956 with an original boundary of 3,840 ha (9,489 acres). Subsequent expansions in 1962 and 1978 added 2,287 ha (5,651 acres) and 55 ha (136 acres) respectively totaling 6,182 ha (15,276 acres). The primary

legislative mandate of Virgin Islands National Park is to protect outstanding scenic values and features of national significance. In 1976, the United Nations Educational, Scientific and Cultural Organization (UNESCO) through its Man and the Biosphere (MAB) program designated the park as a Biosphere Reserve.

VIIS contains examples of most subtropical Atlantic terrestrial, coastal and marine ecosystems. These include various types of subtropical dry to moist forest, salt ponds, beaches, mangroves, seagrass beds, coral reefs and algal plains. Concerted long-term monitoring of biological resources has been ongoing since the 1960s. In 1993 NPS located the South Florida/Virgin Islands Prototype Long Term Ecological Monitoring Program at Virgin Islands National Park and funding for this program was begun in 1997.

Avian Resources of Puerto Rico and the US Virgin Islands

Puerto Rico and the Virgin Islands are part of the West Indies, a chain of islands that extends from Florida to Venezuela and separate the Caribbean Sea from the Atlantic Ocean. These tropical Islands are located within 17-19° latitude North and 64-68° longitude West about 1,609 kilometers from Florida and 805 kilometers from Venezuela.

The U.S. Virgin Islands are located about 64 kilometers east of the Puerto Rico. These Islands comprise another archipelago that includes St. Thomas, St. John, St. Croix, and numerous uninhabited small islets and cays. The three main Islands were bought by the U.S.A. from Denmark in 1917 and are now U.S. Territory with a total area of 340 km^{2}.

The number, size and shape of the islands comprised within this region combined with climate, topography, geological processes, and human activities have produced a tremendous diversity of habitats. Historically different types of forest covered most of the land area of Puerto Rico and the Virgin Islands. However, forest conversion caused by agricultural and other land use practices have shaped the present landscape. Forested landscape in the U.S. Virgin Islands is typified by sub-tropical dry forest and littoral shrubs.

Including vagrants, exotics and fossils, the total number of bird species in the region sums to 364. Presently, 276 species are known to occur in Puerto Rico and 210 in the Virgin Islands for a total of 284 species in the region (Raffaele 1989). Recent studies indicate that these numbers may change as many native forms may be reclassified as species or subspecies on their own. Raffaele (1989) categorized the regional birds species as follows: 97 breeding permanent residents (94 in Puerto Rico and 60 in the Virgin Islands), 11 breed and leave (11 in Puerto Rico and 10 in the Virgin Islands), 134 non-breeding migrants and visitors (134 Puerto Rico and 129 the Virgin Islands), 31 introduced probable breeders (31 in Puerto Rico and 6 in the Virgin Islands), five introduced possible breeders (same species for both Puerto Rico and the Virgin Islands), and one species recently extirpated from Puerto Rico. As the numbers indicate, migrant species comprise almost half of the species playing a major role in the ecology of the region. Also noteworthy is the establishment of a high number of exotic species. As a result of combining both native and

exotic species, Puerto Rico supports 85 species of breeding land birds, the greatest number of any West Indian island and except for Cuba, harbors the second largest total number of species in the region (Raffaele 1989).

The oceanic nature of the islands in the region has resulted in increased endemism. Puerto Rico harbors 16 endemic bird species including one endemic genus (*Nesospingus*) represented by a single species, the Puerto Rican Tanager (*Nesospingus speculiferus*) and one family (Todidae) shared with the rest of the West Indian islands but found nowhere else. Rafaele (1989) considered 51 species to be threatened in the region mostly because of the detrimental effects of habitat alteration.

Avian Conservation in VIIS

Avian Biodiversity: VIIS has an avian inventory and a checklist of birds that is available for the public. Staff has identified the need to update the checklist.

Verified records of birds in VIIS have been entered into the NPS I&M program's database, NPSpecies, and may be viewed via the internet at http://www.nature.nps.gov/im/app/npspp with a user identification and password combination authorized by the NPS for NPS personnel and NPS cooperators. For a complete listing of birds documented in the park, see Sasso and Patterson (2002).

Threatened and Endangered Species: Several Federally listed threatened or endangered species nest in the park, most notably Brown Pelican and occasionally the Roseate Tern. The recently delisted American Peregrine Falcon occurs as a rare but regular winter resident in the park and vicinity.

Several USVI Territory **Listed** species occur in VIIS including Brown Pelican, Roseate Tern, White-tailed Tropicbird, Audubon's Shearwater (?), Bridled Quail-Dove, White-crowned Pigeon, White-cheeked Pintail, Least Grebe, Great Blue Heron, Great Egret, Snowy Egret, Black-crowned Night Heron, Puerto Rican Flycatcher, and Least Tern.

Several high priority PIF species for the Caribbean occur in VIIS (see Appendix A and B). Prominent among these species are Roseate Tern, White-crowned Pigeon, Yellow Warbler, White-cheeked Pintail, Bridled Quail-Dove, Audubon's Shearwater (?), Brown Pelican, Scaly-naped Pigeon, Antillean Crested Hummingbird, Puerto Rican Flycatcher, Lesser Antillean Bullfinch, White-tailed Tropicbird, and several Neotropical migrants including Worm-eating Warbler, Black-throated Blue Warbler, Prairie Warbler, and Cape May Warbler. Several high priority species may not occur on St. John or in the park and may include Puerto Rican Screech Owl, Antillean Mango, West Indian Whistling Duck, Caribbean Coot, and Ruddy Duck.

Additionally, many wintering Neotropical migrants, mostly wood warblers, utilize the large continuous forests of the park and St. John. Though many of these species are not listed,

they are of high conservation concern in the continental U.S. and conservation efforts for this species extend to the USVI. Conservation of these species should be coordinated with the Virgin Islands Department of Planning and Natural Resources (VIDPNR) (see contacts).

Park Priorities: Park staff and consultants have not identified any particular species that is a park management concern or high priority for conservation. Rather, park staff is concerned about conserving all birds and their habitats in VIIS. However, several species that occur in VIIS are high priority in the Caribbean and conservation efforts in the park could focus on these species or groups of species.

Inventory: A complete inventory has been recognized as important information for park managers and is being conducted within the framework of the NPS I&M Program. VIIS is one of seven parks in the NPS South Florida/Caribbean I&M Network for which a plan to conduct high priority inventory projects has been prepared (Sasso and Patterson 2000). Although VIIS avian inventory is considered complete in relation to the NPS's I&M goals (90% or greater species known), additional inventory is desired to determine breeding bird distribution and abundance in the upland portions of the park.

Monitoring: Currently, several avian monitoring projects are being conducted at VIIS. These are:

- Brown Pelican surveys are conducted weekly to count nesting pairs and numbers of chicks in nests
- Colonial waterbird surveys are conducted in cooperation with the VIDPNR) and US Fish and Wildlife Service
- Least Tern nesting at Salt Pond is monitored during nesting season
- Park staff participate in a Christmas Bird Count (CBC) which is centered on St. John
- Laurel Trager, Division of Interpretation, records observations in a personal journal

Research: Scientific research is permitted within the park. Currently, USFWS staff from Puerto Rico are conducting a constant effort mist netting program in the park to better determine how the role that the park has in stopover and wintering ecology of Neotropical migrants.

Outreach: The park has a very active interpretive and outreach program related to birds and bird conservation. Highlights include:

- Weekly bird walks at Mary Point Pond conducted by Interpretive specialist, Ms. Laurel Trager, every Sunday year around
- Occasional presentations for students at Virgin Islands Ecological Research Station (VIERS) and park visitors at Cinnamon Bay Campground
- Occasional bird walks at various locations for students at Pine Peace School

- Educational programs presented to students at Pine Peace School
- Community Foundation donated binoculars to students
- Audubon Society bought bird books and David Attenborough videos for students
- Audubon Society published bird guide to Reef Bay, a prominent park watershed
- Articles written for local newspaper

Park Identified Needs for Avian Conservation

VIIS has identified several projects that would increase the avian knowledge of the park. These are:

Monitoring

- Establish a winter Neotropical migrant monitoring program, either repeating work conducted by Askins and Ewert or establishing a new program with comparable results

Data Management:

- Analyze Rob Norton's CBC warbler count data during the 1970's to mid 1980's
- Analyze CBC shorebird data

Coordination with Regional Conservation Initiatives

North American Bird Conservation Initiative

NABCI bird conservation planning units, referred to as Bird Conservation Regions (BCR), are often larger than other planning units associated with other plans, such as Partners In Flight. For example, VIIS is within the NABCI BCR 69 that includes all of the Commonwealth of Puerto Rico, the US Virgin Islands and the British Virgin Islands and includes the physiographic region designated by Partners in Flight as Puerto Rico/Virgin Islands (Figure 2; compare to Figure 1).

Several NABCI BCR's have coordinators whose primary responsibility is to coordinate all bird conservation planning in the BCR, across all agencies and organizations. Currently, the Caribbean BCR does not have a designated coordinator; however, the assistant coordinator for the Atlantic Coast Joint Venture (ACJV) can provide valuable assistance to VIIS with implementation of aspects of this ACIP.

North American Waterfowl Management Plan (NAWMP)

The NAWMP (http://northamerican.fws.gov/NAWMP/nawmphp.htm) is completed and has been revised several times, incorporating updated goals and strategies based on new information. This plan is one of the most successful bird conservation delivery programs in the United States, being monetarily supported by the North American Wetlands Conservation Act (NAWCA). This plan can be consulted for priority waterfowl conservation

needs in the Virgin Islands. The ACJV assistant coordinator has coordination responsibility for the USVI.

Partners In Flight

Goals and strategies for the Caribbean can be found in the draft bird conservation plan, previously submitted to the park (Nunez-Garcia and Hunter 2000). The park will receive updates of the plan as they are completed. The current plan identifies priority bird and habitat conservation goals that must be implemented in order to achieve bird conservation success in this region. Because the Partners In Flight bird conservation plan for this region is better developed than other plans, and includes all species, VIIS will utilize this plan more than any other plan to participate in NABCI implementation.

Similar to NABCI BCR's, PIF physiographic areas often do not have designated coordinators. However, state level non-game agencies with investment in PIF will establish key personnel to develop partnerships among cooperators in the physiographic area. The VI territorial government, Department of Natural Resources has prime responsibility for implementation of the Puerto Rico/US Virgin Islands Partners in Flight bird conservation plan and can be instrumental in implementing recommendations identified in this ACIP and projects important to bird conservation relative to the VI's role in Caribbean bird conservation.

United States Shorebird Conservation Plan (USSCP)

The USSCP has been completed and is available on the world wide web (http://shorebirdplan.fws.gov/). A regional step down plan is in preparation by FWS personnel and should be available in 2003.

Waterbird Conservation for the Americas (WCA)

The WCA plan has been completed and is available on the World Wide Web or can be ordered from the US Fish and Wildlife Service National Conservation Training Center (http://www.waterbirdconservation.org/).

Integration of NABCI Goals and Objectives into Park Planning and Operations

NABCI Implementation Recommendations

To successfully achieve park-established goals and actively participate in NABCI, the park could implement a variety of projects in different NPS programs. Most of these projects would require some level of participation by many existing park programs and could either be achieved through NPS funding, or more likely, through establishing or improving

partnerships with agencies and organizations that already have the necessary expertise to provide guidance, funding, and execution of these programs. Programmatic areas where bird conservation actions are likely to be focused are:

- Inventory
- Monitoring
- Habitat Restoration
- Threat Management (includes exotic species, air quality, water quality, etc.)
- Research
- Compliance
- Outreach
- Partnerships

To the extent appropriate, each of these program areas will be discussed separately and within each, specific opportunities identified that, when implemented, will enable to park to meet its mandates (current and expected) as well as integrate NABCI into its planning and operations. With emphasis added, the park is not expected to implement any of these recommendations or be obligated to pursue any opportunity other than those the park is required to do by law or NPS program or policy. In other words, participation in this effort is currently voluntary. However, participation in these efforts at some level could become mandatory with the completion of an MOU with the FWS regarding EO 13186, **Responsibilities of Federal Agencies to Protect Migratory Birds**. The MOU will establish a formal agreement between the FWS and the NPS to promote bird conservation within the agency by incorporating goals and strategies of existing bird conservation initiatives, plans, and goals into park planning and operations.

Should the park decide to implement any of these projects, further consultation with bird conservation contacts is encouraged to obtain updated information on the relevance of these opportunities in regional bird conservation.

High priority projects are identified in **bold** print. Priorities that the park is encouraged to seek NPS funding for are marked with and asterisk (*****). These projects are those that are critical to the stabilization or improvement of a bird population in the planning region.

Inventory

The park has inventoried its bird fauna exceptionally well. Although the avifauna of VIIS is well documented, distribution and abundance data are desired to fully understand the status of birds in the park so that conservation actions for birds can be implemented, especially for Neotropical migrant birds wintering in the park. Status of high priority species as identified in the Puerto Rico/US Virgin Islands bird conservation plan and the USVI territorial watchlist is needed to effectively structure park management for the continued preservation and enhancement of the park's avifauna.

Abundance and distribution data are needed

- **for wintering birds in the subtropical dry and moist forests, particularly Neotropical migrants***
- **for birds that nest in mangroves***
- **for resident breeding birds in the subtropical dry and moist forests, especially for High Priority forest species such as Bridled Quail-Dove and White-crowned Pigeons***
- **for White-tailed and Red-billed Tropicbirds and Audubon's Shearwater**
- **to determine presence of rare or potentially extirpated species such as Puerto Rican (Virgin Islands) Screech Owl and Antillean Nighthawk**
- **for nesting, migrating, and wintering shorebirds in salt pond habitats of the park, particularly American Oystercatcher and Wilson's Plover.**

Additionally, the park is encouraged to:

- **partner with the VIDPNR and USFWS to coordinate area inventory efforts**
- **verify other avian observational data collected in the park and enter into the appropriate database (NPSpecies, eBird Monitoring Program of Cornell's Laboratory of Ornithology, Columbid Database, etc.)**
- **standardize inventory and monitoring methodology to conform to NPS and/or FWS recommended standards (Fancy and Sauer 2000, Hunter 2000).**

Monitoring

The park has an active bird monitoring program resulting in documentation of many high priority species identified for conservation effort in the Caribbean and occur in the park. Efforts should be made to continue existing monitoring programs, striving to conform to established NPS or FWS surveys protocols. Close coordination with adjacent bird conservation initiatives are needed to identify and implement high priority projects on park lands and to ensure that park efforts contribute to park or regional bird conservation rather than undertake an action or actions that are not needed or are better conducted in other areas. Specific recommendations are to:

- **continue to conduct existing monitoring programs and enter data into the appropriate database (NPSpecies, eBird, or National Point Count Database (USGS 2001) (http://www.mp2-pwrc.usgs.gov/point/)**

- **establish shorebird monitoring program at various salt ponds, especially Salt Pond and Mary Point Pond using International Shorebird Survey (ISS) protocol and submit data to Manomet Center for Conservation Sciences***

- **monitor resident and migrant birds at established forest point counts along ecologically distinct or vegetative/habitat types ***

- **establish monitoring programs based on results of inventory data for High Priority species and with potential for high conservation role for any of these species**

- **standardize inventory and monitoring methodology to conform to NPS and/or FWS recommended standards (Fancy and Sauer 2000, Hunter 2000).**

- **partner with USVI territorial Department of Natural Resources and USFWS staff to coordinate area monitoring efforts**

Habitat Restoration/Management

Recently, habitat restoration efforts have increased on NPS lands; NPS receiving restoration emphasis and guidance in the 2001 Management Policies (NPS 2001). Habitat restoration efforts that parks may undertake are wetland restoration, grassland restoration, woodland restoration, etc. utilizing a wide range of tools to accomplish the restoration. Some of these tools may be but not limited to forest management practices, exotic species management, public use and recreation management, and infrastructure development management.

Due to the protected nature of VIIS lands, and generally those in the national park system, the condition of habitats for bird use may be of higher quality than other natural, developed, agricultural, or forest lands under other management regimes. However, national park lands can be greatly improved for wildlife, and particularly bird use, by restoring processes important for habitat formation, succession, and structural development. Largely, these processes have not been managed historically in the national park system but current policy allows for active management of species, populations, and lands to provide for long-term conservation of park resources.
Protection, restoration, and enhancement of habitats in VIIS can greatly contribute to

established habitat goals identified in the Puerto Rico/US Virgin Islands bird conservation plan.

Research suggests that the large contiguous moist forests of St. John provide significant habitat for wintering Neotropical migrants (Askins et al. 1989). Management efforts should strive to maximize the amount of remaining forests in the park by avoiding or minimizing park developments, acquiring inholdings, and acquiring conservation easements with landowners on adjacent land and inholdings.

Specific recommendations are to:

- **continue mangrove restoration in Lameshur and protect remaining mangroves throughout the park**

- **identify inholdings of high value and work with landowner to acquire conservation easement or fee title to land***

- **avoid or minimize park developments**

- **work with VI Coastal Zone Management and community developers to design appropriate landscapes suitable for island avifauna and minimize impacts to native habitats and species**

- **develop a Wild Burro Management Plan that identifies the need to reduce or eliminate their impact on forest vegetation and soils***

- restore and/or improve hydrological quality and processes where needed, especially in coastal mangrove and salt ponds

- assess Pre-Columbian landscape cover and determine feasibility of restoring landscape within the context of the park's enabling legislation

Threat Management

Impact of exotic species on birds at VIIS is perhaps the greatest threat to the avifauna of VIIS. Though this impact is largely unquantified, the elimination of many ground nesting animals, including birds, by the introduced mongoose is well documented throughout the Caribbean. Other significant introduced mammals such as feral hogs, domestic and feral dogs and cats, feral and domestic goats, and wild burros occur in the park and may damage birds directly through predation or habitat alteration. The park is encouraged to:

- **continue to aggressively reduce populations of these species throughout the island and cooperate with VIDPNR to manage the wild burro population**

- **manage visitor use and predation (fencing?) at Salt Pond to reduce or eliminate these disturbances to the Least Tern nesting colony***

- **identify, monitor, and document bird mortality associated with the communication tower on Bordeaux Mountain, especially during migrations of Neotropical migrants***

- **work with adjacent landowners and neighbors, the local community, and pubic officials to curb unregulated and free roaming feral and domestic dogs, cats, pigs, and goats in the park***

- **identify potential bird injury or mortality associated with fishing gear and fishing practices in the park and nearby waters, especially for Brown Pelican and Brown Booby***

Although exotic plants species are negatively impacting habitat at VIIS, the nature of this impact on native birds is unknown. Genip and Spanish Lime are common in the moist gallery forest of the park, and the basin moist forest has essentially been extirpated by colonization by Genip and Sweet Lime. It is important to

- **establish and continue inventory and monitoring of exotic plant species***

- **identify any potential impact these species have on native avifauna***

- **establish appropriate management programs to restore native forests***

If necessary, consult with regional Exotic Plant Management Team (EPMT) to remove exotic plant species. Currently, no EPMT provides service the VIIS area. Until an EPMT is established that can provide assistance to VIIS, staff is directed to consult with the regional pest management specialist (see contacts).

Additionally, the park is encouraged to:

- **hire additional protection staff to better manage threats and implement projects identified in this plan***

- **develop close working relationship with VIDPNR Coastal Zone Management to promote protection of islands natural resources**

- **develop aggressive outreach and education program for ongoing rat, cat, and**

mongoose eradication/reduction efforts*

Research

- **determine feasibility to reintroduce extirpated species that occur elsewhere in the Caribbean (Puerto Rican Screech Owl)**

- **cooperate with research scientists who desire to conduct research on avian ecology**

- **list park needs and projects on Research Permit and Reporting System web site (RPRS)**

- develop contact with South Florida/Caribbean Cooperative Ecosystem Studies Unit (CESU) at the University of Miami, Miami, FL

Compliance

Park compliance with the Migratory Bird Treaty Act and the Executive Order 13186, **Responsibilities of Federal Agencies to Protect Migratory Birds,** is necessary to assure that park activities incorporate bird conservation into park planning and operations. Further, to ensure that migratory birds are considered in all phases of park planning processes, especially during the National Environmental Policy Act (NEPA) and the Director's Order #12 Compliance processes, the park should consider adding specific language in project evaluations that requires consideration and implications of park projects on migratory birds. The MOU being developed between the NPS and the FWS will likely contain specific language requiring a park to consider implications of park projects on migratory birds. Additional considerations are to encourage:

- **park staff to begin specific consideration of migratory birds during park planning processes***

- park staff to attend USFWS training on implementation of EO 13186 at the National Conservation Training Center (NCTC) (when available) or other training on migratory bird conservation in North America. NCTC has several courses and training related to conservation of migratory birds (http://training.fws.gov/courses.html).

The USFWS NCTC offers and reserves two tuition free slots for National Park Service employees wishing to attend NCTC courses on a first come, first served basis. Additionally, discount lodging is also available while attending a NCTC course.

Outreach

- **participate in International Migratory Bird Day (IMBD) events with a local partner (http://birds.fws.gov/imbd.html)***

- **update the bird checklist for public availability***

- **nominate VIIS as an Important Bird Area (http://www.abcbirds.org/iba/nominstr.htm)***

- **continue to develop and implement outreach and educational programs to enhance visibility of bird conservation issues***

- **develop aggressive outreach and education program for ongoing rat, cat, and mongoose eradication/reduction efforts**

- **continue to provide bird conservation information and issues in the Virgin Island Audubon Society newsletter, *The Bananaquit***

- **encourage Virgin Islands Audubon Society to participate in ongoing and new inventory and monitoring programs**

- **encourage accurate documentation and reporting from these and random outings by visitors (see Cornell University's eBird monitoring program (Cornell Lab. Ornith. 2002 (http://www.ebird.org/about/index.jsp)**

- **work with adjacent landowners and neighbors, the local community, and pubic officials to curb unregulated and free roaming feral and domestic dogs and cats in the park**

- **develop Parks as Classrooms project related to habitat and bird conservation***

- **acquire bird coloring books and other outreach materials from USFWS and distribute at visitor center, school programs, and contact points**

- **develop and produce a recording of bird calls common to the island**

- **develop bird identification posters for schools in the area**

- park interpretation/education staff are encouraged to attend USFWS training on

Migratory Bird Education at NCTC

- consider adding links to bird conservation information, data, etc. to the park's web site home page

- support bird conservation by serving shade-grown coffees at meetings, events, and the office buildings in the park (http://www.americanbirding.org/programs/conssbcof3.htm)

- participate in bird conservation efforts of the Society for the Conservation and Study of Caribbean Birds (SCSCB), including subscribing to this organization's electronic information forum

- explore cultural affiliation of landscape to inhabitants, both historical and contemporary. Cultures are strongly tied to the landscape they inhabit and birds often play a role in a cultural tie to the landscape. When these connections are discovered and preserved, a greater appreciation for the landscape and it's value to the culture can be achieved

- summarize and publish known information on prehistoric avifauna (extinct shearwater and flightless rail) of St. John

- summarize and publish Taino use of birds on St. John

Partners and Partnerships

Partnerships for land conservation and protection will perhaps have the greatest positive influence on bird conservation above all other landscape scale planning. Specific recommendations are to:

- **keep abreast of USVI territorial initiatives that could impact park resources, particularly with Coastal Zone Management**

- **cooperate and VIDPNR in the preparation and implementation of the USVI Comprehensive Wildlife Conservation Plan**

- **work with the White-crowned Pigeon Working Group of the SCSCB to determine appropriate conservation actions for this species in the park**

- **become a contributing member of the Caribbean Columbid Population Data Center, a cooperative effort of the Puerto Rico Department of Natural Resources, USFWS, and other Caribbean interests to assess populations**

status and implement conservation actions necessary for these species

- **contact the nearest Joint Venture office (see Funding section for explanation of Joint Ventures) or BCR coordinator to develop partnerships and funding proposals tiered to priorities established by the park, this ACIP, and the Puerto Rico and US Virgin Islands Bird conservation plan**

- **encourage the USVI territorial government to become a member of the Atlantic Coast Joint Venture, increasing USVI partners chances to utilize NAWCA funds for bird and habitat conservation projects**

- continue to maintain productive relationship with local Audubon Society

- explore the potential to strengthen the Man and the Biosphere program

- explore the potential to utilize facilities and expertise at the Virgin Island Environmental Research Station (VIERS) to conduct needed avian research and implementation of aspects of this plan

Funding Opportunities

Internal NPS funding is often an effective source to obtain funding; however, the project will have to be a fairly high priority among the park's natural resource program to successfully compete for the limited funding available in the NPS. Therefore, partnerships and outside funding programs are often more productive for securing bird conservation funding. Within this ACIP, identified priority projects that are considered to be high park priorities as well as NABCI priorities are marked with and asterisk (*). VIIS is encouraged to enter all high priority projects into the NPS Performance Management Information System (PMIS) database.

Funding for conservation projects for neotropical migrants is also available through the Park Flight program.

With the exception of the North American Waterfowl Management Plan (NAWMP and its associated funding legislation, the North American Wetland Conservation Act), funding opportunities for bird conservation programs, plans, and initiatives have been lacking. Only within the last decade have other appropriate and specific sources for bird conservation funding been created and used. The NAWMP has been supported for approximately 14 years by the North American Wetlands Conservation Act (NAWCA 1989). This program has provided $487 million in appropriated funds matched with $1.7 billion for wetland and bird conservation projects since its inception. In 2002 alone, over $70 million US dollars were awarded to US and Canadian agencies and organizations to enhance waterfowl populations by improving, restoring, or protecting wetland habitats. To adequately evaluate projects and distribute these funds, partnerships called Joint Ventures

were established. Nationally, 14 (11 US, 3 Canada)
Joint Ventures have been established, several which are funded and staffed. Internet links to Joint Ventures are:

(http://southwest.fws.gov/gulfcoastjv/ojvcontact.html) and
(http://northamerican.fws.gov/NAWMP/jv.htm).

Funding through NAWCA is highly underutilized by the NPS and any park unit that has wetland, water, or bird conservation needs associated with wetland are encouraged to investigate using this funding source. Naturally, there are certain requirements to be eligible for all grants and park managers are encouraged to consult with the nearest Joint Venture, BCR, PIF Coordinator, to learn how this program might be applicable to implementation of this plan, and other park wetland issues. VIIS is not within a region which has an operational Joint Venture, but contact with the Atlantic Coast Joint Venture will provide opportunity to investigate use of this funding source and developing proposals.

Internal FWS funding programs may be used to support projects, but no effective method of project proposal delivery to these sources is currently in place for the NPS. Current funding in these programs may result from FWS familiarity with NPS needs, or

NPS participation in one of the area FWS Ecosystem Teams, where a project has been identified and proposed to be funded through the Ecosystem Team.

One unexplored yet potentially fruitful funding source for national parks is the myriad of grants through the FWS State Programs, where grants are awarded to private individuals engaged in habitat conservation projects. No funding is directly available to national parks, but identified projects with important or critical adjacent landowners can sometimes be funded through these sources. Similar programs are available if the adjacent landowner is a federally recognized American Indian tribe.

Specific congressional appropriations to protect migratory birds has recently been authorized under the Neotropical Migratory Bird Conservation Act (2000) (http://www.nfwf.org/programs/nmbcapp.htm). Appropriations through this Act are authorized up to $5 million per year. However, in 2000, appropriation was approximately $3.75 million and a majority of this funding was directed toward projects in Central and South America.

Many of the identified projects are eligible for funding under various grant programs of the National Fish and Wildlife Foundation (http://www.nfwf.org/programs/programs.htm).

Other prominent funding sources available to NPS managers for bird conservation are listed on this projects web site at:

http://southeast.fws.gov/birds/NPSHighlits.htm.

Funding opportunities for migratory bird conservation are available yet most natural resource agencies are not fully aware of and/or understanding of how to use these sources. Perhaps a consolidated migratory bird funding source catalog will become available to managers in the future; this is needed.

Contacts

Primary contacts within the region can be obtained by viewing the web site for the Southeastern Bird Conservation Initiative, National Park Service at http://southeast.fws.gov/birds/npsbirds.htm. This web site will provide contact information of the appropriate bird conservation coordinator in the region for park personnel. Park staff are encouraged to view the web site and obtain contact information. Primary contacts for VIIS are:

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APPENDIX A

PUERTO RICO AND VIRGIN ISLANDS (BCR 69) BASED ON CONTINENTAL AND REGIONAL WATCH LIST AMONG ALL BIRDS WITHIN SOUTHEAST U.S., AND THE WEST INDIES*

(Action Levels: IM=Immediate Management; MA=Management Attention; PR=Long-Term Planning and Responsibility) (subspecies/populations of interest noted; all species breed or are resident unless otherwise indicated; ba=number of breeding adults)

Tier I. Continental Conservation Interest

a. Multiple Causes for concern across entire range

White-tailed Tropicbird	(500-600 pairs, 14-19% in West Indies)	IM
Red-billed Tropicbird	(375-450 pairs, 14-22% in West Indies)	IM
West Indian Whistling-Duck	(<100 ba, 1-5% globally)	IM
Black Rail	(Extirpated?)	IM
Snowy Plover	(Threatened Pacific Coast; West Indies subspecies)	IM
Piping Plover	(Endangered, winter)	IM
Plain Pigeon	(Endangered; <5,000 ba, <10% globally)	IM
Puerto Rican Parrot	(Endangered; <100 ba in the wild, 100% globally)	IM
Puerto Rican Nightjar	(Endangered; <2,000 ba, 100% globally)	IM
White-necked Crow	(Endangered/Extirpated from Puerto Rico)	IM
Bicknell's Thrush	(Possible rare winter in Puerto Rico)	PR
Golden-winged Warbler	(Rare winter)	PR
Elfin-Woods Warbler	(Candidate for Listing; <1,000 ba, 100% globally	IM
Yellow-shouldered Blackbird	(Endangered; <500 ba, 100% globally)	IM

b. Moderately abundant or widespread with declines and/or high threats

Audubon's Shearwater	(~150 pairs, 2-4% in West Indies)	IM
Masked Booby	(300 pairs, 50% in West Indies)	IM
Red-footed Booby	(1,450-2,650 pairs, 15-33% in West Indies)	IM
Brown Booby	(2,075-2,300 pairs, 22-36% in West Indies)	MA
Little Blue Heron		MA
American Golden-Plover	(Rare southbound transient)	PR
Lesser Yellowlegs	(non-breeding)	MA
Solitary Sandpiper	(transient)	MA
Upland Sandpiper	(Rare transient)	PR
Whimbrel	(non-breeding)	MA
Sanderling	(non-breeding)	MA
Semipalmated Sandpiper	(non-breeding)	MA
Western Sandpiper	(non-breeding)	MA
Stilt Sandpiper	(non-breeding)	MA
Wilson's Snipe	(winter)	MA
Gull-billed Tern	(non-breeding?)	PR
Roseate Tern	(North Atl. Endangered, West Indies Threatened; 1,200-3,600 pairs, >25% in West Indies)	IM
Least Tern	(Calif. & interior subspecies Endangered; 300-450 pairs, 8-25% in West Indies)	IM
White-crowned Pigeon		MA
Mangrove Cuckoo		MA

Short-eared Owl	(Greater Antillean subspecies)	MA
Puerto Rican Vireo	(100 % globally)	MA
Prairie Warbler	(winter)	MA
Prothonotary Warbler	(winter)	MA
Worm-eating Warbler	(winter)	MA
Kentucky Warbler	(Rare winter)	PR
Greater Antillean Oriole	(10-20% globally)	MA

c. Restricted distributions and/or low population size

Magnificent Frigatebird	(700-900 pairs, 13-21% in West Indies)	IM
Reddish Egret	(Rare, non-breeding)	PR
Caribbean Coot	(1,000 ba, <50,000 West Indies)	IM
Wilson's Plover		MA
American Oystercatcher	(Eastern North American subspecies)	IM
Red Knot	(non-breeding; presumably Alaskan subspecies)	PR
Bridled Tern	(900-1,700 pairs, 15-40% in West Indies)	MA
Antillean Nighthawk		PR
Black Swift	(West Indian subspecies)	MA
Lesser Antillean Pewee	(Puerto Rican subspecies)	PR
Blue-winged Warbler	(Rare, winter)	PR
Adelaide's Warbler	(100% globally)	PR
Swainsons's Warbler	(Rare, winter)	PR

Tier II. Regional Conservation Interest

a. High Concern

Brown Pelican	(West Indies, Endangered; 520-850 pairs, 25-40% in West Indies)	IM
Green Heron		MA
Yellow-crowned Night-Heron		PR
Black-bellied Plover	(non-breeding)	MA
Ruddy Turnstone	(non-breeding)	MA
Least Sandpiper	(non-breeding)	MA
Antillean Mango	(nearly extirpated on Virgin Islands)	MA
Black-whiskered Vireo		PR

b. High Threats

Pied-billed Grebe	(breeding populations only)	MA
Least Bittern		MA
Black-crowned Night-Heron		MA
Greater Flamingo	(Extirpated as a resident, may be recolonizing)	MA
White-cheeked Pintail	(Lesser subspecies; <5,000 ba Puerto Rico-Virgin Islands; ~60,000 ba in West Indies)	MA
Ruddy Duck	(West Indian subspecies; ~1,500 ba Puerto Rico; <<50,000 ba West Indies)	MA
Masked Duck	(West Indian populations; <100 ba Puerto Rico; <<50,000 ba West Indies)	MA
Sharp-shinned Hawk	(Puerto Rican subspecies, Endangered; <100 ba)	IM
Broad-winged Hawk	(Puerto Rican subspecies, Endangered; <100 ba)	IM
American Kestrel	(Eastern Caribbean subspecies)	MA

Clapper Rail		MA
Yellow-breasted Crake	(Hispaniolan-Puerto Rican subspecies)	MA
Purple Gallinule		MA
Limpkin	(Hispaniolan-Puerto Rican subspecies)	IM
Willet		MA
Key West Quail-Dove		MA
Bridled Quail-Dove		MA
Puerto Rican Screech-Owl	(Virgin Islands subspecies, extirpated except on Culebra?)	IM
Yellow Warbler	(West Indian "Golden" subspecies)	MA
Louisiana Waterthrush	(winter)	MA

c. High Responsibility

Tricolored Heron		PR
Black-necked Stilt		PR
Pectoral Sandpiper	(transient)	PR
Sooty Tern	(55,000-80,000 pairs, 20-40% in West Indies)	PR
Black Tern	(transient)	PR
Brown Noddy	(1,300-2,100 pairs, 7-18% in West Indies)	PR
Scaly-naped Pigeon		PR
Zenaida Dove		PR
Puerto Rican Lizard-Cuckoo	(100% global)	PR
Puerto Rican Screech-Owl	(Puerto Rican subspecies; 100% globally)	PR
Green Mango	(100% globally)	PR
Antillean Crested Hummingbird		PR
Puerto Rican Emerald	(100% globally)	PR
Puerto Rican Tody	(100% globally)	PR
Puerto Rican Woodpecker	(100% globally)	PR
Caribbean Elaenia		PR
Puerto Rican Flycatcher	(100% global, nearly extirpated Virgin Islands)	PR
Gray Kingbird		PR
Loggerhead Kingbird	(Puerto Rican-Vieques subspecies)	PR
Caribbean Martin		PR
Cave Swallow		PR
Red-legged Thrush	(Hispaniolan-Puerto Rican subspecies)	PR
Northern Parula	(winter)	PR
Cape May Warbler	(winter)	PR
Black-throated Blue Warbler	(winter)	PR
Puerto Rican Tanager		PR
Puerto Rican Spindalis		PR
Antillean Euphonia		PR
Puerto Rican Bullfinch	(Puerto Rican subspecies; 100% globally)	PR
Grasshopper Sparrow	(Puerto Rican subspecies)	PR

Tier III. Additional State, Territorial Listed Species (drawn from species in Tier IV)

Least Grebe	PR
Great Blue Heron	PR
Great Egret	PR
Snowy Egret	PR

Tier IV. Additional Local or Regional Interest Species (also Stewardship Species identified by Avifaunal Biome supporting vast majority of breeding population)

Glossy Ibis				PR
Northern Pintail		(winter)		MA
Blue-winged Teal		(winter)		MA
Lesser Scaup		(winter)		MA
Northern Harrier	(winter)		PR	
Osprey				PR
Merlin		(mostly transient)		PR
Peregrine Falcon		(mostly transient)		PR
Sora		(winter)		PR
Common Moorhen				PR
Semipalmated Plover		(non-breeding)		PR
Killdeer				PR
Greater Yellowlegs		(non-breeding)		PR
Spotted Sandpiper		(non-breeding)		PR
White-rumped Sandpiper		(transient)		PR
Royal Tern		(115-315 pairs, >25% in West Indies)		PR
Sandwich Tern		(800-3,600 pairs, 28-71% in West Indies)	PR	
White-winged Dove				PR
Mourning Dove				PR
Yellow-billed Cuckoo				PR
Common Nighthawk				PR
Chuck-will's-widow		(Rare, winter)		PR
White-eyed Vireo		(Rare, winter)		PR
Yellow-throated Vireo		(Rare, winter)		PR
Magnolia Warbler		(Northern Forest Biome, winter)		PR
Yellow-throated Warbler		(winter)		PR
Palm Warbler		(Northern Forest Biome, winter)		PR
Blackpoll Warbler		(transient)		PR
Black-and-white Warbler	(winter)		PR	
American Redstart		(winter)		PR
Ovenbird		(winter)		PR
Northern Waterthrush		(winter)		PR
Hooded Warbler	(Rare, winter)		PR	
Indigo Bunting		(non-breeding)		PR
Bobolink		(transient)		PR
Baltimore Oriole		(transient)		PR

*

WL=WatchList score used for Continental Scoring (PIF Approach); species with WL SUBTOT combined scores of (1) 15 or more, (2) 14 with Tmax+PT $\geq$5, or (3) with 13 with PT=5 are identified. using formula:

Combined Score = PT + PS + maximum of (BD or ND) + maximum of (TB or TN)

Tier=

I. Continental Conservation Interest (Continental WatchList): (a) Species with multiple causes for concern across their entire range; (b) Moderately abundant or widespread species with declines or high threats, and (c) Species with restricted distributions or low population size.

Species with multiple causes for concern across their entire range: These species are considered by many to be of highest continental concern and of highest priority for conservation actions at national and international scales. A majority of these are legally listed as Endangered or Threatened in either the U.S. or Canada, and as such have recovery plans in place. Notable in this group, however, are several species without legal status, including Bicknell's Thrush and Saltmarsh Sharp-tailed Sparrow.

Moderately abundant or widespread species with declines or high threats: These species are on the Watch List primarily because they are declining and/or threatened throughout their range, though still fairly widespread or with moderately large populations. Many of these species still number in the millions (e.g. Dickcissel, Wood Thrush), but are threatened with serious reductions in population or geographic range in the future. Several other species (e.g. Swallow-tailed Kite, Mangrove Cuckoo, Elegant Trogon) are fairly widespread outside the U.S. and Canada, but are threatened in the U.S. portion of their range. Five species are afforded U.S. federal legal status in part of their range or for a particular recognized subspecies. This group also includes four resident game bird species with seriously declining populations.
Species with restricted distributions or low population size: These species are on the Watch List because they are restricted to a small range or have small global populations (often both). Many of these species are not known to be declining or seriously threatened at present, but many others are, (e.g. Spotted Owl, Montezuma Quail, Bendire's Thrasher, Rufous-winged Sparrow, Audubon's Oriole). We recognize that these species with small populations and restricted range are particularly vulnerable to relatively minor changes from current conditions, whether or not their populations are currently in decline.

II. Regional Conservation Interest (non-WatchList; TOT$\geq$19): (a) high regional concern (AI+PT$\geq$8); (b) high regional threats (TB+TN$\geq$7, or TB or TN=5) and includes taxa (subspecies and populations) of regional conservation interest not otherwise included in categories above; (c) high regional responsibility (as measured by percent of global, continental, or regional populations).

III Additional Federally and/or State listed.

IV Local or regional concern or interest, including Stewardship Species as defined in the Continental PIF Plan for North America:

Stewardship Species: Stewardship Species, whether on the Watch List or not, are of continental importance because they represent all the large biogeographic regions in North America. They are broadly distributed across Canada and the U.S. during the breeding seasons, in a pattern that mirrors the richness of all landbird species. Winter Stewardship Species are much more heavily concentrated in the southern U.S., particularly the southwest and into Mexico, and along the U.S. west coast. Stewardship actions that preserve healthy populations of these species will address the PIF goal of 'keeping common birds common.' These species, which are both of high overall concern and also largely dependent on a single biogeographic region, merit special attention for conservation action within their core range.

Component Scores to determine Continental WatchList (minus AI) and Regional Scores (and all smaller geographical units, Bird Conservation Regions, Physiographic Areas, States, Provinces, Territories, etc.) are defined as follows:

PT=Population Trend based on a combination of data sources, principally BBS tempered by local and state datasets for breeding species. For non-breeding species usually best professional judgment often based in part on continental trends shown in BBS and/or CBC.

5=Definite decrease
4=Possible decrease
3=Trend uncertain, No data

2=Possible increase, stable
1=Definite increase

Some guidelines based on BBS data, but for waterbirds trends are often dramatic and not linear so an inspection of trend graphs often is required to make a judgment as to trend score, again tempered by local and state data sets if they exist.

Significant increase (BBS trend ≥1.36%/yr, $P \leq 0.10$, df>13)	1
Possible increase (≥0.47 to 1.36%/ yr, $P \leq 0.35$, w/any df)	2a
Possible increase (≥1.36%/yr, $0.1 < P \leq 0.35$, df>13)	2a
Possible increase (≥1.36%/yr, $P \leq 0.10$, df<13)	2a
Stable (> -0.54 to < +0.47%/yr, and UCI<0.47 OR LCI>-0.54)	2b
- except when trend is negative and P≤0.10 and LCI<-0.54, then Possible decrease	4
Trend uncertain (≤-0.54%/yr or ≥0.47%/yr and $P>0.35$)	3
Trend uncertain (>-0.54%/yr and <0.47%/yr and UCI>0.47 AND LCI<-0.54)	3
No data	3
Possible decrease (either of next 3 options, but based on 6-13 degrees of freedom)	4
Possible decrease (≤-0.54 to -2.27%/yr, $P=0.0$-0.35)	4
Possible decrease (≤-2.27%/yr, $0.1 < P \leq 0.35$)	4
Significant decrease (≤-2.27%/yr and $P \leq 0.10$)	5

PS=Population Size based on best population estimates globally
5=Rare (<50 thousand breeding individuals globally)
4=Uncommon (50-500 thousand breeding individuals globally)
3=Fairly Common (500 thousand-5 million breeding individuals globally)
2=Common (5 million to 50 million breeding individuals globally)
1=Abundant (50 million + breeding individuals globally)

TB and TN=Threats Breeding and Threats Non-breeding

5=Extreme deterioration in the future suitability of breeding/non-breeding conditions is expected; species is in danger of regional extirpation or major range contraction, or has already been extirpated
4=Severe deterioration in the future suitability of breeding/non-breeding conditions is expected
3=Slight to moderate decline in the future suitability of breeding/non-breeding conditions is expected
2=Expected future conditions for breeding/non-breeding populations are expected to remain stable; no known threats
1=Expected future conditions for breeding/non-breeding populations are enhanced by human activities or land-uses; potentially a 'problem' species

BD and ND=Breeding Distribution and Non-breeding Distribution

5=Very Local Distribution (<500,000 km2, or very restricted coastal areas or interior uplands)
4=Local Distribution (>500,000 and <1,000,000 km2, or <1,600 km of coast)
3=Moderate Distribution (>1,000,000 and <2,000,000 km2, or >1,600 to <5,000 km of coast)
2=Widespread (>2,000,000 and <4,000,000 km2, or >5,000 to <8,000 km of coast)
1=Very Widespread (>4,000,000 km2, or >8,000 km of coast)

SUBTOT=Subtotal of six scores (absent AI) used to calculate Combined Score for Continental WatchList

AI=Area Importance, "relative" relative abundance for the species for each area within range scaled against its maximum relative abundance (i.e., the BCR or physiographic area supporting the highest relative abundance)

5=Very High relative abundance (~50+% of maximum relative abundance)
4=High relative abundance (~25-49% of maximum relative abundance)
3=Moderate relative abundance (~10-24% of maximum relative abundance)
2=Low relative abundance (~1-9% of maximum relative abundance)
1=Peripheral, scattered occurrences.

TOT=Total Score of all seven factors used for identifying Tiers for which species best fits for conservation planning at Planning Region/Bird Conservation Region/Physiographic Area.

Act. Level=Action Level at present based on expert opinion, but ultimately rules based on scores would be preferable.

IM=Immediate management needed to reverse or stabilize significant, long-term population declines in species with small populations, or to protect species with the smallest populations for which trends are poorly known. Lack of action may lead to extirpations or extinction.

MA=Management or other on-the-ground conservation actions needed to reverse or stabilize significant, long-term population declines in species that are still relatively abundant.

PR=Long-term Planning and Responsibility needed for species to ensure that sustainable populations are maintained for species for which a region has high responsibility for that species.

PC=Population Control/Suppression needed for species that are otherwise secure and increasing that may come into conflict with other species of higher conservation concern or other resources of interest.

APPENDIX B

Bird-Habitat Relationships for Puerto Rico and Virgin Islands, West Indies.

Conservation Tier	Limestone and montane forests	Mangrove and coastal woodlands	Shrub-scrub	Grassland/ Open lands	Landbird Transients	Marshes/long-legged waders	Open water	Mudflats	Beach front and salt ponds	Nesting seabirds
I a. Multiple concerns continentally	Plain Pigeon	West Indian Whistling-Duck	Yellow-shouldered Blackbird			West Indian Whistling-Duck	West Indian Whistling-Duck		Snowy Plover	White-tailed Tropicbird
	Puerto Rican Parrot	Yellow-shouldered Blackbird				Black Rail			Piping Plover*	Red-billed Tropicbird
	Puerto Rican Nightjar									
	White-necked Crow									
	Bicknell's Thrush*									
	Golden-winged Warbler*									
	Elfin-woods Warbler									
I b. High continental threats and/or declining	Mangrove Cuckoo**	White-crowned Pigeon**	Prairie Warbler*	American Golden-Plover*		Little Blue Heron*		Lesser Yellowlegs*	Sanderling*	Audubon's Shearwater
	Puerto Rican Vireo	Mangrove Cuckoo**		Upland Sandpiper*		Wilson's Snipe		Solitary Sandpiper*	Gull-billed Tern	Masked Booby
	Worm-eating Warbler*	Prothonotary Warbler*		Short-eared Owl				Whimbrel*		Red-footed Booby
	Kentucky Warbler*							Semipalmated Sandpiper*		Brown Booby

	Greater Antillean Oriole							Western Sandpiper*		Roseate Tern
								Stilt Sandpiper*		Least Tern
								Short-billed Dowticher*		
Conservation Tier	**Limestone and montane forests**	**Mangrove and coastal woodlands**	**Shrub-scrub**	**Grassland/ Open lands**	**Landbird Transients**	**Marshes/long-legged waders**	**Open water**	**Mudflats**	**Beach front and salt ponds**	**Nesting seabirds**
I c. Local and/or rare continentally	Black Swift**	Lesser Antillean Pewee	Lesser Antillean Pewee	Antillean Nighthawk**		Caribbean Coot	Caribbean Coot		Reddish Egret	Magnificent Frigatebird
	Lesser Antillean Pewee		Adelaide's Warbler						Wilson's Plover*	Bridled Tern
	Blue-winged Warbler*								American Oystercatcher*	
	Adelaide's Warbler								Red Knot*	
	Swainson's Warbler*									
II a. High concern regionally	Black-whiskered Vireo**	Green Heron*	Antillean Mango			Green Heron*		Black-bellied Plover*	Ruddy Turnstone*	Brown Pelican
		Yellow-crowned Night Heron*				Yellow-crowned Night Heron*		Least Sandpiper*		
II b. High threats regionally	Sharp-shinned Hawk	Clapper Rail	American Kestrel	American Kestrel (w/nest trees)		Pied-billed Grebe	Pied-billed Grebe	Greater Flamingo	Willet*	
	Broad-winged Hawk	Yellow "Golden" Warbler	Key West Quail-Dove			Least Bittern*	White-cheeked Pintail			

	Limpkin					Black-crowned Night-Heron*	Ruddy Duck			
	Bridled Quail-Dove					White-cheeked Pintail	Masked Duck			
	Puerto Rican Screech- Owl (VI)					Ruddy Duck				
	Louisiana Waterthrush*					Masked Duck				
						Yellow-breasted Crake				
						Purple Gallinule*				
Conservation Tier	**Limestone and montane forests**	**Mangrove and coastal woodlands**	**Shrub-scrub**	**Grassland/ Open lands**	**Landbird Transients**	**Marshes/long-legged waders**	**Open water**	**Mudflats**	**Beach front and salt ponds**	**Nesting seabirds**
II c. High responsibility regionally	Scaly-naped Pigeon	Puerto Rican Flycatcher	Antillean Crested Hummingbird	Zenaida Dove		Tricolored Heron*		Black-necked Stilt*	Black-necked Stilt*	Sooty Tern
	Puerto Rican Lizard-Cuckoo	Northern Parula*	Caribbean Elaenia	Gray Kingbird**				Pectoral Sandpiper*	Black Tern*	Brown Noddy
	Puerto Rican Screech-Owl (PR subsp.)	Cape May Warbler*	Puerto Rican Flycatcher	Caribbean Martin**						
	Green Mango		Gray Kingbird**	Cave Swallow						
	Puerto Rican Emerald		Northern Parula*	Grasshopper Sparrow						
	Puerto Rican Tody		Puerto Rican Bullfinch							
	Puerto Rican Woodpecker									
	Puerto Rican Flycatcher									
	Loggerhead Kingbird									
	Red-legged									

	Thrush									
	Northern Parula*									
	Cape May Warbler*									
	Black-throated Blue Warbler*									
	Puerto Rican Tanager									
	Puerto Rican Spindalis									
	Antillean Euphonia									
	Puerto Rican Bullfinch									
Conservation Tier	**Limestone and montane forests**	**Mangrove and coastal woodlands**	**Shrub-scrub**	**Grassland/ Open lands**	**Landbird Transients**	**Marshes/long-legged waders**	**Open water**	**Mudflats**	**Beach front and salt ponds**	**Nesting seabirds**
III. Additional State Listed						Least Grebe (USVI)	Least Grebe (USVI)			
						Great Blue Heron (USVI)				
						Great Egret* (USVI)				
						Snowy Egret* (USVI)				
IV. Local or regional interest	Chuck-will's-widow*	White-winged Dove	White-winged Dove	Northern Harrier	Merlin*	Glossy Ibis	Northern Pintail	Semipalmated Plover*		Royal Tern
	Yellow-throated Vireo*	Yellow-billed Cuckoo*	Yellow-billed Cuckoo*	Killdeer	Peregrine Falcon*	Sora	Blue-winged Teal*	Greater Yellowlegs*		Sandwich Tern
	Magnolia Warbler*	Yellow-throated Warbler*	White-eyed Vireo*	Mourning Dove	Common Nighthawk*	Common Moorhen*	Lesser Scaup	Spotted Sandpiper*		

	Blackpoll Warbler*	Palm Warbler*	Indigo Bunting*	Indigo Bunting*	Bobolink*		Osprey*	White-rumped Sandpiper*		
	Black-and-white Warbler*	Blackpoll Warbler*			Baltimore Oriole*					
	American Redstart*	Black-and-white Warbler*								
	Ovenbird*	American Redstart*								
	Hooded Warbler*	Northern Waterthrush*								
		Hooded Warbler*								

*Nearctic-Neotropical Migrant species, those species with populations principally breeding in temperate North American areas that winter principally in tropical North American and/or South America areas.

**Intratropical Migrants species, those species breeding in the northern tropical areas of North America that winter principally further south in tropical North America and/or South America areas.

APPENDIX M

INVASIVE PLANT SPECIES IN (OR NEAR) SFCN PARKS

South Florida / Caribbean Network in consultation with Tony Pernas
2005

Appendix M. Invasive plant species in (or near) SFCN parks. This is a list of the more problematic invasive plant species in the South Florida and Caribbean Network parks. Other non-native plants are present but not considered problematic. Compiled with assistance from Tony Pernas.

		PARKS							Ecological Zones						
Common name	**Scientific name**	EVER	BICY	BISC	DRTO	VIIS	BUIS	SARI	Freshwater wet prairies & marshes	Forested uplands and wetlands	Island interior	Coastal wetlands	Florida and Biscayne Bays	Coastal shelf / deep oceanic	Comment
Shoebutton	*Ardisia elliptica*	X	X						X	X					
Casuarina	*Casuarina cunninghamiana, C. equisetifolia, C. gauca*	X	X	X	X	X	X	X	X	X	X	X			
Wild Taro	*Colocasia esculenta.*	X	X						X	X					On some tree islands in Shark Slough
Latherleaf	*Colubrina asiatica*	X		X	X							X			
Air potato	*Dioscorea bulbifera*	X	X							X					
Water Hyacinth	*Eichhornia crassipes*	X	X						X						
Hydrilla	*Hydrilla verticillata*	X	X						X						
Cogongrass	*Imperata cylindrica*	X	X							X					
Lygodium	*Lygodium japonicum, L. microphyllum*	X	X	X					X	X					
Melaleuca	*Melaleuca quinquenervia*	X	X	X					X						
Silkreed	*Neyraudia reynaudiana*	X	X							X					Disturbed areas along roads
Guinea grass	*Urochloa maximum (formerly Panicum maximum)*	minor	minor			X	X	X	minor	minor	X				
Torpedograss	*Panicum repens*	X	X						X						
Elephantgrass	*Pennisetum purpureum*	X	X						X	X					
Waterlettuce	*Pistia stratiotes*	X	X						X						
Beach naupaka, Inkberry	*Scaevola sericea*	X		X	X	X	X	X				X			
Brazilian Pepper	*Schinus terebinthifolius*	X	X	X	X	X	X	X	X	X	X	X			
Tropical Soda Apple	*Solanum viarum*	X	X							X					
Java Plum	*Syzygium cumini*	X	X							X					
Seaside Mahoe	*Thespesia populnea*	X		X	X	X	X	X				X			Disturbed areas, cattle grazing
Pacific algae	*Caulerpa brachypus*	Near		Near	Near								X	X	

APPENDIX N

NON-NATIVE FAUNA SPECIES IN (OR NEAR) SFCN PARKS

South Florida / Caribbean Network in consultation with
Skip Snow, Jeff Kline, and Raul Urgelles
2008

APPENDIX N. Non-native fauna species in (or near) SFCN parks.

This list was compiled in part from lists developed by Skip Snow, Jeff Kline, Lodge (2005), Waddell (2005) and personal communications with Raul Urgelles (2008) and park staff. Not all species are considered invasive.

			PARKS							Ecological Zones					
Taxa	Common name	Scientific name	EVER	BICY	BISC	DRTO	VIIS	BUIS	SARI	Wet prairies and marshes	Forest uplands and wetlands	Coastal wetlands	Island interiors	Florida and Biscayne Bay	Coastal Shelf and Deep Oceanic
Invertebrate	Australian Spotted (White-spotted) Jellyfish	*Phyllorhiza punctata*			?	?	?	?	?						X
Invertebrate	Asian Clam	*Corbicula fluminea*	X							X	?	X			
Invertebrate	Island Applesnail	*Pomacea insularum*	X							X					
Invertebrate	Goldenhorn Marisa	*Marisa cornuaurietus*	X							X					
Invertebrate	Red-rimmed Melania	*Melanoides tuberculata*	X							X		X			
Invertebrate	Lobate Lac Scale	*Paratachardina lobata*	X	X							X				
Invertebrate	Brown Citrus Aphid	*Toxoptera citricida*	X								X				
Invertebrate	Prickly Pear Moth	*Cactoblastis cactorum*	X								X				
Invertebrate	Agave Weevil	*Scyphophorus acupunctatus*					X						X		
Invertebrate	Bromeliad Weevil	*Metamasius callizona*	X	X							X	X			
Invertebrate	Diaprepes Weevil	*Diaprepes abbreviatus*	X								X				
Invertebrate	Fire Ant	*Solenopsis invicta*	X	X	X						X				
Fish	Grass Carp	*Ctenopharyngodon idella*	X							X					
Fish	Walking Catfish	*Clarias batrachus*	X	X						X	X				
Fish	Brown Hoplo	*Hoplosternum littorale*	X	X						X	X				
Fish	Orinoco Sailfin Catfish	*Pterygoplichthys multiradiatus*	X							X	?				
Fish	Pike Killifish	*Belonesox belizanus*	X		?					X	X				
Fish	Spot-finned Spiny Eel (Peacock Eel)	*Macrognathus siamensis*	X							X	?	X			
Fish	Asian Swamp Eel	*Monopterus albus*	X							X					
Fish	Lionfish	*Pterois miles, P. volitans*			?									X	X
Fish	Oscar	*Astronotus ocellatus*	X	X	?					X	?				
Fish	Peacock Cichlid	*Cichla ocellaris*	X							X	?				
Fish	Black Acara	*Cichlasoma bimaculatum*	X	X	?					X	X				
Fish	Jaguar Guapote	*Cichlasoma managuense*	X							X					
Fish	Mayan Cichlid	*Cichlasoma urophthalmus*	X	X	X					X	X	X			
Fish	African Jewelfish	*Hemichromis letourneauxi*	X		?					X	X	X			
Fish	Banded Cichlid	*Heros severus*	X							X	?	X			
Fish	Blue Tilapia	*Oreochromis aureus*	X							X					
Fish	Mozambique Tilapia	*Oreochromis mossambicus*	X		?					X					
Fish	Spotted Tilapia	*Tilapia mariae*	X	X						X	X	X			
Herpetofauna	Giant (Cane) Toad	*Bufo marinus*	X		X		X		X	X		X			
Herpetofauna	Puerto Rican Coqui	*Eleutherodactylus coqui*					X		X				X		
Herpetofauna	Greenhouse Frog	*Eleutherodactylus planirostris*	X	X	X						X				
Herpetofauna	Cuban Treefrog	*Osteopilus septentrionalis*	X		X		X		X	X	X		X		
Herpetofauna	Spectacled (Brown) Caiman	*Caiman crocodilus*	X							X	X	X		X	
Herpetofauna	Red-footed Tortoise*	*Geochelone carbonaria*					X		X				X		
Herpetofauna	Red-eared Slider	*Trachemys scripta elegans*	?	?			X		X	X			X		
Herpetofauna	Mexican Spinytail Iguana	*Ctenosaura pectinata*	X		X						X				
Herpetofauna	Black Spinytail Iguana	*Ctenosaura similis*	X		X						X				

APPENDIX N. Non-native fauna species in (or near) SFCN parks.

This list was compiled in part from lists developed by Skip Snow, Jeff Kline, Lodge (2005), Waddell (2005) and personal communications with Raul Urgelles (2008) and park staff. Not all species are considered invasive.

			PARKS							Ecological Zones					
Taxa	**Common name**	**Scientific name**	**EVER**	**BICY**	**BISC**	**DRTO**	**VIIS**	**BUIS**	**SARI**	**Wet prairies and marshes**	**Forest uplands and wetlands**	**Coastal wetlands**	**Island interiors**	**Florida and Biscayne Bay**	**Coastal Shelf and Deep Oceanic**
Herpetofauna	Green Iguana*	*Iguana iguana*	X		X		X		?		X	X			
Herpetofauna	Cuban Knight Anole	*Anolis equestris*	X								X				
Herpetofauna	Brown Anole	*Anolis sagrei*	X	X	X	X				X	X		X		
Herpetofauna	Tokay Gecko	*Gekko gecko*	X		X						X				
Herpetofauna	Indo-Pacific Gecko	*Hemidactylus garnotti*	X			?							X		
Herpetofauna	Tropical House Gecko	*Hemidactylus mabouia*	X			?	X		X				X		
Herpetofauna	Turnip-tailed Gecko*	*Thecadactylus rapicauda*					X		X				X		
Herpetofauna	Nile Monitor	*Varanus niloticus*			X						X	X			
Herpetofauna	Brahminy Blind Snake	*Ramphotyphlops braminus*			X										
Herpetofauna	Burmese Python	*Python molorus bivittatus*	X	X						X	X	X			
Herpetofauna	Other large constrictors	*Boa* spp., *Python* spp.	X							X	X	X			
Herpetofauna	Corn Snake	*Elaphe guttata guttata*					X		X				X		
Bird	Sacred Ibis	*Threskiornis aethiopicus*	Near	Near						X	X	X			
Bird	Purple Swamphen	*Porphyrio porphyrio*	Near							X					
Bird	Monk Parakeet	*Myiopsitta monachus*	X								X				
Bird	Parrots and parakeets	Family Psittacidae	X	X							X				
Bird	Helmeted Guineafowl	*Numida meleagris*							X				X		
Bird	House Sparrow	*Passer domesticus*	?	?	X										
Bird	Common Myna	*Acridotheres tristis*	X								X				
Bird	European Starling	*Sturnus vulgaris*	X	X	X					X	X		X		
Mammal	Nine-banded Armadillo	*Dasypus novemcinctus*	X	X							X				
Mammal	House Mouse	*Mus musculus*	X	X	?	X	X		X		X		X		
Mammal	Norway Rat	*Rattus norvegicus*	X	X			X		X		X	X	X		
Mammal	Black Rat	*Rattus rattus*	X	X	X	X	X		X		X	X	X		
Mammal	Mexican Red-bellied Squirrel	*Sciurus aureogaster*	X		X								X		
Mammal	Small Indian Mongoose	*Herpestes javanicus*					X		X			X	X		
Mammal	Feral & domestic cats	*Felis catus*	X	X	X		X		X		X	X	X		
Mammal	Feral & domestic dogs	*Canis familiaris*	X	X	X		X		X		X	X	X		
Mammal	Coyote (range extension?)	*Canis latrans*	X	X							X				
Mammal	Feral Pig	*Sus scrofa*	X	X			X		X		X	X	X		
Mammal	Goat	*Capra aegagrus hircus*					X					X	X		
Mammal	Feral Donkey	*Equus asinus*					X					X	X		
Mammal	White-tailed Deer	*Odocoileus virginianus*							X			X	X		
Mammal	Rhesus Macaque	*Macaca mulatta*	X								X				
Mammal	Common Squirrel Monkey	*Saimiri sciureus*	X								X				

* U. S. Virgin Islands introduction thought to have been Pre-Colombian

APPENDIX O

SUMMARY OF INDICATOR IDENTIFICATION

AND RANKING PROCESS

O.1 Vital Signs Indicator Identification Workshops
O.2 List of Participants Vital Signs Indicator Identification Workshops
O.3 List of Participants in the SFCN Web-based Ranking Process
O.4 Web-based Ranking Instructions
O.5 Vital Signs Ranking Meeting Summary
O.6 Consolidation of 62 Indicators into 42 Vital Signs
O.7 SFCN Indicator Worksheets

APPENDIX O.1

Vital Signs Indicator Identification Workshops

Vital Signs Indicator Identification Workshops

The SFCN held three Vital Signs Indicator Development Workshops in FY06. Two of these were held in South Florida, the first dealing with South Florida bays & marine areas (Jan. 18-19), while the second focused on South Florida uplands & wetlands (Feb. 1-2). The third workshop was held in St. Croix and focused on both uplands & marine areas (Mar. 6-7). The 70 participants (see Appendix O.2) in the 3 workshops included NPS managers and staff, non-NPS natural resource managers and agency staff, and area scientists.

Each workshop was organized to review the SFCN conceptual models and identify potential vital signs indicators to meet the goals of the NPS Inventory and Monitoring Program to:

- Determine the status and trends of the condition of park ecosystems to allow managers to make better-informed decisions and to work more effectively with other agencies and individuals for the benefit of park resources.
- Provide early warning of abnormal conditions of selected resources to help develop effective mitigation measures and reduce costs of management
- Provide data to better understand the dynamic nature and condition of park ecosystems and to provide reference points for comparisons with other, altered environments
- Provide data to meet certain legal and congressional mandates related to natural resource protection and visitor enjoyment
- Provide a means of measuring progress towards performance goals

Workshop participants completed indicator worksheets for each of the high priority indicators identified by their workshop group (Figure 1). Essential information requested on the worksheet included: monitoring question, indicator name, ecosystem type, metric, methods (including frequency, timing and scale), basic assumptions, constraints, and references (Figure 1).

Workshop summaries and related information have been posted to the SFCN website: (http://www.nature.nps.gov/im/units/SFCN/ products.htm#vitalsigns).

Post-Workshop Editing

Indicator worksheets from the workshops and a few received after the workshops were reviewed by members of the SFCN staff and edited for clarity and consistency. Worksheet authors were informed in the case of major edits. Indicators produced by different workgroups that were highly redundant in purpose, scope, and methodology were consolidated. A justification section was added to each indicator to make them more understandable to persons who had not attended the workshops.

Vital Signs Indicator Database

All available information from the indicator worksheets (Figure 1) was entered into a network database developed by the Network Data Manager and based on a data structure provided by the National Monitoring Coordinator. This database in turn

was used as the foundation for the network's web-based vital signs indicator ranking tool.

Figure 1. SFCN indicator worksheet template with category definitions.

Indicator Worksheet

Who worked on this indicator worksheet (so we can call you with questions):

Indicator: *Specific indicator to monitor*

Monitoring Question(s): *Monitoring question(s) that will be addressed*

Which conceptual model(s) is this indicator linked to?

- ☐ 2.3 Freshwater Wet Prairies and Marshes Ecological Zone
- ☐ 2.4 Forest Uplands and Wetlands Ecological Zone
- ☐ 2.5 Island Interior Ecological Zone
- ☐ 2.6 Mangroves, Beaches & Tidal wetlands Ecological Zone
- ☐ 2.7 Florida Bay Ecological Zone
- ☐ 2.8 Biscayne Bay Ecological Zone
- ☐ 2.9 Coastal Shelf / Deep Oceanic Ecological Zone

Which parks are associated with this indicator?

South Florida Parks

- ☐ Big Cypress National Preserve (BICY)
- ☐ Biscayne National Park (BISC)
- ☐ Dry Tortugas National Park (DRTO)
- ☐ Everglades National Park (EVER)

U.S. Virgin Islands Parks

- ☐ Buck Island Reef Natl. Monument (BUIS)
- ☐ Salt River Bay Nat. Hist. Park & Ecol. Res. (SARI)
- ☐ Virgin Islands National Park (VIIS)

Metric: *Refers to the elements to be measured and the data to be collected*

Method: *Short description of a methodology or references a developed protocol*

Frequency: *Stipulates how often the indicator should be measured*

- ☐ Continuous
- ☐ Monthly
- ☐ Annual
- ☐ Every _____ Years
- ☐ Other (Please specify):

Timing: *Specifies the time of year that data collection should occur*

Scale of Collection: *Scale at which data should be collected*

- ☐ Regional (incl. areas outside parks)
- ☐ Park-wide _____
- ☐ Other (Please specify):
- ☐ Multiple Parks
- ☐ Site Specific_____

Scale of Process or Element Operation: Scale *at which the process or element operates*

- ☐ Regional (incl. areas outside parks)
- ☐ Park-wide _____
- ☐ Other (Please specify):
- ☐ Multiple Parks
- ☐ Site Specific_____

Scale of Analysis: *Scale at which analysis can be inferred*

- ☐ Regional (incl. areas outside parks)
- ☐ Park-wide _____
- ☐ Other (Please specify):
- ☐ Multiple Parks
- ☐ Site Specific_____

Basic Assumptions: *Specifies the underlying assumption(s) that, if not true, would invalidate this indicator/methodology*

Research Needs: *Identifies any known research need(s) that would facilitate understanding of how this indicator fits within the ecosystem model*

Management Goal: *Desired future condition*

Threshold Target: *Stipulates the resource condition (numerically if possible) and the amount of variation from this condition that will be tolerated (accepted as natural variation). If insufficient knowledge exists, say "insufficient knowledge."*

Response*: Specifies what management action is recommended if the threshold or target is not met*

Constraints: *Lists issues/concerns about the indicator related to its successful implementation*

Status: *Identifies whether monitoring is proposed, in development, or on-going*

Estimated cost: *Rough estimate of cost, either in total or per sample, per replicate, etc.*

References: Contacts, *experts or literature relevant to the indicator (continue on back if necessary)*

The SFCN database was linked to dynamic web pages posted on the network web site using a system that had been previously developed by the San Francisco Bay Area Network (SFAN) and successfully used by both the SFAN as well as the Mediterranean Coast Network (MEDN). This linkage allowed revisions to the database to be immediately incorporated into the web page. However the primary purpose was to use the linked web pages as the SFCN ranking instrument.

Selection of Ranking Participants

Over 130 persons, including previous workshop invitees, NPS resource management staff, and additional area scientists and agency staff representing a diverse array of specialty areas, were invited to use the web-based database tool to rank the network's indicators. These invitees were also asked to spread information about the ranking process to friends and colleagues and invite them to participate as well. The 102 people who participated in the ranking process are listed in Appendix O-3.

Criteria for Prioritizing Vital Signs

The four criteria utilized to rank vital signs indicators reflect important qualities of an effective vital signs monitoring program and were modified from the Cumberland-Piedmont Network ranking criteria, Jackson *et al*. (2000), Tegler *et al*. (2001), and Andreasen *et al*. (2001) (Figure 2). "Legal Mandate" and "Management Significance" criterion were ranked by SFCN staff and then forwarded to each park for review and correction. "Ecological Significance" and "Feasibility" were ranked via the online ranking process.

Initial Ranking Process and Ranking Instrument

The initial ranking process was conducted using a web-based ranking methodology. The SFCN database and associated web pages functioned as the source of indicator ranking information and as the receptacle for ranking scores and participant comments.

Participants from previous workshops, additional subject experts, regional NPS staff, and other selected agency officials were sent a background statement, instructions, and descriptions of the ranking process via email. All invited participants were given a password, giving them access to the ranking website (www.nature.nps.gov/im/units/SFCN/Ranking.htm) which also contained links to background and instructional materials. Login names and passwords were used to provide sufficient security during the ranking process. Upon reviewing the instructions and ranking criteria, participants were asked to rank each indicator from "very low" to "very high" with respect to "Ecological Significance" and "Feasibility" (Figure 3). Participants also had the option of choosing "no opinion" for each criterion if they had insufficient knowledge about the indicator to evaluate it. Participants could view the existing information for each indicator, print any or all of the information, rank indicators in accordance with the SFCN criteria, review their scores, and change them as often as the participants wished during the three week

window that the database was open. The ranking instructions which were sent to all participants can be found in Appendix O-4.

Figure 2. Criteria for prioritizing South Florida / Caribbean Network indicators.

Primary Criteria	Sub-criteria*	Prioritization Scheme
Ecological Significance	a) Ecological Importance: The indicator represents a resource or function of high ecological importance based on conceptual models and/or literature. b) Good indicator of system resource or function: There is a strong, defensible linkage between the indicator and the ecological function or critical resource it is intended to represent. c) Early warning/sensitive to change: The indicator provides early warning of undesirable changes to important resources. d) Supporting data/scientific work: Reference conditions exist within the region, and/or threshold values are in available literature e) Connectivity: The indicator affects/responds to ecological processes at other spatial scales and levels of biological organization	*Very High*—I **strongly agree** with all **5** of these statements. *High*—I **strongly agree with 4** of these statements *Moderate*—I **strongly agree with 3** of these statements *Low*—I **strongly agree** with **2** of these statements. *Very Low*--This is an important indicator to monitor, but I **do not strongly agree** with more than 1 of these statements. *No opinion*--I do not know enough about this criterion for this indicator to rank it.
Feasibility	a) Well-documented rigorous protocols: Well-documented, scientifically sound monitoring protocols already exist for the indicator. b) Technically feasible: Implementation of monitoring protocols is feasible given the constraints of site accessibility, sample size, equipment maintenance, etc. c) Interpretable: The indicator is sensitive to change and has a high signal to noise ratio that can be distinguished from naturally occurring variability. Results are repeatable with different qualified personnel. d) Low-cost: Sampling and analysis techniques are doable with low to moderate cost relative to information gained. e) Cost-sharing opportunities: The opportunity for cost-sharing partnerships with existing NPS monitoring, other agencies, universities, or private organizations in the region exists.	*Very High*—I **strongly agree** with all **5** of these statements. *High*—I **strongly agree with 4** of these statements *Moderate*—I **strongly agree with 3** of these statements *Low*—I **strongly agree** with **2** of these statements. *Very Low*--This is an important indicator to monitor, but I **do not strongly agree** with more than 1 of these statements. *No opinion*—I do not know enough about this criterion for this indicator to rank it.

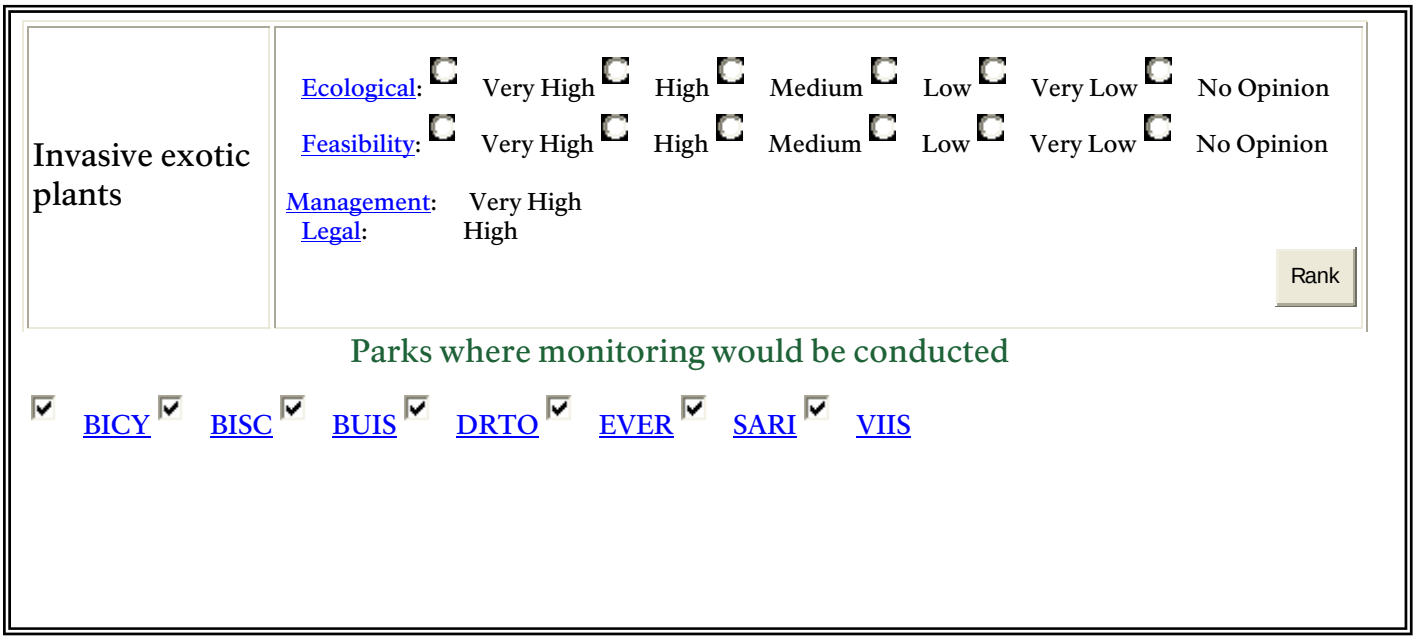
Primary Criteria	Sub-criteria*	Prioritization Scheme
Management Significance	a) Relevant to key management decisions: There is an obvious, direct application of the data to a key management decision(s), or for evaluating the effectiveness of past management decisions (can include performance towards (GPRA) goals and/or park Strategic Plans). b) Early warning: Monitoring results are likely to provide early warning of resource impairment. c) Allow better-informed management: Data are badly needed to give managers a better understanding of park resources so that they can make informed decisions. d) Clearly understood: The indicator will produce results that are clearly understood and accepted by park managers, other policy makers, research scientists, and the general public. e) Public interest: Data are of high interest to the public.	*Very High*—I **strongly agree** with all **5** of these statements. *High*—I **strongly agree with 4** of these statements *Moderate*—I **strongly agree with 3** of these statements *Low*—I **strongly agree** with **2** of these statements. *Very Low*--This is an important indicator to monitor, but I **do not strongly agree** with more than 1 of these statements. *No opinion*—I do not know enough about this criterion for this indicator to rank it.
Legal Mandate	This criterion is part of 'Management Significance' but is purposely duplicated here to emphasize those indicators and resources that are required to be monitored by some legal or policy mandate. The intent is to give additional priority to an indicator if a park is directed to monitor specific resources because of some binding legal or Congressional mandate, such as specific legislation and executive orders, or park enabling legislation. The binding document may be with parties at the local, state, regional, or federal level.	*Very High*—Legal requirement: The park is **required** to monitor this specific resource/ indicator by some specific, binding, legal mandate (e.g., Endangered Species Act for an endangered species, Clean Air Act for Class 1 airsheds, Clean Water Act). *High*—Executive Order, Mandate, Park Enabling Legislation: The resource/indicator is specifically covered by an Executive Order (e.g., invasive plants, wetlands) or Mandate, or specifically identified in park enabling legislation. *Moderate*— Goal: There is a GPRA goal specifically mentioned for the resource/indicator being monitored, or the need to monitor the resource is generally indicated by some type of federal or state law (e.g., CERP). *Low*— Concern: The resource/indicator is listed as a sensitive resource or resource of concern by credible state, regional, or local conservation agencies or organizations, but it is not specifically identified in any legally-binding federal or state legislation.

Primary Criteria	Sub-criteria*	Prioritization Scheme
		Very Low— The resource/indicator is covered by the Organic Act and other general legislative or Congressional mandates such as the Omnibus Park Management Act and GPRA, and by NPS Management Policies, but there is no specific legal mandate for this particular resource. *No opinion*—I do not know enough about this criterion for this indicator to rank it.

Additionally, participants were given two locations in which to provide feedback. The comment box under the ranking scores could be used to explain ranking scores. A second comment box was intended for information on citations or methods that were not included in the worksheet. Comments were taken into consideration as indicator ranking results were analyzed and will be considered during protocol development.

Figure 3 depicts an example ranking dialog box for the Invasive exotic plants indicator. During the ranking process, within the dialog box, underlined text provided hyperlinks to protocol database information for the indicator as well as descriptive information for each ranking criterion. Protocol information specific to each indicator was found immediately below the dialog box on the ranking website.

Figure 3. Example of an indicator ranking dialog box for the indicator "Invasive Exotic Plants." Underlined text indicates a hyperlink to descriptive materials.



SFCN Web-based Ranking Results

Participant Response Rate

Of the 130+ people invited to rank the proposed SFCN vital signs, 102 people participated. Thirty-three (33) of the 102 participants were NPS employees and 69 were non-NPS scorers. It should be noted that not all people who participated in the prioritization process ranked all 69 indicators. The participants are listed in Appendix O-3.

Ecological Significance and Feasibility

Ecological significance and feasibility were ranked via the web-based ranking process.

Management Significance and Legal Mandate

Management and legal scores were developed by SFCN staff, following criteria listed in Figure 2, and then submitted to each park for review.

Calculation of Ecological-Feasibility Index (EF Index)

The 69 SFCN indicators were ranked by creating a weighted index from the average "Ecological Significance" score and average "Feasibility" score. For each indicator, scores were first converted to numerical values with "Very High" = 5 and "Very Low" = 1. Then average scores were calculated across all respondents for each of "Ecological Significance" and "Feasibility." These scores were then combined in a weighted index as follows:

EF Index =2*(Average Ecological Score) + (Average Feasibility Score)

The results are given in O.1.1. Please note that the number of responses (scores) for each indicator varied since not all participants ranked all of the indicators. Only rankings of "Very High" to "Very Low" were included in the calculation of the averages. Non-responses or "No Opinion" responses were not included.

Alternative Ecological-Feasibility-Management-Legal Index (EFML Index)

"Management Significance" and "Legal Mandate" scores were assigned by SFCN. An alternative EFML index was created by adding these scores to the EFML index as follows:

EFML Index = EF Index + Management Score + Legal Mandate Score

A majority of indicators were ranked under Management Significance as Very High (35/69) or High (11/69), reflecting that the workshops had produced many indicators highly relevant to management. However, this meant Management Significance had little affect in changing scores and that Legal Mandate, whose scores ranged more

widely, produced much of the changes in the EFML Index from the previously described EF Index. Federally listed species (e.g., Florida Panther, Colonial Nesting Birds), marine fish communities, and water quality indicators all received boosts in the rankings compared with the EF Index. In contrast, 11 vegetation indices, 2 amphibian indices, and 2 exploited communities were ranked lower under the EFML index.

SFCN staff chose to focus on the EF Index as the ranking index for all additional queries for the following reasons:

- The Management Significance and Legal Mandate scores had only received minimal review from the parks due to a limited review window
- Legal Mandate played a large role in changes in the index
- Management Significance played a small role in changes in the index
- The primary purpose of the program is to monitor ecosystem condition rather than legal mandates

Key Assumptions and Biases

The SFCN vital signs selection and prioritization process is not a perfect representation of a rigorous scientific study. Rather, it was designed as tool to assist decision-makers in distilling complex natural resource management issues into a ranked list of indicators to assist final selection of vital signs for a flexible yet effective monitoring program. The SFCN prioritization process, therefore, has several inherent assumptions and biases. Consequently, interpretation of the results has been complicated by the fact that:

- We assumed all significant management issues have been captured
- We assumed all significant indicators have been represented
- We assumed all perspectives have been represented
- We assumed descriptive statistics were adequate for ranking the SFCN vital signs
- Participating scorers were a pre-selected group (i.e., not random)
- Participants were, for the most part, selected by the SFCN
- Not all data fields were complete for each indicator
- The sample size (number of people who scored indicators) was low (102 total participants; median for any one indicator=42 scores; smallest was 22 scores)
- The number of scorers (N) varied for each indicator (22-69 scores/indicator)
- Response rate for each indicator may have been affected by the order of the list of indicators (ordered according to national I&M categories)

A summary of the actual number of scores by rank category “Very High,” “High,” “Medium,” “Low,” and “Very Low” is shown in Table 2. This table shows the distribution of the actual scores and standard deviation.

Additional Sorts and Data Comparisons

Additional sorts and comparisons were conducted:

Table 3. shows a comparison of rankings using the EF Index, EFML Index and "Ecological Only" ranking.

Table 4. Splits indicators into "Uplands and wetlands" vs "Bays and Marine" lists and compares them side by side using the EF Index and listing the original ranks from Table 1.

Table 5. Creates two list of indicators based on the EF Index compared side by side:

Florida indicators (excludes USVI only indicators) ranked by participants claiming a Florida specialty.

USVI indicators (excludes (Florida only indicators) ranked by participants claiming a Caribbean specialty.

Table 6 Compares the rankings of NPS staff and non-NPS participants side by side.

Table 7 Shows rankings of indicators relevant to each park based on EF Index.

Table O.1.1. Indicators plus average rankings sorted by Ecological-Feasibility Index plus levels of existing monitoring estimated to be currently occuring for each indicator by park.

Ecological-Feasibility index =(Average Ecological Rank Score)*2 + (Average Feasibility Score)

○ No monitoring occuring but within indicator geographic scope.

◑ Some monitoring occurring, but either protocol or sampling scope would need change

● Lots of monitoring occuring, little change presumed needed to level of effort, protocol, or scope

Rank Order	Indicator	Ecol. Sign.	Feas.	Mgmt Sign.	Legal	EF Index	# People	BICY	BISC	BUIS	DRTO	EVER	SARI	VIIS
1	Coral Communities	4.77	4.28	5	4	13.82	61		◑	◑	◑		○	◑
2	Exploited Fish Assemblage - Grouper, Snapper, (parrotfish, surgeonfish in USVI)- population structure, status, and trends	4.52	4.33	5	3	13.37	52		◑	◑	◑	◑	◑	◑
3	Hydrology = water stage, flow, timing, and duration.	4.55	4.19	5	3	13.28	64	●	●		○	●	○	○
4	Seagrass and other SAV cover and community composition	4.48	4.14	5	3	13.11	64		◑	○	◑	●	○	◑
5	Water Quality- Nutrients characteristics of the marine water bodies	4.33	4.08	5	5	12.75	63		●	○	◑	●	○	●
6	Invasive exotic plants	4.36	4.00	5	4	12.72	69	●	●	●	●	●	●	●
7	Freshwater Inputs to Estuaries	4.36	3.93	4	3	12.64	56	○	●			◑	○	
8	Marine Invertebrates - Rare, threatened, and endangered species - Acropora, Diadema, Antipathes	4.33	3.98	3	4	12.63	49		○	◑	○		○	◑
9	Shape, orientation, location, and coverage of vegetation community types	4.30	3.98	5	3	12.57	44	◑	◑		○	●		
10	Wading birds - Regional South Florida - Systematic Reconnaissance Flights	4.27	3.97	5	4	12.50	30	●				●		

Table O.1.1. Indicators plus average rankings sorted by Ecological-Feasibility Index plus levels of existing monitoring estimated to be currently occuring for each indicator by park.

Ecological-Feasibility index =(Average Ecological Rank Score)*2 + (Average Feasibility Score)

○ No monitoring occuring but within indicator geographic scope.

◑ Some monitoring occurring, but either protocol or sampling scope would need change

● Lots of monitoring occuring, little change presumed needed to level of effort, protocol, or scope

Rank Order	Indicator	Ecol. Sign.	Feas.	Mgmt Sign.	Legal	EF Index	# People	BICY	BISC	BUIS	DRTO	EVER	SARI	VIIS
11	Spatial and Temporal Salinity Patterns	4.23	4.00	4	3	12.46	57		◑	○		◑	○	○
12	Surface Water Quality-physiochemical surface water characteristics at specific locations.	4.21	3.93	5	5	12.36	56	◑		○		●	○	○
13	Exploited Inverts (Lobster, Conch, Crabs, Shrimp, Stone Crab, Blue Crab, Clams, Oysters, Sponges, Welks)	4.20	3.94	5	3	12.34	50		◑	◑	◑	◑	◑	◑
14	Land Development inside/outside the park (within 5 mile radius for USVI parks, radius may be expanded to 75 miles in South Florida)	4.23	3.87	5	3	12.32	53	◑	◑	◑	◑	◑	◑	◑
15	Marine Fish Communities - Coastal Shelf / Deep oceanic - Status, structure, trends	4.22	3.86	5	4	12.29	51		●	●	●	●	●	●
16	Colonial Nesting Birds (e.g. Least terns, pelicans, boobies, roseatte terns, egrets, storks, herons)	4.17	3.94	5	5	12.28	36	●	●	●	●	●	○	●
17	Invasive exotic fauna	4.26	3.68	5	4	12.20	57	○	◑	◑	◑	◑	○	○
18	Nutrient Loading and Sediment Loading	4.16	3.75	5	5	12.06	64	◑	●			●	○	◑
19	Visitor Use (Both commercial and individual/personal use)	3.93	4.11	5	4	11.96	55	◑	◑	◑	◑	◑	○	◑
20	Early detection, status, and trends of non-indigenous aquatic species.	4.16	3.60	5	4	11.91	51	○				◑		

Table O.1.1. Indicators plus average rankings sorted by Ecological-Feasibility Index plus levels of existing monitoring estimated to be currently occuring for each indicator by park.

Ecological-Feasibility index =(Average Ecological Rank Score)*2 + (Average Feasibility Score)

○ No monitoring occuring but within indicator geographic scope.

◑ Some monitoring occurring, but either protocol or sampling scope would need change

● Lots of monitoring occuring, little change presumed needed to level of effort, protocol, or scope

Rank Order	Indicator	Ecol. Sign.	Feas.	Mgmt Sign.	Legal	EF Index	# People	BICY	BISC	BUIS	DRTO	EVER	SARI	VIIS
21	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Visual Assessment	4.06	3.73	5	4	11.85	51	○	◑	○	○	◑	○	○
22	Location of critical ecotones - field plots/transects	3.97	3.85	4	3	11.79	39	◑	○	○	○	◑	◑	◑
23	Periphyton	4.03	3.62	4	3	11.67	38	○	○			●		
24	Freshwater fish and large macro-invertebrates in wet prairies and marshes	4.03	3.59	5	3	11.66	32	◑				●		
25	Contaminants in water column, organisms, and sediments.	4.07	3.52	5	5	11.65	60	◑	◑	○	○	◑	○	○
26	Long-term, within-community vegetation shifts using permanent plots	3.91	3.82	1	1	11.64	44	◑	○	○	○	◑	○	●
27	Sea Turtles	3.89	3.82	4	5	11.60	55		◑	●	●	○	○	●
28	American crocodile (Crocodylus acutus)	3.90	3.80	3	5	11.60	40		●			●		
29	American alligator (Alligator mississippiensis)	3.85	3.88	4	3	11.57	33	●				●		
30	Benthic community spatial & temporal changes in extent and distribution - remote sensing	4.02	3.47	5	4	11.51	57		◑	◑	◑	◑	◑	◑

Table O.1.1. Indicators plus average rankings sorted by Ecological-Feasibility Index plus levels of existing monitoring estimated to be currently occuring for each indicator by park.

Ecological-Feasibility index =(Average Ecological Rank Score)*2 + (Average Feasibility Score)

○ No monitoring occuring but within indicator geographic scope.

◑ Some monitoring occurring, but either protocol or sampling scope would need change

● Lots of monitoring occuring, little change presumed needed to level of effort, protocol, or scope

Rank Order	Indicator	Ecol. Sign.	Feas.	Mgmt Sign.	Legal	EF Index	# People	BICY	BISC	BUIS	DRTO	EVER	SARI	VIIS
31	Spiny Lobster - population structure, status, and trends	3.87	3.68	5	3	11.43	47		◑	◑	◑	○	○	○
32	Ecotone shifts along wetland boundaries - Mangrove to marsh to cypress- Aerial photography	3.89	3.64	4	3	11.41	44	○	○			◑		
33	Sediment elevation in mangroves and mud banks (Fl Bay) Salt Ponds (USVI) and Mangroves fringes	3.79	3.78	5	3	11.35	42	○	○	○		●	○	○
34	Marine Vertebrates - Rare, threatened, and endangered species - Crocodiles, Dolphin, Manatee, Sea Turtles, Protected marine mammals.	3.90	3.48	3	5	11.28	51	◑	◑	◑	◑	◑	○	◑
35	Physical drivers of mangrove-marsh ecotone	3.80	3.57	4	3	11.17	35		◑			◑		
36	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Seining	3.82	3.49	5	4	11.12	44	○	◑	○	○	◑	○	○
37	Amphibians - South Florida	3.78	3.56	3	2	11.12	37	○	○			○		
38	Fire Return Interval Departure	3.76	3.60	3	2	11.11	37	◑				◑		
39	Goliath Grouper (Red Hind in VI) - population structure, status, and trends	3.71	3.65	5	3	11.07	48		◑	○	◑	●	○	◑
40	Land Birds - residential and migratory	3.74	3.50	2	4	10.97	34	○	◑	◑	○	○	○	◑

Table O.1.1. Indicators plus average rankings sorted by Ecological-Feasibility Index plus levels of existing monitoring estimated to be currently occuring for each indicator by park.

Ecological-Feasibility index =(Average Ecological Rank Score)*2 + (Average Feasibility Score)

○ No monitoring occuring but within indicator geographic scope.

◑ Some monitoring occurring, but either protocol or sampling scope would need change

● Lots of monitoring occuring, little change presumed needed to level of effort, protocol, or scope

Rank Order	Indicator	Ecol. Sign.	Feas.	Mgmt Sign.	Legal	EF Index	# People	BICY	BISC	BUIS	DRTO	EVER	SARI	VIIS
41	Critically Imperiled and Rare Plants:	3.79	3.38	3	3	10.95	42	○	◑	○	○	◑	○	○
42	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Throw trap	3.69	3.52	5	4	10.90	45	○	◑	○	○	◑	○	○
43	Location of Hammock-Pineland ecotone - field plots/transects	3.63	3.63	4	2	10.89	27	○				○		
44	Pink Shrimp population structure, status, and trends	3.72	3.38	5	3	10.83	36		●	○	○	●	○	○
45	Aquatic invertebrates in wet prairies and marshes	3.81	3.16	3	1	10.77	31	◑	○			●		
46	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Trawling	3.67	3.38	5	4	10.72	42	○	◑		○	◑		
47	Land birds - Mangrove - population abundance and distribution	3.66	3.38	2	2	10.69	29	○	○	○	○	○	○	○
48	Bonnethead, Lemon, Bull, Nurse Sharks - population structure, status, and trends	3.70	3.25	5	3	10.65	40		◑		●	●		
49	Florida panther	3.63	3.37	4	5	10.63	30	●				●		
50	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Other trapping	3.67	3.26	5	4	10.61	43	○	◑	○	○	◑	○	○

Table O.1.1. Indicators plus average rankings sorted by Ecological-Feasibility Index plus levels of existing monitoring estimated to be currently occuring for each indicator by park.

Ecological-Feasibility index =(Average Ecological Rank Score)*2 + (Average Feasibility Score)

○ No monitoring occuring but within indicator geographic scope.

◑ Some monitoring occurring, but either protocol or sampling scope would need change

● Lots of monitoring occuring, little change presumed needed to level of effort, protocol, or scope

Rank Order	Indicator	Ecol. Sign.	Feas.	Mgmt Sign.	Legal	EF Index	# People	BICY	BISC	BUIS	DRTO	EVER	SARI	VIIS
51	Gray Snapper (Schoolmaster in VI)- population structure, status, & trends	3.53	3.53	5	3	10.60	45		●	○	◑	◑	○	◑
52	Position and Spatial Extent of Mud Banks, Buttonwood Embankment and Berms	3.50	3.43	5	3	10.43	34	○	○			◑		
53	Oyster population structure, status, and trends	3.47	3.46	5	3	10.40	36		○			○		
54	Spotted Sea Trout - population structure, status, and trends	3.55	3.29	5	3	10.39	31		◑		◑	◑		
55	Landbirds - Pine Rockland - population abundance and distribution.	3.48	3.35	3	2	10.30	23	◑				◑		
56	Phytoplankton composition and biomass	3.49	3.31	4	3	10.29	51		◑		◑	◑		
57	Spatial and temporal changes in extent and distribution of substrate type (marl vs. peat).	3.38	3.30	3	3	10.05	37					○		
58	Snook - population structure, status, and trends	3.35	3.29	5	3	9.99	37	○	●		◑	●		
59	Infaunal benthic community structure and abundance for animals	3.55	2.84	2	1	9.94	40		○			○		
60	Pig Frog (Rana grylio)	3.32	3.20	3	2	9.84	25	○	○			○		

Table O.1.1. Indicators plus average rankings sorted by Ecological-Feasibility Index plus levels of existing monitoring estimated to be currently occuring for each indicator by park.

Ecological-Feasibility index =(Average Ecological Rank Score)*2 + (Average Feasibility Score)

○ No monitoring occuring but within indicator geographic scope.

◑ Some monitoring occurring, but either protocol or sampling scope would need change

● Lots of monitoring occuring, little change presumed needed to level of effort, protocol, or scope

Rank Order	Indicator	Ecol. Sign.	Feas.	Mgmt Sign.	Legal	EF Index	# People	BICY	BISC	BUIS	DRTO	EVER	SARI	VIIS
61	Amphibians - USVI	3.32	3.10	3	2	9.74	31						○	○
62	Landbirds-Cavity-nesting pine rockland birds - Demographics (Fecundity and Survival)	3.18	3.18	3	2	9.55	22	◑				◑		
63	Sawfish- population structure, status, and trends	3.23	2.91	3	5	9.37	35		○		○	◑		
64	Reptiles - USVI	3.06	3.23	2	2	9.36	31			○			○	○
65	Long-term sediment elevation changes in cypress strands and domes	2.97	3.00	1	1	8.93	29	○				○		
66	Florida Box Turtle, Terrapene Carolina bauri	2.86	3.00	1	2	8.71	28	○	○			○		
67	Bats - USVI	2.87	2.70	3	2	8.43	30			○			○	○
68	Butterflies	2.82	2.79	2	5	8.42	33	○	◑	○	○	◑	○	○
69	Island Insects	2.61	2.41	1	1	7.62	28		○	○	○		○	○

Table O.1.2. Distribution of participant scores across ranking categories

Rank Order	Indicator	Ecological Significance							Feasibility						
				# participants/rank							# participants/rank				
		Avg	SD	Very High	High	Med-ium	Low	Very Low	Avg	SD	Very High	High	Med-ium	Low	Very Low
1	Coral Communities	4.77	0.42	47	14				4.28	0.80	29	21	1	1	
2	Exploited Fish Assemblage - Grouper, Snapper, (parrotfish, surgeonfish in USVI)- population structure, status, and trends	4.52	0.78	33	15	3		1	4.33	0.82	25	2	5		1
3	Hydrology = water stage, flow, timing, and duration.	4.55	0.80	43	16	3	1	1	4.19	0.89	29	21	11	3	
4	Seagrass and other SAV cover and community composition	4.48	0.67	37	21	6			4.14	0.79	24	26	13	1	
5	Water Quality- Nutrients characteristics of the marine water bodies	4.33	0.92	35	18	7	2	1	4.08	1.00	26	22	11	2	2
6	Invasive exotic plants	4.36	0.91	42	13	11	3		4.00	1.10	27	22	13	1	4
7	Freshwater Inputs to Estuaries	4.36	0.77	27	24	4		1	3.93	1.02	19	2	13	2	2
8	Marine Invertebrates - Rare, threatened, and endangered species - Acropora, Diadema, Antipathes	4.33	0.88	26	16	4	3		3.98	1.01	17	2	7	4	1
9	Shape, orientation, location, and coverage of vegetation community types	4.30	0.82	22	14	7	1		3.98	0.85	13	19	1	2	
10	Wading birds - Regional South Florida - Systematic Reconnaissance Flights	4.27	0.91	15	1	3	2		3.97	0.89	8	16	3	3	

Table O.1.2. Distribution of participant scores across ranking categories

Rank Order	Indicator	Ecological Significance							Feasibility						
				# participants/rank							# participants/rank				
		Avg	SD	Very High	High	Med-ium	Low	Very Low	Avg	SD	Very High	High	Med-ium	Low	Very Low
11	Spatial and Temporal Salinity Patterns	4.23	0.93	27	2	7	2	1	4.00	0.96	2	19	13	2	1
12	Surface Water Quality- physiochemical surface water characteristics at specific locations.	4.21	0.82	24	22	8	2		3.93	0.84	14	26	12	3	
13	Exploited Inverts (Lobster, Conch, Crabs, Shrimp, Stone Crab, Blue Crab, Clams, Oysters, Sponges, Welks)	4.20	0.86	22	18	8	2		3.94	0.98	16	17	12	2	1
14	Land Development inside/outside the park (within 5 mile radius for USVI parks, radius may be expanded to 75 miles in South Florida)	4.23	1.01	27	16	7	1	2	3.87	1.06	15	24	9	2	3
15	Marine Fish Communities - Coastal Shelf / Deep oceanic - Status, structure, trends	4.22	0.97	24	19	4	3	1	3.86	1.04	15	21	1	3	2
16	Colonial Nesting Birds (e.g. Least terns, pelicans, boobies, roseatte terns, egrets, storks, herons)	4.17	0.97	17	1	8		1	3.94	0.89	1	16	9		1
17	Invasive exotic fauna	4.26	0.88	29	16	1	2		3.68	1.05	14	18	18	4	2
18	Nutrient Loading and Sediment Loading	4.16	0.88	26	25	11	1	1	3.75	0.89	15	22	23	4	
19	Visitor Use (Both commercial and individual/personal use)	3.93	1.18	23	16	7	7	2	4.11	0.99	24	18	9	3	1
20	Early detection, status, and trends of non-indigenous aquatic species.	4.16	1.10	27	12	6	5	1	3.60	1.03	1	19	13	7	1

Table O.1.2. Distribution of participant scores across ranking categories

Rank Order	Indicator	Ecological Significance							Feasibility						
				# participants/rank							# participants/rank				
		Avg	SD	Very High	High	Med-ium	Low	Very Low	Avg	SD	Very High	High	Med-ium	Low	Very Low
21	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Visual Assessment	4.06	1.01	22	14	12	2	1	3.73	1.11	15	14	14	4	2
22	Location of critical ecotones - field plots/transects	3.97	0.90	11	2	4	4		3.85	0.90	8	21	7	2	1
23	Periphyton	4.03	1.05	16	11	8	2	1	3.62	0.95	7	13	14	2	1
24	Freshwater fish and large macro-invertebrates in wet prairies and marshes	4.03	0.78	1	13	9			3.59	1.13	7	12	8	3	2
25	Contaminants in water column, organisms, and sediments.	4.07	0.90	22	24	1	4		3.52	1.11	14	16	19	9	2
26	Long-term, within-community vegetation shifts using permanent plots	3.91	1.01	14	18	6	6		3.82	0.99	1	23	5	5	1
27	Sea Turtles	3.89	0.92	14	26	11	3	1	3.82	0.92	12	26	14	1	2
28	American crocodile (Crocodylus acutus)	3.90	1.01	14	11	13	1	1	3.80	0.97	11	13	14	1	1
29	American alligator (Alligator mississippiensis)	3.85	1.15	12	9	9	1	2	3.88	0.98	9	13	8	1	1
30	Benthic community spatial & temporal changes in extent and distribution - remote sensing	4.02	0.97	22	18	14	2	1	3.47	1.07	1	17	2	5	3

Table O.1.2. Distribution of participant scores across ranking categories

Rank Order	Indicator	Ecological Significance							Feasibility						
				# participants/rank							# participants/rank				
		Avg	SD	Very High	High	Med-ium	Low	Very Low	Avg	SD	Very High	High	Med-ium	Low	Very Low
31	Spiny Lobster - population structure, status, and trends	3.87	1.06	15	18	8	5	1	3.68	1.09	11	19	1	5	2
32	Ecotone shifts along wetland boundaries - Mangrove to marsh to cypress- Aerial photography	3.89	0.87	11	2	1	3		3.64	0.89	6	22	1	6	
33	Sediment elevation in mangroves and mud banks (Fl Bay) Salt Ponds (USVI) and Mangroves fringes	3.79	0.90	1	16	13	3		3.78	1.06	11	16	1	2	2
34	Marine Vertebrates - Rare, threatened, and endangered species - Crocodiles, Dolphin, Manatee, Sea Turtles, Protected marine mammals.	3.90	1.06	18	16	13	2	2	3.48	1.01	8	17	18	5	2
35	Physical drivers of mangrove-marsh ecotone	3.80	0.96	9	13	11	1	1	3.57	1.01	7	11	13	3	1
36	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Seining	3.82	1.08	15	12	12	4	1	3.49	1.10	8	13	13	5	2
37	Amphibians - South Florida	3.78	0.79	8	13	16			3.56	0.84	3	18	12	2	1
38	Fire Return Interval Departure	3.76	0.95	1	11	13	3		3.60	1.17	7	16	6	3	3
39	Goliath Grouper (Red Hind in VI) - population structure, status, and trends	3.71	1.27	17	13	8	7	3	3.65	1.16	12	16	11	4	3
40	Land Birds - residential and migratory	3.74	1.02	9	12	8	5		3.50	0.99	5	13	11	4	1

Table O.1.2. Distribution of participant scores across ranking categories

Rank Order	Indicator	Ecological Significance							Feasibility						
				# participants/rank							# participants/rank				
		Avg	SD	Very High	High	Med-ium	Low	Very Low	Avg	SD	Very High	High	Med-ium	Low	Very Low
41	Critically Imperiled and Rare Plants:	3.79	1.02	12	14	12	3	1	3.38	1.25	1	1	11	8	3
42	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Throw trap	3.69	1.06	13	12	13	7		3.52	0.92	6	16	14	6	
43	Location of Hammock-Pineland ecotone - field plots/transects	3.63	0.74	2	15	8	2		3.63	0.93	4	12	9	1	1
44	Pink Shrimp population structure, status, and trends	3.72	1.06	6	21	5	1	3	3.38	1.07	4	13	12	2	3
45	Aquatic invertebrates in wet prairies and marshes	3.81	1.08	9	12	6	3	1	3.16	1.27	6	6	11	5	4
46	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Trawling	3.67	1.20	14	9	12	5	2	3.38	1.16	6	14	12	3	4
47	Land birds - Mangrove - population abundance and distribution	3.66	0.94	6	1	1	3		3.38	0.90	3	1	11	5	
48	Bonnethead, Lemon, Bull, Nurse Sharks - population structure, status, and trends	3.70	0.82	6	19	12	3		3.25	1.06	4	13	15	5	3
49	Florida panther	3.63	1.07	7	1	9	3	1	3.37	1.10	4	11	9	4	2
50	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Other trapping	3.67	1.04	11	13	14	4	1	3.26	1.06	4	12	15	4	3

Table O.1.2. Distribution of participant scores across ranking categories

Rank Order	Indicator	Ecological Significance							Feasibility						
				# participants/rank							# participants/rank				
		Avg	SD	Very High	High	Med-ium	Low	Very Low	Avg	SD	Very High	High	Med-ium	Low	Very Low
51	Gray Snapper (Schoolmaster in VI)-population structure, status, & trends	3.53	1.06	9	15	13	7	1	3.53	1.10	1	12	13	7	1
52	Position and Spatial Extent of Mud Banks, Buttonwood Embankment and Berms	3.50	1.11	7	11	9	6	1	3.43	1.17	5	15	9	2	4
53	Oyster population structure, status, and trends	3.47	1.23	9	1	8	7	2	3.46	1.09	6	12	11	4	2
54	Spotted Sea Trout - population structure, status, and trends	3.55	0.96	4	14	9	3	1	3.29	0.94	3	9	14	4	1
55	Landbirds - Pine Rockland - population abundance and distribution.	3.48	0.79	2	9	1	2		3.35	0.93	3	6	1	4	
56	Phytoplankton composition and biomass	3.49	1.19	12	15	13	8	3	3.31	1.09	6	19	14	9	3
57	Spatial and temporal changes in extent and distribution of substrate type (marl vs. peat).	3.38	1.19	6	14	8	6	3	3.30	0.97	3	14	12	7	1
58	Snook - population structure, status, and trends	3.35	1.06	6	1	13	7	1	3.29	1.05	5	9	13	7	1
59	Infaunal benthic community structure and abundance for animals	3.55	1.13	6	21	5	5	3	2.84	1.13	1	12	11	8	6
60	Pig Frog (Rana grylio)	3.32	0.95	2	9	1	3	1	3.20	0.87	2	5	15	2	1

Table O.1.2. Distribution of participant scores across ranking categories

Rank Order	Indicator	Ecological Significance							Feasibility						
				# participants/rank							# participants/rank				
		Avg	SD	Very High	High	Med-ium	Low	Very Low	Avg	SD	Very High	High	Med-ium	Low	Very Low
61	Amphibians - USVI	3.32	0.65	1	1	18	2		3.10	0.91	1	9	15	4	2
62	Landbirds-Cavity-nesting pine rockland birds - Demographics (Fecundity and Survival)	3.18	0.96	1	7	11	1	2	3.18	0.96	1	7	11	1	2
63	Sawfish- population structure, status, and trends	3.23	1.17	4	12	11	4	4	2.91	1.09	2	8	15	5	5
64	Reptiles - USVI	3.06	1.00	1	1	13	4	3	3.23	0.90	1	11	14	2	2
65	Long-term sediment elevation changes in cypress strands and domes	2.97	1.12	3	5	12	6	3	3.00	1.11	1	11	9	5	4
66	Florida Box Turtle, Terrapene Carolina bauri	2.86	0.93	1	5	13	7	2	3.00	0.94	1	7	13	5	2
67	Bats - USVI	2.87	0.97	1	6	14	6	3	2.70	0.88		5	14	8	3
68	Butterflies	2.82	1.07	2	6	13	8	4	2.79	1.11	1	9	1	8	5
69	Island Insects	2.61	1.20	1	6	9	5	7	2.41	1.05	1	2	1	8	6

Table O.1.3. Comparison of EF Index, Ecological Only, and EFML Index Rankings

EF Rank	Ecological/Feasibility Weighted EF Index	Ecological Only	Shift	EFML Index	Shift
1	Coral Communities	Coral Communities	-	Coral Communities	-
2	Exploited Fish Assemblage - Grouper, Snapper, (parrotfish, surgeonfish in USVI)- population structure, status, and trends	Hydrology = water stage, flow, timing, and duration.	1	Water Quality- Nutrients characteristics of the marine water bodies	3
3	Hydrology = water stage, flow, timing, and duration.	Exploited Fish Assemblage - Grouper, Snapper, (parrotfish, surgeonfish in USVI)- population structure, status, and trends	-1	Surface Water Quality- physiochemical surface water characteristics at specific locations.	9
4	Seagrass and other SAV cover and community composition	Seagrass and other SAV cover and community composition	-	Colonial Nesting Birds (e.g. Least terns, pelicans, boobies, roseatte terns, egrets, storks, herons)	12
5	Water Quality- Nutrients characteristics of the marine water bodies	Invasive exotic plants	1	Nutrient Loading and Sediment Loading	13
6	Invasive exotic plants	Freshwater Inputs to Estuaries	1	Invasive exotic plants	-
7	Freshwater Inputs to Estuaries	Water Quality- Nutrients characteristics of the marine water bodies	-2	Contaminants in water column, organisms, and sediments.	18
8	Marine Invertebrates - Rare, threatened, and endangered species - Acropora, Diadema, Antipathes	Marine Invertebrates - Rare, threatened, and endangered species - Acropora, Diadema, Antipathes	-	Wading birds - Regional South Florida - Systematic Reconnaissance Flights	2
9	Shape, orientation, location, and coverage of vegetation community types	Shape, orientation, location, and coverage of vegetation community types	-	Exploited Fish Assemblage - Grouper, Snapper, (parrotfish, surgeonfish in USVI)- population structure, status, and trends	-7
10	Wading birds - Regional South Florida - Systematic Reconnaissance Flights	Wading birds - Regional South Florida - Systematic Reconnaissance Flights	-	Marine Fish Communities - Coastal Shelf / Deep oceanic - Status, structure, trends	5
11	Spatial and Temporal Salinity Patterns	Invasive exotic fauna	6	Hydrology = water stage, flow, timing, and duration.	-8
12	Surface Water Quality- physiochemical surface water characteristics at specific locations.	Spatial and Temporal Salinity Patterns	-1	Invasive exotic fauna	5
13	Exploited Inverts (Lobster, Conch, Crabs, Shrimp, Stone Crab, Blue Crab, Clams, Oysters, Sponges, Welks)	Land Development inside/outside the park (within 5 mile radius for USVI parks, radius may be expanded to 75 miles in South Florida)	1	Seagrass and other SAV cover and community composition	-9
14	Land Development inside/outside the park (within 5 mile radius for USVI parks, radius may be expanded to 75 miles in South Florida)	Marine Fish Communities - Coastal Shelf / Deep oceanic - Status, structure, trends	1	Visitor Use (Both commercial and individual/personal use)	5
15	Marine Fish Communities - Coastal Shelf / Deep oceanic - Status, structure, trends	Surface Water Quality- physiochemical surface water characteristics at specific locations.	-3	Early detection, status, and trends of non-indigenous aquatic species.	5

Table O.1.3. Comparison of EF Index, Ecological Only, and EFML Index Rankings

Rank	Ecological/Feasibility Weighted EF Index	Ecological Only	Shift	EFML Index	Shift
16	Colonial Nesting Birds (e.g. Least terns, pelicans, boobies, roseatte terns, egrets, storks, herons)	Exploited Inverts (Lobster, Conch, Crabs, Shrimp, Stone Crab, Blue Crab, Clams, Oysters, Sponges, Welks)	-3	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Visual Assessment	5
17	Invasive exotic fauna	Colonial Nesting Birds (e.g. Least terns, pelicans, boobies, roseatte terns, egrets, storks, herons)	-1	Sea Turtles	1-
18	Nutrient Loading and Sediment Loading	Early detection, status, and trends of non-indigenous aquatic species.	2	Shape, orientation, location, and coverage of vegetation community types	-9
19	Visitor Use (Both commercial and individual/personal use)	Nutrient Loading and Sediment Loading	-1	Benthic community spatial & temporal changes in extent and distribution -remote sensing	11
20	Early detection, status, and trends of non-indigenous aquatic species.	Contaminants in water column, organisms, and sediments.	5	Exploited Inverts (Lobster, Conch, Crabs, Shrimp, Stone Crab, Blue Crab, Clams, Oysters, Sponges, Welks)	-7
21	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Visual Assessment	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Visual Assessment	-	Land Development inside/outside the park (within 5 mile radius for USVI parks, radius may be expanded to 75 miles in South Florida)	-7
22	Location of critical ecotones - field plots/transects	Freshwater fish and large macro-invertebrates in wet prairies and marshes	2	Marine Fish Communities - Bays/Mangroves - Status, structure, trends -	14
23	Periphyton	Periphyton	-	Marine Fish Communities - Bays/Mangroves - Status, structure, trends -	19
24	Freshwater fish and large macro-invertebrates in wet prairies and marshes	Benthic community spatial & temporal changes in extent and distribution -remote sensing	6	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Trawling	22
25	Contaminants in water column, organisms, and sediments.	Location of critical ecotones - field plots/transects	-3	Freshwater Inputs to Estuaries	-18
26	Long-term, within-community vegetation shifts using permanent plots	Visitor Use (Both commercial and individual/personal use)	-7	Freshwater fish and large macro-invertebrates in wet prairies and marshes	-2
27	Sea Turtles	Long-term, within-community vegetation shifts using permanent plots	-1	Marine Invertebrates - Rare, threatened, and endangered species - Acropora, Diadema, Antipathes	-19
28	American crocodile (Crocodylus acutus)	Marine Vertebrates - Rare, threatened, and endangered species - Crocodiles, Dolphin, Manatee, Sea Turtles, Protected marine mammals.	6	Florida panther	21
29	American alligator (Alligator mississippiensis)	American crocodile (Crocodylus acutus)	-1	American crocodile (Crocodylus acutus)	-1
30	Benthic community spatial & temporal changes in extent and distribution -remote sensing	Sea Turtles	-3	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Other trapping	2-

Table O.1.3. Comparison of EF Index, Ecological Only, and EFML Index Rankings

Rank	Ecological/Feasibility Weighted EF Index	Ecological Only	Shift	EFML Index	Shift
31	Spiny Lobster - population structure, status, and trends	Ecotone shifts along wetland boundaries - Mangrove to marsh to cypress- Aerial photography	1	Spatial and Temporal Salinity Patterns	-2-
32	Ecotone shifts along wetland boundaries - Mangrove to marsh to cypress- Aerial photography	Spiny Lobster - population structure, status, and trends	-1	Spiny Lobster - population structure, status, and trends	-1
33	Sediment elevation in mangroves and mud banks (Fl Bay) Salt Ponds (USVI) and Mangroves fringes	American alligator (Alligator mississippiensis)	-4	Sediment elevation in mangroves and mud banks (Fl Bay) Salt Ponds (USVI) and Mangroves fringes	-
34	Marine Vertebrates - Rare, threatened, and endangered species - Crocodiles, Dolphin, Manatee, Sea Turtles, Protected marine mammals.	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Seining	2	Marine Vertebrates - Rare, threatened, and endangered species - Crocodiles, Dolphin, Manatee, Sea Turtles, Protected marine mammals.	-
35	Physical drivers of mangrove-marsh ecotone	Aquatic invertebrates in wet prairies and marshes	1-	Goliath Grouper (Red Hind in VI) - population structure, status, and trends	4
36	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Seining	Physical drivers of mangrove-marsh ecotone	-1	Pink Shrimp population structure, status, and trends	8
37	Amphibians - South Florida	Sediment elevation in mangroves and mud banks (Fl Bay) Salt Ponds (USVI) and Mangroves fringes	-4	Location of critical ecotones - field plots/transects	-15
38	Fire Return Interval Departure	Critically Imperiled and Rare Plants:	3	Periphyton	-15
39	Goliath Grouper (Red Hind in VI) - population structure, status, and trends	Amphibians - South Florida	-2	Bonnethead, Lemon, Bull, Nurse Sharks - population structure, status, and trends	9
40	Land Birds - residential and migratory	Fire Return Interval Departure	-2	Gray Snapper (Schoolmaster in VI)- population structure, status, & trends	11
41	Critically Imperiled and Rare Plants:	Land Birds - residential and migratory	-1	American alligator (Alligator mississippiensis)	-12
42	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Throw trap	Pink Shrimp population structure, status, and trends	2	Position and Spatial Extent of Mud Banks, Buttonwood Embankment and Berms	1-
43	Location of Hammock-Pineland ecotone - field plots/transects	Goliath Grouper (Red Hind in VI) - population structure, status, and trends	-4	Ecotone shifts along wetland boundaries - Mangrove to marsh to cypress- Aerial photography	-11
44	Pink Shrimp population structure, status, and trends	Bonnethead, Lemon, Bull, Nurse Sharks - population structure, status, and trends	4	Oyster population structure, status, and trends	9
45	Aquatic invertebrates in wet prairies and marshes	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Throw trap	-3	Spotted Sea Trout - population structure, status, and trends	9

Table O.1.3. Comparison of EF Index, Ecological Only, and EFML Index Rankings

Rank	Ecological/Feasibility Weighted EF Index	Ecological Only	Shift	EFML Index	Shift
46	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Trawling	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Other trapping	4	Physical drivers of mangrove-marsh ecotone	-11
47	Land birds - Mangrove - population abundance and distribution	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Trawling	-1	Snook - population structure, status, and trends	11
48	Bonnethead, Lemon, Bull, Nurse Sharks - population structure, status, and trends	Land birds - Mangrove - population abundance and distribution	-1	Sawfish- population structure, status, and trends	15
49	Florida panther	Florida panther	-	Phytoplankton composition and biomass	7
50	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Other trapping	Location of Hammock-Pineland ecotone - field plots/transects	-7	Land Birds - residential and migratory	-1-
51	Gray Snapper (Schoolmaster in VI)- population structure, status, & trends	Infaunal benthic community structure and abundance for animals	8	Critically Imperiled and Rare Plants:	-1-
52	Position and Spatial Extent of Mud Banks, Buttonwood Embankment and Berms	Spotted Sea Trout - population structure, status, and trends	2	Location of Hammock-Pineland ecotone - field plots/transects	-9
53	Oyster population structure, status, and trends	Gray Snapper (Schoolmaster in VI)- population structure, status, & trends	-2	Amphibians - South Florida	-16
54	Spotted Sea Trout - population structure, status, and trends	Position and Spatial Extent of Mud Banks, Buttonwood Embankment and Berms	-2	Fire Return Interval Departure	-16
55	Landbirds - Pine Rockland - population abundance and distribution.	Phytoplankton composition and biomass	1	Spatial and temporal changes in extent and distribution of substrate type (marl vs. peat).	2
56	Phytoplankton composition and biomass	Landbirds - Pine Rockland - population abundance and distribution.	-1	Butterflies	12
57	Spatial and temporal changes in extent and distribution of substrate type (marl vs. peat).	Oyster population structure, status, and trends	-4	Landbirds - Pine Rockland - population abundance and distribution.	-2
58	Snook - population structure, status, and trends	Spatial and temporal changes in extent and distribution of substrate type (marl vs. peat).	-1	Pig Frog (Rana grylio)	2
59	Infaunal benthic community structure and abundance for animals	Snook - population structure, status, and trends	-1	Aquatic invertebrates in wet prairies and marshes	-14
60	Pig Frog (Rana grylio)	Amphibians - USVI	1	Amphibians - USVI	1

Table O.1.3. Comparison of EF Index, Ecological Only, and EFML Index Rankings

Rank	Ecological/Feasibility Weighted EF Index	Ecological Only	Shift	EFML Index	Shift
61	Amphibians - USVI	Pig Frog (Rana grylio)	-1	Land birds - Mangrove - population abundance and distribution	-14
62	Landbirds-Cavity-nesting pine rockland birds - Demographics (Fecundity and Survival)	Sawfish- population structure, status, and trends	1	Landbirds-Cavity-nesting pine rockland birds - Demographics (Fecundity and Survival)	-
63	Sawfish- population structure, status, and trends	Landbirds-Cavity-nesting pine rockland birds - Demographics (Fecundity and Survival)	-1	Long-term, within-community vegetation shifts using permanent plots	-37
64	Reptiles - USVI	Reptiles - USVI	-	Bats - USVI	3
65	Long-term sediment elevation changes in cypress strands and domes	Long-term sediment elevation changes in cypress strands and domes	-	Reptiles - USVI	-1
66	Florida Box Turtle, Terrapene Carolina bauri	Bats - USVI	1	Infaunal benthic community structure and abundance for animals	-7
67	Bats - USVI	Florida Box Turtle, Terrapene Carolina bauri	-1	Florida Box Turtle, Terrapene Carolina bauri	-1
68	Butterflies	Butterflies	-	Long-term sediment elevation changes in cypress strands and domes	-3
69	Island Insects	Island Insects	-	Island Insects	-

Table O.1.4a. Bays & Marine areas indicators. Indicators that spend all or most of their life in the sub-tidal zone or below. Includes crocodiles, sea turtles, and manatees.

Bays/ Marine rank	Origi-nal Rank	Indicator
1	1	Coral Communities
2	2	Exploited Fish Assemblage - Grouper, Snapper, (parrotfish, surgeonfish in USVI)- population structure, status, and trends
3	4	Seagrass and other SAV cover and community composition
4	5	Water Quality- Nutrients characteristics of the marine water bodies
5	7	Freshwater Inputs to Estuaries
6	8	Marine Invertebrates - Rare, threatened, and endangered species - Acropora, Diadema, Antipathes
7	11	Spatial and Temporal Salinity Patterns
8	13	Exploited Inverts (Lobster, Conch, Crabs, Shrimp, Stone Crab, Blue Crab, Clams, Oysters, Sponges, Welks)
9	15	Marine Fish Communities - Coastal Shelf / Deep oceanic - Status, structure, trends
10	18	Nutrient Loading and Sediment Loading

Table O.1.4b. Uplands and wetlands indicators. From inter-tidal zone inland including mangroves and emergent tidal vegetation.

Uplands/ Wetlands Rank	Origi-nal Rank	Indicator
1	3	Hydrology = water stage, flow, timing, and duration.
2	6	Invasive exotic plants
3	9	Shape, orientation, location, and coverage of vegetation community types
4	10	Wading birds - Regional South Florida - Systematic Reconnaissance Flights
5	12	Surface Water Quality- physiochemical surface water characteristics at specific locations.
6	14	Land Development inside/outside the park (within 5 mile radius for USVI parks, radius may be expanded to 75 miles in South Florida)
7	16	Colonial Nesting Birds (e.g. Least terns, pelicans, boobies, roseatte terns, egrets, storks, herons)
8	17	Invasive exotic fauna
9	18	Nutrient Loading and Sediment Loading
10	19	Visitor Use (Both commercial and individual/personal use)

Table O.1.4a. Bays & Marine areas indicators. Indicators that spend all or most of their life in the sub-tidal zone or below. Includes crocodiles, sea turtles, and manatees.

Bays/ Marine rank	Origi-nal Rank	Indicator
11	19	Visitor Use (Both commercial and individual/personal use)
12	21	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Visual Assessment
13	25	Contaminants in water column, organisms, and sediments.
14	27	Sea Turtles
15	28	American crocodile (Crocodylus acutus)
16	30	Benthic community spatial & temporal changes in extent and distribution -remote sensing
17	31	Spiny Lobster - population structure, status, and trends
18	34	Marine Vertebrates - Rare, threatened, and endangered species - Crocodiles, Dolphin, Manatee, Sea Turtles, Protected marine mammals.
19	36	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Seining
20	39	Goliath Grouper (Red Hind in VI) - population structure, status, and trends

Table O.1.4b. Uplands and wetlands indicators. From inter-tidal zone inland including mangroves and emergent tidal vegetation.

Uplands/ Wetlands Rank	Origi-nal Rank	Indicator
11	20	Early detection, status, and trends of non-indigenous aquatic species.
12	22	Location of critical ecotones - field plots/transects
13	23	Periphyton
14	24	Freshwater fish and large macro-invertebrates in wet prairies and marshes
15	25	Contaminants in water column, organisms, and sediments.
16	26	Long-term, within-community vegetation shifts using permanent plots
17	29	American alligator (Alligator mississippiensis)
18	32	Ecotone shifts along wetland boundaries - Mangrove to marsh to cypress- Aerial photography
19	33	Sediment elevation in mangroves and mud banks (Fl Bay) Salt Ponds (USVI) and Mangroves fringes
20	35	Physical drivers of mangrove-marsh ecotone

Table O.1.4a. Bays & Marine areas indicators. Indicators that spend all or most of their life in the sub-tidal zone or below. Includes crocodiles, sea turtles, and manatees.

Bays/ Marine rank	Origi-nal Rank	Indicator
21	42	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Throw trap
22	44	Pink Shrimp population structure, status, and trends
23	46	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Trawling
24	48	Bonnethead, Lemon, Bull, Nurse Sharks - population structure, status, and trends
25	50	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Other trapping
26	51	Gray Snapper (Schoolmaster in VI)- population structure, status, & trends
27	53	Oyster population structure, status, and trends
28	54	Spotted Sea Trout - population structure, status, and trends
29	56	Phytoplankton composition and biomass
30	58	Snook - population structure, status, and trends
31	59	Infaunal benthic community structure and abundance for animals
32	63	Sawfish- population structure, status, and trends

Table O.1.4b. Uplands and wetlands indicators. From inter-tidal zone inland including mangroves and emergent tidal vegetation.

Uplands/ Wetlands Rank	Origi-nal Rank	Indicator
21	37	Amphibians - South Florida
22	38	Fire Return Interval Departure
23	40	Land Birds - residential and migratory
24	41	Critically Imperiled and Rare Plants:
25	43	Location of Hammock-Pineland ecotone - field plots/transects
26	45	Aquatic invertebrates in wet prairies and marshes
27	47	Land birds - Mangrove - population abundance and distribution
28	49	Florida panther
29	52	Position and Spatial Extent of Mud Banks, Buttonwood Embankment and Berms
30	55	Landbirds - Pine Rockland - population abundance and distribution.
31	57	Spatial and temporal changes in extent and distribution of substrate type (marl vs. peat).
32	60	Pig Frog (Rana grylio)

Table O.1.4a. Bays & Marine areas indicators. Indicators that spend all or most of their life in the sub-tidal zone or below. Includes crocodiles, sea turtles, and manatees.

Bays/ Marine rank	Original Rank	Indicator

Table O.1.4b. Uplands and wetlands indicators. From inter-tidal zone inland including mangroves and emergent tidal vegetation.

Uplands/ Wetlands Rank	Original Rank	Indicator
33	61	Amphibians - USVI
34	62	Landbirds-Cavity-nesting pine rockland birds - Demographics (Fecundity and Survival)
35	64	Reptiles - USVI
36	65	Long-term sediment elevation changes in cypress strands and domes
37	66	Florida Box Turtle, Terrapene Carolina bauri
38	67	Bats - USVI
39	68	Butterflies
40	69	Island Insects

Table O.1.5a. Florida Ranks. Ranking of Florida indicators by participants with S. Florida specialty (does not include USVI only indicators)

Florida Rank	Original Rank	Indicator
1	3	Hydrology = water stage, flow, timing, and duration.
2	1	Coral Communities
3	6	Invasive exotic plants
4	4	Seagrass and other SAV cover and community composition
5	2	Exploited Fish Assemblage - Grouper, Snapper, (parrotfish, surgeonfish in USVI)- population structure, status, and trends
6	11	Spatial and Temporal Salinity Patterns
7	5	Water Quality- Nutrients characteristics of the marine water bodies
8	12	Surface Water Quality- physiochemical surface water characteristics at specific locations.
9	9	Shape, orientation, location, and coverage of vegetation community types
10	17	Invasive exotic fauna

Table O.1.5b. Caribbean Ranks. Ranking of USVI indicators by participants with Caribbean specialty (does not include Florida only indicators)

USVI Rank	Original Rank	Indicator
1	1	Coral Communities
2	2	Exploited Fish Assemblage - Grouper, Snapper, (parrotfish, surgeonfish in USVI)- population structure, status, and trends
3	5	Water Quality- Nutrients characteristics of the marine water bodies
4	19	Visitor Use (Both commercial and individual/personal use)
5	14	Land Development inside/outside the park (within 5 mile radius for USVI parks, radius may be expanded to 75 miles in South Florida)
6	15	Marine Fish Communities - Coastal Shelf / Deep oceanic - Status, structure, trends
7	8	Marine Invertebrates - Rare, threatened, and endangered species - Acropora, Diadema, Antipathes
8	16	Colonial Nesting Birds (e.g. Least terns, pelicans, boobies, roseatte terns, egrets, storks, herons)
9	25	Contaminants in water column, organisms, and sediments.
10	4	Seagrass and other SAV cover and community composition

Table O.1.5a. Florida Ranks. Ranking of Florida indicators by participants with S. Florida specialty (does not include USVI only indicators)

Florida Rank	Original Rank	Indicator
11	7	Freshwater Inputs to Estuaries
12	10	Wading birds - Regional South Florida - Systematic Reconnaissance Flights
13	14	Land Development inside/outside the park (within 5 mile radius for USVI parks, radius may be expanded to 75 miles in South Florida)
14	20	Early detection, status, and trends of non-indigenous aquatic species.
15	8	Marine Invertebrates - Rare, threatened, and endangered species - Acropora, Diadema, Antipathes
16	16	Colonial Nesting Birds (e.g. Least terns, pelicans, boobies, roseatte terns, egrets, storks, herons)
17	28	American crocodile (Crocodylus acutus)
18	23	Periphyton
19	29	American alligator (Alligator mississippiensis)
20	18	Nutrient Loading and Sediment Loading

Table O.1.5b. Caribbean Ranks. Ranking of USVI indicators by participants with Caribbean specialty (does not include Florida only indicators)

USVI Rank	Original Rank	Indicator
11	13	Exploited Inverts (Lobster, Conch, Crabs, Shrimp, Stone Crab, Blue Crab, Clams, Oysters, Sponges, Welks)
12	18	Nutrient Loading and Sediment Loading
13	21	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Visual Assessment
14	7	Freshwater Inputs to Estuaries
15	33	Sediment elevation in mangroves and mud banks (Fl Bay) Salt Ponds (USVI) and Mangroves fringes
16	12	Surface Water Quality- physiochemical surface water characteristics at specific locations.
17	6	Invasive exotic plants
18	40	Land Birds - residential and migratory
19	3	Hydrology = water stage, flow, timing, and duration.
20	17	Invasive exotic fauna

Table O.1.5a. Florida Ranks. Ranking of Florida indicators by participants with S. Florida specialty (does not include USVI only indicators)

Florida Rank	Original Rank	Indicator
21	26	Long-term, within-community vegetation shifts using permanent plots
22	24	Freshwater fish and large macro-invertebrates in wet prairies and marshes
23	45	Aquatic invertebrates in wet prairies and marshes
24	34	Marine Vertebrates - Rare, threatened, and endangered species - Crocodiles, Dolphin, Manatee, Sea Turtles, Protected marine mammals.
25	27	Sea Turtles
26	22	Location of critical ecotones - field plots/transects
27	25	Contaminants in water column, organisms, and sediments.
28	35	Physical drivers of mangrove-marsh ecotone
29	15	Marine Fish Communities - Coastal Shelf / Deep oceanic - Status, structure, trends
30	13	Exploited Inverts (Lobster, Conch, Crabs, Shrimp, Stone Crab, Blue Crab, Clams, Oysters, Sponges, Welks)

Table O.1.5b. Caribbean Ranks. Ranking of USVI indicators by participants with Caribbean specialty (does not include Florida only indicators)

USVI Rank	Original Rank	Indicator
21	42	Marine Fish Communities-Bays/Mangroves - Status, structure, trends - Throw trap
22	30	Benthic community spatial & temporal changes in extent and distribution -remote sensing
23	27	Sea Turtles
24	44	Pink Shrimp population structure, status, and trends
25	31	Spiny Lobster - population structure, status, and trends
26	50	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Other trapping
27	11	Spatial and Temporal Salinity Patterns
28	36	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Seining
29	39	Goliath Grouper (Red Hind in VI) - population structure, status, and trends
30	34	Marine Vertebrates - Rare, threatened, and endangered species - Crocodiles, Dolphin, Manatee, Sea Turtles, Protected marine mammals.

Table O.1.5a. Florida Ranks. Ranking of Florida indicators by participants with S. Florida specialty (does not include USVI only indicators)

Florida Rank	Original Rank	Indicator
31	37	Amphibians - South Florida
32	21	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Visual Assessment
33	41	Critically Imperiled and Rare Plants:
34	38	Fire Return Interval Departure
35	32	Ecotone shifts along wetland boundaries - Mangrove to marsh to cypress- Aerial photography
36	31	Spiny Lobster - population structure, status, and trends
37	49	Florida panther
38	19	Visitor Use (Both commercial and individual/personal use)
39	30	Benthic community spatial & temporal changes in extent and distribution -remote sensing
40	53	Oyster population structure, status, and trends

Table O.1.5b. Caribbean Ranks. Ranking of USVI indicators by participants with Caribbean specialty (does not include Florida only indicators)

USVI Rank	Original Rank	Indicator
31	47	Land birds - Mangrove - population abundance and distribution
32	22	Location of critical ecotones - field plots/transects
33	26	Long-term, within-community vegetation shifts using permanent plots
34	46	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Trawling
35	41	Critically Imperiled and Rare Plants:
36	67	Bats - USVI
37	51	Gray Snapper (Schoolmaster in VI)- population structure, status, & trends
38	61	Amphibians - USVI
39	68	Butterflies
40	64	Reptiles - USVI

Table O.1.5a. Florida Ranks. Ranking of Florida indicators by participants with S. Florida specialty (does not include USVI only indicators)

Florida Rank	Original Rank	Indicator
41	36	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Seining
42	47	Land birds - Mangrove - population abundance and distribution
43	43	Location of Hammock-Pineland ecotone - field plots/transects
44	40	Land Birds - residential and migratory
45	39	Goliath Grouper (Red Hind in VI) - population structure, status, and trends
46	55	Landbirds - Pine Rockland - population abundance and distribution.
47	46	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Trawling
48	42	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Throw trap
49	54	Spotted Sea Trout - population structure, status, and trends
50	57	Spatial and temporal changes in extent and distribution of substrate type (marl vs. peat).

Table O.1.5b. Caribbean Ranks. Ranking of USVI indicators by participants with Caribbean specialty (does not include Florida only indicators)

USVI Rank	Original Rank	Indicator
41	69	Island Insects

Table O.1.5a. Florida Ranks. Ranking of Florida indicators by participants with S. Florida specialty (does not include USVI only indicators)

Florida Rank	Original Rank	Indicator
51	33	Sediment elevation in mangroves and mud banks (Fl Bay) Salt Ponds (USVI) and Mangroves fringes
52	59	Infaunal benthic community structure and abundance for animals
53	56	Phytoplankton composition and biomass
54	58	Snook - population structure, status,& trends
55	48	Bonnethead, Lemon, Bull, Nurse Sharks - population structure, status, and trends
56	44	Pink Shrimp population structure, status, and trends
57	50	Marine Fish Communities-Bays/Mangroves - Status, structure, trends - Other trapping
58	51	Gray Snapper (Schoolmaster in VI)- population structure, status, & trends
59	52	Position and Spatial Extent of Mud Banks, Buttonwood Embankment and Berms
60	62	Landbirds-Cavity-nesting pine rockland birds - Demographics (Fecundity and Survival)
61	60	Pig Frog (Rana grylio)
62	63	Sawfish- population structure, status, and trends
63	65	Long-term sediment elevation changes in cypress strands and domes
64	68	Butterflies
65	66	Florida Box Turtle, Terrapene Carolina bauri
66	69	Island Insects

Table O.1.5b. Caribbean Ranks. Ranking of USVI indicators by participants with Caribbean specialty (does not include Florida only indicators)

USVI Rank	Original Rank	Indicator

Table O.1.6. NPS staff only rankings

NPS only rank	Original Rank	Indicator
1	3	Hydrology = water stage, flow, timing, and duration.
2	1	Coral Communities
3	4	Seagrass and other SAV cover and community composition
4	6	Invasive exotic plants
5	16	Colonial Nesting Birds (e.g. Least terns, pelicans, boobies, roseatte terns, egrets, storks, herons)
6	10	Wading birds - Regional South Florida - Systematic Reconnaissance Flights
7	17	Invasive exotic fauna
8	11	Spatial and Temporal Salinity Patterns
9	12	Surface Water Quality- physiochemical surface water characteristics at specific locations.
10	20	Early detection, status, and trends of non-indigenous aquatic species.

Table O.1.6b. Non-park staff only rankings.

Non-NPS rank	Original Rank	Indicator
1	2	Exploited Fish Assemblage - Grouper, Snapper, (parrotfish, surgeonfish in USVI)- population structure, status, and trends
2	1	Coral Communities
3	8	Marine Invertebrates - Rare, threatened, and endangered species - Acropora, Diadema, Antipathes
4	5	Water Quality- Nutrients characteristics of the marine water bodies
5	4	Seagrass and other SAV cover and community composition
6	7	Freshwater Inputs to Estuaries
7	9	Shape, orientation, location, and coverage of vegetation community types
8	3	Hydrology = water stage, flow, timing, and duration.
9	15	Marine Fish Communities - Coastal Shelf / Deep oceanic - Status, structure, trends
10	19	Visitor Use (Both commercial and individual/personal use)

Table O.1.6. NPS staff only rankings

NPS only rank	Original Rank	Indicator
11	2	Exploited Fish Assemblage - Grouper, Snapper, (parrotfish, surgeonfish in USVI)- population structure, status, and trends
12	7	Freshwater Inputs to Estuaries
13	5	Water Quality- Nutrients characteristics of the marine water bodies
14	26	Long-term, within-community vegetation shifts using permanent plots
15	9	Shape, orientation, location, and coverage of vegetation community types
16	8	Marine Invertebrates - Rare, threatened, and endangered species - Acropora, Diadema, Antipathes
17	14	Land Development inside/outside the park (within 5 mile radius for USVI parks, radius may be expanded to 75 miles in South Florida)
18	27	Sea Turtles
19	18	Nutrient Loading and Sediment Loading
20	13	Exploited Inverts (Lobster, Conch, Crabs, Shrimp, Stone Crab, Blue Crab, Clams, Oysters, Sponges, Welks)

Table O.1.6b. Non-park staff only rankings.

Non-NPS rank	Original Rank	Indicator
11	6	Invasive exotic plants
12	13	Exploited Inverts (Lobster, Conch, Crabs, Shrimp, Stone Crab, Blue Crab, Clams, Oysters, Sponges, Welks)
13	14	Land Development inside/outside the park (within 5 mile radius for USVI parks, radius may be expanded to 75 miles in South Florida)
14	11	Spatial and Temporal Salinity Patterns
15	10	Wading birds - Regional South Florida - Systematic Reconnaissance Flights
16	12	Surface Water Quality- physiochemical surface water characteristics at specific locations.
17	21	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Visual Assessment
18	18	Nutrient Loading and Sediment Loading
19	22	Location of critical ecotones - field plots/transects
20	17	Invasive exotic fauna

Table O.1.6. NPS staff only rankings

NPS only rank	Original Rank	Indicator
21	30	Benthic community spatial & temporal changes in extent and distribution -remote sensing
22	24	Freshwater fish and large macro-invertebrates in wet prairies and marshes
23	23	Periphyton
24	15	Marine Fish Communities - Coastal Shelf / Deep oceanic - Status, structure, trends
25	25	Contaminants in water column, organisms, and sediments.
26	22	Location of critical ecotones - field plots/transects
27	28	American crocodile (Crocodylus acutus)
28	34	Marine Vertebrates - Rare, threatened, and endangered species - Crocodiles, Dolphin, Manatee, Sea Turtles, Protected marine mammals.
29	29	American alligator (Alligator mississippiensis)
30	33	Sediment elevation in mangroves and mud banks (Fl Bay) Salt Ponds (USVI) and Mangroves fringes

Table O.1.6b. Non-park staff only rankings.

Non-NPS rank	Original Rank	Indicator
21	36	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Seining
22	16	Colonial Nesting Birds (e.g. Least terns, pelicans, boobies, roseatte terns, egrets, storks, herons)
23	29	American alligator (Alligator mississippiensis)
24	28	American crocodile (Crocodylus acutus)
25	25	Contaminants in water column, organisms, and sediments.
26	31	Spiny Lobster - population structure, status, and trends
27	23	Periphyton
28	44	Pink Shrimp population structure, status, and trends
29	24	Freshwater fish and large macro-invertebrates in wet prairies and marshes
30	20	Early detection, status, and trends of non-indigenous aquatic species.

Table O.1.6. NPS staff only rankings

NPS only rank	Original Rank	Indicator
31	32	Ecotone shifts along wetland boundaries - Mangrove to marsh to cypress- Aerial photography
32	21	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Visual Assessment
33	47	Land birds - Mangrove - population abundance and distribution
34	31	Spiny Lobster - population structure, status, and trends
35	38	Fire Return Interval Departure
36	19	Visitor Use (Both commercial and individual/personal use)
37	40	Land Birds - residential and migratory
38	37	Amphibians - South Florida
39	45	Aquatic invertebrates in wet prairies and marshes
40	39	Goliath Grouper (Red Hind in VI) - population structure, status, and trends

Table O.1.6b. Non-park staff only rankings.

Non-NPS rank	Original Rank	Indicator
31	46	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Trawling
32	32	Ecotone shifts along wetland boundaries - Mangrove to marsh to cypress- Aerial photography
33	35	Physical drivers of mangrove-marsh ecotone
34	33	Sediment elevation in mangroves and mud banks (Fl Bay) Salt Ponds (USVI) and Mangroves fringes
35	37	Amphibians - South Florida
36	27	Sea Turtles
37	38	Fire Return Interval Departure
38	30	Benthic community spatial & temporal changes in extent and distribution -remote sensing
39	39	Goliath Grouper (Red Hind in VI) - population structure, status, and trends
40	43	Location of Hammock-Pineland ecotone - field plots/transects

Table O.1.6. NPS staff only rankings

NPS only rank	Original Rank	Indicator
41	41	Critically Imperiled and Rare Plants:
42	35	Physical drivers of mangrove-marsh ecotone
43	43	Location of Hammock-Pineland ecotone - field plots/transects
44	57	Spatial and temporal changes in extent and distribution of substrate type (marl vs. peat).
45	42	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Throw trap
46	55	Landbirds - Pine Rockland - population abundance and distribution.
47	49	Florida panther
48	64	Reptiles - USVI
49	59	Infaunal benthic community structure and abundance for animals
50	50	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Other trapping

Table O.1.6b. Non-park staff only rankings.

Non-NPS rank	Original Rank	Indicator
41	34	Marine Vertebrates - Rare, threatened, and endangered species - Crocodiles, Dolphin, Manatee, Sea Turtles, Protected marine mammals.
42	42	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Throw trap
43	51	Gray Snapper (Schoolmaster in VI)- population structure, status, & trends
44	48	Bonnethead, Lemon, Bull, Nurse Sharks - population structure, status, and trends
45	40	Land Birds - residential and migratory
46	41	Critically Imperiled and Rare Plants:
47	26	Long-term, within-community vegetation shifts using permanent plots
48	54	Spotted Sea Trout - population structure, status, and trends
49	53	Oyster population structure, status, and trends
50	50	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Other trapping

Table O.1.6. NPS staff only rankings

NPS only rank	Original Rank	Indicator
51	36	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Seining
52	44	Pink Shrimp population structure, status, and trends
53	62	Landbirds-Cavity-nesting pine rockland birds - Demographics (Fecundity and Survival)
54	48	Bonnethead, Lemon, Bull, Nurse Sharks - population structure, status, and trends
55	60	Pig Frog (Rana grylio)
56	52	Position and Spatial Extent of Mud Banks, Buttonwood Embankment and Berms
57	61	Amphibians - USVI
58	56	Phytoplankton composition and biomass
59	54	Spotted Sea Trout - population structure, status, and trends
60	51	Gray Snapper (Schoolmaster in VI)- population structure, status, & trends

Table O.1.6b. Non-park staff only rankings.

Non-NPS rank	Original Rank	Indicator
51	49	Florida panther
52	45	Aquatic invertebrates in wet prairies and marshes
53	52	Position and Spatial Extent of Mud Banks, Buttonwood Embankment and Berms
54	58	Snook - population structure, status, and trends
55	56	Phytoplankton composition and biomass
56	47	Land birds - Mangrove - population abundance and distribution
57	55	Landbirds - Pine Rockland - population abundance and distribution.
58	60	Pig Frog (Rana grylio)
59	63	Sawfish- population structure, status, and trends
60	61	Amphibians - USVI

Table O.1.6. NPS staff only rankings

NPS only rank	Original Rank	Indicator
61	53	Oyster population structure, status, and trends
62	46	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Trawling
63	58	Snook - population structure, status, and trends
64	68	Butterflies
65	67	Bats - USVI
66	63	Sawfish- population structure, status, and trends
67	69	Island Insects
68	66	Florida Box Turtle, Terrapene Carolina bauri
69	65	Long-term sediment elevation changes in cypress strands and domes

Table O.1.6b. Non-park staff only rankings.

Non-NPS rank	Original Rank	Indicator
61	59	Infaunal benthic community structure and abundance for animals
62	57	Spatial and temporal changes in extent and distribution of substrate type (marl vs. peat).
63	65	Long-term sediment elevation changes in cypress strands and domes
64	62	Landbirds-Cavity-nesting pine rockland birds - Demographics (Fecundity and Survival)
65	66	Florida Box Turtle, Terrapene Carolina bauri
66	64	Reptiles - USVI
67	67	Bats - USVI
68	68	Butterflies
69	69	Island Insects

Table O.1.7a. Big Cypress National Preserve Indicators. Includes only indicators for which the BICY box was checked on the indicator worksheet.

BICY rank	Original Rank	Indicator
1	3	Hydrology = water stage, flow, timing, and duration.
2	6	Invasive exotic plants
3	7	Freshwater Inputs to Estuaries
4	9	Shape, orientation, location, and coverage of vegetation community types
5	10	Wading birds - Regional South Florida - Systematic Reconnaissance Flights
6	12	Surface Water Quality- physiochemical surface water characteristics at specific locations.
7	14	Land Development inside/outside the park (within 5 mile radius for USVI parks, radius may be expanded to 75 miles in South Florida)
8	16	Colonial Nesting Birds (e.g. Least terns, pelicans, boobies, roseatte terns, egrets, storks, herons)
9	17	Invasive exotic fauna
10	19	Visitor Use (Both commercial and individual/personal use)
11	20	Early detection, status, and trends of non-indigenous aquatic species.
12	21	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Visual Assessment
13	22	Location of critical ecotones - field plots/transects
14	23	Periphyton
15	24	Freshwater fish and large macro-invertebrates in wet prairies and marshes
16	25	Contaminants in water column, organisms, and sediments.
17	26	Long-term, within-community vegetation shifts using permanent plots
18	29	American alligator (Alligator mississippiensis)
19	32	Ecotone shifts along wetland boundaries - Mangrove to marsh to cypress- Aerial photography
20	33	Sediment elevation in mangroves and mud banks (Fl Bay) Salt Ponds (USVI) and Mangroves fringes

Table O.1.7a. Big Cypress National Preserve Indicators. Includes only indicators for which the BICY box was checked on the indicator worksheet.

BICY rank	Original Rank	Indicator
21	34	Marine Vertebrates - Rare, threatened, and endangered species - Crocodiles, Dolphin, Manatee, Sea Turtles, Protected marine mammals.
22	36	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Seining
23	37	Amphibians - South Florida
24	38	Fire Return Interval Departure
25	40	Land Birds - residential and migratory
26	41	Critically Imperiled and Rare Plants:
27	42	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Throw trap
28	43	Location of Hammock-Pineland ecotone - field plots/transects
29	45	Aquatic invertebrates in wet prairies and marshes
30	46	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Trawling
31	47	Land birds - Mangrove - population abundance and distribution
32	49	Florida panther
33	50	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Other trapping
34	52	Position and Spatial Extent of Mud Banks, Buttonwood Embankment and Berms
35	55	Landbirds - Pine Rockland - population abundance and distribution.
36	58	Snook - population structure, status, and trends
37	60	Pig Frog (Rana grylio)
38	62	Landbirds-Cavity-nesting pine rockland birds - Demographics (Fecundity and Survival)
39	65	Long-term sediment elevation changes in cypress strands and domes
40	66	Florida Box Turtle, Terrapene Carolina bauri
41	68	Butterflies

Table O.1.7b. Biscayne National Park Indicators. Includes only indicators for which the BISC box was checked on the indicator worksheet.

BISC rank	Original Rank	Indicator
1	1	Coral Communities
2	2	Exploited Fish Assemblage - Grouper, Snapper, (parrotfish, surgeonfish in USVI)- population structure, status, and trends
3	3	Hydrology = water stage, flow, timing, and duration.
4	4	Seagrass and other SAV cover and community composition
5	5	Water Quality- Nutrients characteristics of the marine water bodies
6	6	Invasive exotic plants
7	7	Freshwater Inputs to Estuaries
8	8	Marine Invertebrates - Rare, threatened, and endangered species - Acropora, Diadema, Antipathes
9	9	Shape, orientation, location, and coverage of vegetation community types
10	11	Spatial and Temporal Salinity Patterns
11	13	Exploited Inverts (Lobster, Conch, Crabs, Shrimp, Stone Crab, Blue Crab, Clams, Oysters, Sponges, Welks)
12	14	Land Development inside/outside the park (within 5 mile radius for USVI parks, radius may be expanded to 75 miles in South Florida)
13	15	Marine Fish Communities - Coastal Shelf / Deep oceanic - Status, structure, trends
14	16	Colonial Nesting Birds (e.g. Least terns, pelicans, boobies, roseatte terns, egrets, storks, herons)
15	17	Invasive exotic fauna
16	18	Nutrient Loading and Sediment Loading
17	19	Visitor Use (Both commercial and individual/personal use)
18	21	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Visual Assessment
19	22	Location of critical ecotones - field plots/transects
20	23	Periphyton

Table O.1.7c. Buck Island Reef National Monument Indicators. Includes only indicators for which the BUIS box was checked on the indicator worksheet.

BUIS rank	Original Rank	Indicator
1	1	Coral Communities
2	2	Exploited Fish Assemblage - Grouper, Snapper, (parrotfish, surgeonfish in USVI)- population structure, status, and trends
3	4	Seagrass and other SAV cover and community composition
4	5	Water Quality- Nutrients characteristics of the marine water bodies
5	6	Invasive exotic plants
6	8	Marine Invertebrates - Rare, threatened, and endangered species - Acropora, Diadema, Antipathes
7	11	Spatial and Temporal Salinity Patterns
8	12	Surface Water Quality- physiochemical surface water characteristics at specific locations.
9	13	Exploited Inverts (Lobster, Conch, Crabs, Shrimp, Stone Crab, Blue Crab, Clams, Oysters, Sponges, Welks)
10	14	Land Development inside/outside the park (within 5 mile radius for USVI parks, radius may be expanded to 75 miles in South Florida)
11	15	Marine Fish Communities - Coastal Shelf / Deep oceanic - Status, structure, trends
12	16	Colonial Nesting Birds (e.g. Least terns, pelicans, boobies, roseatte terns, egrets, storks, herons)
13	17	Invasive exotic fauna
14	19	Visitor Use (Both commercial and individual/personal use)
15	21	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Visual Assessment
16	22	Location of critical ecotones - field plots/transects
17	25	Contaminants in water column, organisms, and sediments.
18	26	Long-term, within-community vegetation shifts using permanent plots
19	27	Sea Turtles
20	30	Benthic community spatial & temporal changes in extent and distribution -remote sensing

Table O.1.7c. Buck Island Reef National Monument Indicators. Includes only indicators for which the BUIS box was checked on the indicator worksheet.

BUIS rank	Original Rank	Indicator
21	31	Spiny Lobster - population structure, status, and trends
22	33	Sediment elevation in mangroves and mud banks (Fl Bay) Salt Ponds (USVI) and Mangroves fringes
23	34	Marine Vertebrates - Rare, threatened, and endangered species - Crocodiles, Dolphin, Manatee, Sea Turtles, Protected marine mammals.
24	36	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Seining
25	39	Goliath Grouper (Red Hind in VI) - population structure, status, and trends
26	40	Land Birds - residential and migratory
27	41	Critically Imperiled and Rare Plants:
28	42	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Throw trap
29	44	Pink Shrimp population structure, status, and trends
30	47	Land birds - Mangrove - population abundance and distribution
31	50	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Other trapping
32	51	Gray Snapper (Schoolmaster in VI)- population structure, status, & trends
33	64	Reptiles - USVI
34	67	Bats - USVI
35	68	Butterflies
36	69	Island Insects

Table O.1.7d. Dry Tortugas National Park Indicators. Includes only indicators for which the DRTO box was checked on the indicator worksheet.

DRTO rank	Original Rank	Indicator
1	1	Coral Communities
2	2	Exploited Fish Assemblage - Grouper, Snapper, (parrotfish, surgeonfish in USVI)- population structure, status, and trends
3	3	Hydrology = water stage, flow, timing, and duration.
4	4	Seagrass and other SAV cover and community composition
5	5	Water Quality- Nutrients characteristics of the marine water bodies
6	6	Invasive exotic plants
7	8	Marine Invertebrates - Rare, threatened, and endangered species - Acropora, Diadema, Antipathes
8	9	Shape, orientation, location, and coverage of vegetation community types
9	13	Exploited Inverts (Lobster, Conch, Crabs, Shrimp, Stone Crab, Blue Crab, Clams, Oysters, Sponges, Welks)
10	14	Land Development inside/outside the park (within 5 mile radius for USVI parks, radius may be expanded to 75 miles in South Florida)
11	15	Marine Fish Communities - Coastal Shelf / Deep oceanic - Status, structure, trends
12	16	Colonial Nesting Birds (e.g. Least terns, pelicans, boobies, roseatte terns, egrets, storks, herons)
13	17	Invasive exotic fauna
14	19	Visitor Use (Both commercial and individual/personal use)
15	21	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Visual Assessment
16	22	Location of critical ecotones - field plots/transects
17	25	Contaminants in water column, organisms, and sediments.
18	26	Long-term, within-community vegetation shifts using permanent plots
19	27	Sea Turtles
20	30	Benthic community spatial & temporal changes in extent and distribution -remote sensing

Table O.1.7d. Dry Tortugas National Park Indicators. Includes only indicators for which the DRTO box was checked on the indicator worksheet.

DRTO rank	Original Rank	Indicator
21	31	Spiny Lobster - population structure, status, and trends
22	34	Marine Vertebrates - Rare, threatened, and endangered species - Crocodiles, Dolphin, Manatee, Sea Turtles, Protected marine mammals.
23	36	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Seining
24	39	Goliath Grouper (Red Hind in VI) - population structure, status, and trends
25	40	Land Birds - residential and migratory
26	41	Critically Imperiled and Rare Plants:
27	42	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Throw trap
28	44	Pink Shrimp population structure, status, and trends
29	46	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Trawling
30	47	Land birds - Mangrove - population abundance and distribution
31	48	Bonnethead, Lemon, Bull, Nurse Sharks - population structure, status, and trends
32	50	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Other trapping
33	51	Gray Snapper (Schoolmaster in VI)- population structure, status, & trends
34	54	Spotted Sea Trout - population structure, status, and trends
35	56	Phytoplankton composition and biomass
36	58	Snook - population structure, status, and trends
37	63	Sawfish- population structure, status, and trends
38	68	Butterflies
39	69	Island Insects

Table O.1.7e. Everglades National Park Indicators. Includes only indicators for which the EVER box was checked on the indicator worksheet.

EVER rank	Original Rank	Indicator
1	2	Exploited Fish Assemblage - Grouper, Snapper, (parrotfish, surgeonfish in USVI)- population structure, status, and trends
2	3	Hydrology = water stage, flow, timing, and duration.
3	4	Seagrass and other SAV cover and community composition
4	5	Water Quality- Nutrients characteristics of the marine water bodies
5	6	Invasive exotic plants
6	7	Freshwater Inputs to Estuaries
7	9	Shape, orientation, location, and coverage of vegetation community types
8	10	Wading birds - Regional South Florida - Systematic Reconnaissance Flights
9	11	Spatial and Temporal Salinity Patterns
10	12	Surface Water Quality- physiochemical surface water characteristics at specific locations.
11	13	Exploited Inverts (Lobster, Conch, Crabs, Shrimp, Stone Crab, Blue Crab, Clams, Oysters, Sponges, Welks)
12	14	Land Development inside/outside the park (within 5 mile radius for USVI parks, radius may be expanded to 75 miles in South Florida)
13	15	Marine Fish Communities - Coastal Shelf / Deep oceanic - Status, structure, trends
14	16	Colonial Nesting Birds (e.g. Least terns, pelicans, boobies, roseatte terns, egrets, storks, herons)
15	17	Invasive exotic fauna
16	18	Nutrient Loading and Sediment Loading
17	19	Visitor Use (Both commercial and individual/personal use)
18	20	Early detection, status, and trends of non-indigenous aquatic species.
19	21	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Visual Assessment
20	22	Location of critical ecotones - field plots/transects

Table O.1.7e. Everglades National Park Indicators. Includes only indicators for which the EVER box was checked on the indicator worksheet.

EVER rank	Original Rank	Indicator
21	23	Periphyton
22	24	Freshwater fish and large macro-invertebrates in wet prairies and marshes
23	25	Contaminants in water column, organisms, and sediments.
24	26	Long-term, within-community vegetation shifts using permanent plots
25	27	Sea Turtles
26	28	American crocodile (Crocodylus acutus)
27	29	American alligator (Alligator mississippiensis)
28	30	Benthic community spatial & temporal changes in extent and distribution -remote sensing
29	31	Spiny Lobster - population structure, status, and trends
30	32	Ecotone shifts along wetland boundaries - Mangrove to marsh to cypress- Aerial photography
31	33	Sediment elevation in mangroves and mud banks (Fl Bay) Salt Ponds (USVI) and Mangroves fringes
32	34	Marine Vertebrates - Rare, threatened, and endangered species - Crocodiles, Dolphin, Manatee, Sea Turtles, Protected marine mammals.
33	35	Physical drivers of mangrove-marsh ecotone
34	36	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Seining
35	37	Amphibians - South Florida
36	38	Fire Return Interval Departure
37	39	Goliath Grouper (Red Hind in VI) - population structure, status, and trends
38	40	Land Birds - residential and migratory
39	41	Critically Imperiled and Rare Plants:
40	42	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Throw trap

Table O.1.7e. Everglades National Park Indicators. Includes only indicators for which the EVER box was checked on the indicator worksheet.

EVER rank	Original Rank	Indicator
41	43	Location of Hammock-Pineland ecotone - field plots/transects
42	44	Pink Shrimp population structure, status, and trends
43	45	Aquatic invertebrates in wet prairies and marshes
44	47	Land birds - Mangrove - population abundance and distribution
45	48	Bonnethead, Lemon, Bull, Nurse Sharks - population structure, status, and trends
46	49	Florida panther
47	50	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Other trapping
48	51	Gray Snapper (Schoolmaster in VI)- population structure, status, & trends
49	52	Position and Spatial Extent of Mud Banks, Buttonwood Embankment and Berms
50	53	Oyster population structure, status, and trends
51	54	Spotted Sea Trout - population structure, status, and trends
52	55	Landbirds - Pine Rockland - population abundance and distribution.
53	56	Phytoplankton composition and biomass
54	57	Spatial and temporal changes in extent and distribution of substrate type (marl vs. peat).
55	58	Snook - population structure, status, and trends
56	59	Infaunal benthic community structure and abundance for animals
57	60	Pig Frog (Rana grylio)
58	62	Landbirds-Cavity-nesting pine rockland birds - Demographics (Fecundity and Survival)
59	63	Sawfish- population structure, status, and trends
60	65	Long-term sediment elevation changes in cypress strands and domes
61	66	Florida Box Turtle, Terrapene Carolina bauri
62	68	Butterflies

Table O.1.7f. Salt River Bay National Historical Park and Ecological Preserve. Includes only indicators for which the SARI box was checked on the indicator worksheet.

SARI rank	Original Rank	Indicator
1	1	Coral Communities
2	2	Exploited Fish Assemblage - Grouper, Snapper, (parrotfish, surgeonfish in USVI)- population structure, status, and trends
3	3	Hydrology = water stage, flow, timing, and duration.
4	4	Seagrass and other SAV cover and community composition
5	5	Water Quality- Nutrients characteristics of the marine water bodies
6	6	Invasive exotic plants
7	7	Freshwater Inputs to Estuaries
8	8	Marine Invertebrates - Rare, threatened, and endangered species - Acropora, Diadema, Antipathes
9	11	Spatial and Temporal Salinity Patterns
10	12	Surface Water Quality- physiochemical surface water characteristics at specific locations.
11	13	Exploited Inverts (Lobster, Conch, Crabs, Shrimp, Stone Crab, Blue Crab, Clams, Oysters, Sponges, Welks)
12	14	Land Development inside/outside the park (within 5 mile radius for USVI parks, radius may be expanded to 75 miles in South Florida)
13	15	Marine Fish Communities - Coastal Shelf / Deep oceanic - Status, structure, trends
14	16	Colonial Nesting Birds (e.g. Least terns, pelicans, boobies, roseatte terns, egrets, storks, herons)
15	17	Invasive exotic fauna
16	18	Nutrient Loading and Sediment Loading
17	19	Visitor Use (Both commercial and individual/personal use)
18	21	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Visual Assessment
19	22	Location of critical ecotones - field plots/transects
20	25	Contaminants in water column, organisms, and sediments.

Table O.1.7f. Salt River Bay National Historical Park and Ecological Preserve. Includes only indicators for which the SARI box was checked on the indicator worksheet.

SARI rank	Original Rank	Indicator
21	26	Long-term, within-community vegetation shifts using permanent plots
22	27	Sea Turtles
23	30	Benthic community spatial & temporal changes in extent and distribution -remote sensing
24	31	Spiny Lobster - population structure, status, and trends
25	33	Sediment elevation in mangroves and mud banks (Fl Bay) Salt Ponds (USVI) and Mangroves fringes
26	34	Marine Vertebrates - Rare, threatened, and endangered species - Crocodiles, Dolphin, Manatee, Sea Turtles, Protected marine mammals.
27	36	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Seining
28	39	Goliath Grouper (Red Hind in VI) - population structure, status, and trends
29	40	Land Birds - residential and migratory
30	41	Critically Imperiled and Rare Plants:
31	42	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Throw trap
32	44	Pink Shrimp population structure, status, and trends
33	47	Land birds - Mangrove - population abundance and distribution
34	50	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Other trapping
35	51	Gray Snapper (Schoolmaster in VI)- population structure, status, & trends
36	61	Amphibians - USVI
37	64	Reptiles - USVI
38	67	Bats - USVI
39	68	Butterflies
40	69	Island Insects

Table O.1.7g. Virgin Islands National Park. Includes only indicators for which the VIIS box was checked on the indicator worksheet.

VIIS rank	Original Rank	Indicator
1	1	Coral Communities
2	2	Exploited Fish Assemblage - Grouper, Snapper, (parrotfish, surgeonfish in USVI)- population structure, status, and trends
3	3	Hydrology = water stage, flow, timing, and duration.
4	4	Seagrass and other SAV cover and community composition
5	5	Water Quality- Nutrients characteristics of the marine water bodies
6	6	Invasive exotic plants
7	8	Marine Invertebrates - Rare, threatened, and endangered species - Acropora, Diadema, Antipathes
8	11	Spatial and Temporal Salinity Patterns
9	12	Surface Water Quality- physiochemical surface water characteristics at specific locations.
10	13	Exploited Inverts (Lobster, Conch, Crabs, Shrimp, Stone Crab, Blue Crab, Clams, Oysters, Sponges, Welks)
11	14	Land Development inside/outside the park (within 5 mile radius for USVI parks, radius may be expanded to 75 miles in South Florida)
12	15	Marine Fish Communities - Coastal Shelf / Deep oceanic - Status, structure, trends
13	16	Colonial Nesting Birds (e.g. Least terns, pelicans, boobies, roseatte terns, egrets, storks, herons)
14	17	Invasive exotic fauna
15	18	Nutrient Loading and Sediment Loading
16	19	Visitor Use (Both commercial and individual/personal use)
17	21	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Visual Assessment
18	22	Location of critical ecotones - field plots/transects
19	25	Contaminants in water column, organisms, and sediments.
20	26	Long-term, within-community vegetation shifts using permanent plots

Table O.1.7g. Virgin Islands National Park. Includes only indicators for which the VIIS box was checked on the indicator worksheet.

VIIS rank	Original Rank	Indicator
21	27	Sea Turtles
22	30	Benthic community spatial & temporal changes in extent and distribution -remote sensing
23	31	Spiny Lobster - population structure, status, and trends
24	33	Sediment elevation in mangroves and mud banks (Fl Bay) Salt Ponds (USVI) and Mangroves fringes
25	34	Marine Vertebrates - Rare, threatened, and endangered species - Crocodiles, Dolphin, Manatee, Sea Turtles, Protected marine mammals.
26	36	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Seining
27	39	Goliath Grouper (Red Hind in VI) - population structure, status, and trends
28	40	Land Birds - residential and migratory
29	41	Critically Imperiled and Rare Plants:
30	42	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Throw trap
31	44	Pink Shrimp population structure, status, and trends
32	47	Land birds - Mangrove - population abundance and distribution
33	50	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Other trapping
34	51	Gray Snapper (Schoolmaster in VI)- population structure, status, & trends
35	61	Amphibians - USVI
36	64	Reptiles - USVI
37	67	Bats - USVI
38	68	Butterflies
39	69	Island Insects

Appendix O.2

List of Participants
Vital Signs Indicator Identification Workshops

January 18-19, 2006 South Florida bays & marine areas
February 1-2, 2006 South Florida uplands & freshwater wetlands
March 6-7, 2006 St. Croix uplands & marine areas

Workshop	First Name	Last Name	Company Name
All	Andrea	Atkinson	NPS- SFCN
All	Matt	Patterson	NPS- SFCN
All	Kevin	Whelan	NPS- SFCN
All	Brian	Witcher	NPS- SFCN
Marine	Richard	Alleman	South Florida Water Management District, Planning Department
Marine	Jerry	Ault	Marine Biology and Fisheries- RSMAS
Marine	Sarah	Bellmund	Biscayne National Park
Marine	Stephen	Blair	Restoration & Enhancement Section, DERM
Marine	Jim	Bohnsack	NOAA- SEFSC
Marine	Amanda	Bourque	Biscayne National Park
Marine	Joe	Boyer	Southeast Environmental Research Center
Marine	Joan	Browder	NOAA
Marine	Richard	Curry	Biscayne National Park
Marine	Gary	Davis	Channel Islands National Park
Marine	Bob	Halley	USGS Center for Coastal and Watershed Studies
Marine	Todd	Hopkins	US Fish & Wildlife Service
Marine	Brian	Keller	Florida Keys National Marine Sanctuary
Marine	Todd	Kellison	NOAA
Marine	Tonnie	Maniero	National Park Service
Marine	Amar	Nayegandhi	USGS Center for Coastal Watershed Studies
Marine	Amy	Renshaw	
Marine	Mike	Robblee	USGS Biological Resources Division
Marine	Dave	Rudnick	South Florida Water Management District
Marine	Tom	Schmidt	National Park Service
Marine	Joe	Serafy	NOAA Fisheries, Southeast Fisheries Science Center
Marine	Jim	Tilmant	National Park Service, Water Resources Division
Marine	Hal	Wanless	University of Miami- Department of Geological Sciences
Marine&Terrestrial	Judd	Patterson	NPS- SFCN
Marine&Terrestrial	Sasha	Wright	NPS- SFCN
Terrestrial	Rick	Anderson	Everglades National Park
Terrestrial	Pinar	Balci	SFWMD
Terrestrial	Mike	Barry	TTINWR
Terrestrial	Sonny	Bass	Everglades National Park
Terrestrial	Joe	Bozzo	FFWCC
Terrestrial	Keith	Bradley	IRC
Terrestrial	Jim	Burch	Big Cypress National Preserve
Terrestrial	Bob	Doren	NPS- FIU
Terrestrial	Tom	Dreschol	SFWMD
Terrestrial	Evelyn	Gaiser	FIU
Terrestrial	Bob	Howard	Everglades National Park
Terrestrial	Jeff	Kline	Everglades National Park
Terrestrial	Ken	Krauss	USGS
Terrestrial	Sue	Perry	Everglades National Park
Terrestrial	Tom	Philippi	FIU
Terrestrial	Ken	Rice	USGS
Terrestrial	Jenny	Richards	Florida International University
Terrestrial	Mike	Ross	Florida International University
Terrestrial	Jimi	Sadle	Big Cypress National Preserve

Workshop	First Name	Last Name	Company Name
Terrestrial	Len	Scinto	FIU
Terrestrial	Gary	Slater	
Terrestrial	Craig	Smith	Everglades National Park
Terrestrial	Skip	Snow	Everglades National Park
USVI	Rafe	Boulon	Virgin Islands National Park
USVI	Sheri	Caseau	Virgin Islands National Park
USVI	William	Coles	DFW
USVI	Mark	Drew	The Nature Conservancy
USVI	Kurt	Grove	University of Puerto Rico Sea Grant
USVI	Edwin	Hernandez	University of Puerto Rico Sea Grant
USVI	Zandy	Hillis-Starr	Buck Island Reef National Monument/ Salt River Bay NHP&EP
USVI	Roy	Irwin	NPS- Water Resources Division
USVI	Chris	Jeffrey	National Ocean Service
USVI	Ian	Lundgren	Buck Island Reef National Monument/ Salt River Bay NHP&EP
USVI	Violetta	Mayor	USVI- Department of Planning and Natural Resources
USVI	Charlie	Menza	NOAA
USVI	Jeff	Miller	NPS- SFCN
USVI	Shona	Paterson	TNC
USVI	Caroline	Rogers	USGS Caribbean Field Station
USVI	Shauna	Slingsby	NOAA
USVI	William	Tobias	USVI-DPNR
USVI	Wes	Toller	Fish and Wildlife
USVI	Rob	Waara	NPS- SFCN

Appendix O.3

List of Participants in the SFCN Web-based Ranking Process

LastName	FirstName	Agency	Speciality Category
Alleman	Rick	South Florida Water Management District	marine ecology/biology
Alvear	Elsa	National Park Service-Biscayne National Park	wildlife ecology/biology
Anderson	Rick	National Park Service-Everglades National Park	plant ecology/botany
Atkinson	Andrea	National Park Service-South Florida /Caribbean Network	plant ecology/botany
Ault	Jerald	Univ. of Miami-RSMAS	marine ecology/biology
Aumen	Nick	National Park Service-Everglades National Park	hydrology/water quality/biogeochemical
Beaver	Carl	Florida Fish & Wildlife Conservation Commission	marine ecology/biology
Bellmund	Sarah	National Park Service-Biscayne National Park	marine ecology/biology
Bodle	Mike	South Florida Water Management District	plant ecology/botany
Bohnsack	James	National Oceanic and Atmospheric Administration	wildlife ecology/biology
Boulon	Rafe	National Park Service-Virgin Islands National Park	marine ecology/biology
Bourque	Amanda	National Park Service-Biscayne National Park	marine ecology/biology
Boyer	Joseph N.	Florida International University	hydrology/water quality/biogeochemical
Bozzo	Joseph	Florida Fish & Wildlife Conservation Commission	wildlife ecology/biology
Bradley	Keith	Institute for Regional Conservation	plant ecology/botany
Caldow	Chris	National Oceanic and Atmospheric Administration	marine ecology/biology
Callahan	Michael	Florida Fish & Wildlife Conservation Commission	marine ecology/biology
Caseau	Sheri	National Park Service-Virgin Islands National Park	marine ecology/biology
Cherkiss	Michael	University of Florida	wildlife ecology/biology
Clark	Daniel	National Park Service-Exotic Plant Management Team	plant ecology/botany
Clark	Ron	National Park Service-Big Cypress National Preserve	wildlife ecology/biology
Davidson Hile	Sarah	National Oceanic and Atmospheric Administration	marine ecology/biology
Davis	Gary	National Park Service	marine ecology/biology
Dong	Quan	National Park Service-Everglades National Park	wildlife ecology/biology
Doren	Robert	Florida International University	plant ecology/botany
Dreschel	Thomas	South Florida Water Management District	hydrology/water quality/biogeochemical
Drew	Mark	The Nature Conservancy	marine ecology/biology
Engel	Vic	National Park Service-Everglades National Park	hydrology/water quality/biogeochemical
Gaiser	Evelyn	Florida International University	plant ecology/botany
Geselbracht	Laura	The Nature Conservancy	marine ecology/biology
Grove	Kurt	University of Puerto Rico Sea Grant	geology
Hernandez	Edwin	University of Puerto Rico	wildlife ecology/biology
Halley	Robert	U. S. Geological Survey	geology
Hillis-Starr	Zandy	National Park Service-Buck Island Reef National Monument	wildlife ecology/biology
Hopkins	Todd	U. S. Fish & Wildlife Service	marine ecology/biology
Hunt	John	Florida Fish & Wildlife Conservation Commission	marine ecology/biology
Irwin	Roy	National Park Service-WRD	hydrology/water quality/biogeochemical
LastName	FirstName	Agency	Speciality Category
Jansen	Deborah	National Park Service-Big Cypress National Preserve	wildlife ecology/biology
Jeffery	Brian	University of Florida	wildlife ecology/biology

Jeffrey	Christopher	National Oceanic and Atmospheric Administration	marine ecology/biology
Johnson	Ed	National Oceanic and Atmospheric Administration	hydrology/water quality/biogeochemical
Johnson	Robert	South Florida Water Management District	wildlife ecology/biology
Kearns	Edward	National Park Service-Everglades National Park	physical/chemical oceanography
Keller	Brian	National Oceanic and Atmospheric Administration	marine ecology/biology
Kellison	Todd	National Oceanic and Atmospheric Administration	marine ecology/biology
Kendall	Matt	National Oceanic and Atmospheric Administration	marine ecology/biology
Kline	Jeff	National Park Service-Everglades National Park	wildlife ecology/biology
Krauss	Ken	U. S. Geological Survey	plant ecology/botany
Loomis	Christy	National Park Service- Virgin Islands National Park	wildlife ecology/biology
Maniero	Tonnie	National Park Service	hydrology/water quality/biogeochemical
Mayor	Philippe	USVI DPNR	marine ecology/biology
Mazzotti	Frank	University of Florida	wildlife ecology/biology
McDevitt	Erin	Florida Fish & Wildlife Conservation Commission	marine ecology/biology
Menza	Charles	National Oceanic and Atmospheric Administration	marine ecology/biology
Miller	Jeff	National Park Service-South Florida /Caribbean Network	marine ecology/biology
Morrison	Douglas	National Park Service-Everglades National Park	marine ecology/biology
Muller	Erinn	U. S. Geological Survey	marine ecology/biology
Nemeth	Rick	University of Virgin Islands	marine ecology/biology
Oberhofer	Lori	National Park Service-Everglades National Park	wildlife ecology/biology
Pait	Tony	National Oceanic and Atmospheric Administration	hydrology/water quality/biogeochemical
Patterson	Matt	National Park Service-South Florida /Caribbean Network	marine ecology/biology
Pernas	Tony	National Park Service-Exotic Plant Management Team	plant ecology/botany
Perry	Sue	National Park Service-Everglades National Park	wildlife ecology/biology
Philippi	Tom	Florida International University	plant ecology/botany
Pittman	Simon	National Oceanic and Atmospheric Administration	marine ecology/biology
Pratt	Paul	U.S. Department of Agriculture	plant ecology/botany
Ray	Gary	University of Virgin Islands	plant ecology/botany
Renshaw	Amy	National Park Service-Biscayne National Park	hydrology/water quality/biogeochemical
Rice	Ken	U. S. Geological Survey	wildlife ecology/biology
Richards	Jennifer	Florida International University	wildlife ecology/biology
Rivera-Monroy	Victor	LSU	hydrology/water quality/biogeochemical
Rogers	Caroline	U. S. Geological Survey	marine ecology/biology
Ross	Michael	Florida International University	plant ecology/botany
LastName	FirstName	Agency	Speciality Category
Rutchey	Ken	South Florida Water Management District	plant ecology/botany
Schall	Ted	South Florida Water Management District	wildlife ecology/biology
Schittone	Joe	National Oceanic and Atmospheric Administration	marine ecology/biology
Schmidt	Tom	National Park Service-Everglades National Park	marine ecology/biology
Scinto	Len	Florida International University	hydrology/water quality/biogeochemical
Shoemaker	Wayne	U. S. Geological Survey	hydrology/water quality/biogeochemical
Slingsby	Shauna	National Oceanic and Atmospheric Administration	marine ecology/biology

Smith	Craig	National Park Service-Everglades National Park	plant ecology/botany
Smith	Jacqueline		plant ecology/botany
Smith	Kent	Florida Fish & Wildlife Conservation Commission	marine ecology/biology
Smith	Tyler	University of Virgin Islands	marine ecology/biology
Smith III	Thomas	U. S. Geological Survey	marine ecology/biology
Snow	Skip	National Park Service-Everglades National Park	wildlife ecology/biology
Spitzack	Anthony		marine ecology/biology
Taylor	Christine	Florida International University	marine ecology/biology
Taylor	Marcia	University of Virgin Islands	marine ecology/biology
Thomas	Serge	Florida International University	marine ecology/biology
Tobias	Franco	FIU	wildlife ecology/biology
Tobias	William	USVI DPNR-Fish and Wildlife	marine ecology/biology
Troxler-Gann	Tiffany	Florida International University	hydrology/water quality/biogeochemical
Ugarte	Cristina	University of Florida	wildlife ecology/biology
Verdon	Emilie	Institute for Regional Conservation	wildlife ecology/biology
Waara	Robert	National Park Service-South Florida /Caribbean Network	marine ecology/biology
Weil	Ernesto	University of Puerto Rico	marine ecology/biology
Whelan	Kevin	National Park Service-South Florida /Caribbean Network	hydrology/water quality/biogeochemical
Whitall	Dave	National Oceanic and Atmospheric Administration	hydrology/water quality/biogeochemical
Woodmansee	Steve	Institute for Regional Conservation	plant ecology/botany
Woody	Kimberly	National Oceanic and Atmospheric Administration	marine ecology/biology
Zimmerman	Mike	National Park Service-Everglades National Park	hydrology/water quality/biogeochemical

Appendix O.4

Web-based Ranking Instructions

South Florida/Caribbean Network
Vital Signs Indicator Ranking

Welcome! We want to thank you for participating in the South Florida/Caribbean Inventory and Monitoring Network's Vital Signs ranking process and assistance in developing a large-scale, long-term ecological monitoring program for the National Parks in both South Florida and the U. S. Virgin Islands! We realize how valuable your time is and we sincerely appreciate your participation in this endeavor.

Ranking Process: Sixty-nine potential indicators were identified during a series of 3 NPS Vital Signs indicator identification workshops. These indicators need to be ranked to assist selection of a good sub-set of indicators that will be monitored as "Vital Signs." Each of the 69 indicators will be ranked in 4 separate categories using ranking criteria:

Ranking Category	Your role
Ecological Significance	Ranking
Feasibility	Ranking
Management Significance	Comments
Legal Mandate	Comments

We are asking your assistance in ranking "Ecological Significance" and "Feasibility." SFCN staff drafted rankings for "Management Significance" and "Legal Mandate" and are asking park management to review those rankings in a parallel process. However we would appreciate comments if you feel the rankings should be adjusted. Comments on the details of the indicators are also appreciated.

Your rankings must be entered by **April 26** to be included in the ranking summary analysis.

If you know of additional experts whom you feel should be included in the ranking process, please let them know about this web page. We want a wide range of experts to rank the vital signs. However we request that you not simply forward this web page to general list servers.

Directions:

1. Click on the "Continue to Ranking" link below and identify yourself by entering your personal information in the blanks provided.
2. Print out and read the criteria for prioritizing indicators carefully and refer back to it when ranking.

3. The indicators are shown as a long list and similar topics are grouped together. You don't need to stick with that pattern when completing this activity. We have created a checkoff sheet that lists all the indicators that you can print out and use to check-off indicators completed.
4. Read all of the information provided about the indicators before ranking, especially the monitoring questions, justification, metric, and methodology. This will reduce ranking based solely on assumptions taken from the name of the indicator. For acronym definitions click here.
5. Rank each indicator criteria from very low to very high. We consider all of these indicators important. However the intent of the criteria is to produce a range of scores rather than having everything rank "very high." Please ask yourself if you "strongly agree" about the criteria for a given indicator and this should help with the ranking. The no opinion value should be used if you don't know enough about the criteria or indicator to rank it.
6. After ranking the first indicator, return to the main page and select the next indicator of your choice. You may rank them in any order you choose. You do not need to rank all indicators (although it would be helpful if you would).
7. You may log-in to the site as many times as necessary to finish ranking or change your scores.

Click Below to

!!! Proceed to Ranking !!!

Background and FAQ: For additional background and frequently asked questions about the workshops and Vital Signs selection process, click here.

Technical Support: If you have any questions about the process, or run into any problems, please contact our Data Manager, Brian Witcher at Brian_witcher@nps.gov or at 305-252-0347.

* Parks include: Big Cypress National Preserve (BICY); Biscayne National Park (BISC); Buck Island Reef National Monument (BUIS); Dry Tortugas National Park (DRTO); Everglades National Park (EVER); Salt River Bay National Historical Park and Ecological Preserve (SARI); and Virgin Island National Park (VIIS)

Appendix O.5

Vital Signs Ranking Meeting

South Florida / Caribbean Network Meeting Summary
Vital Signs Ranking Meeting
May 9-10, 2006
St. Croix, USVI

Meeting participants

Park Staff:
- Art Frederick (VIIS)
- Craig Smith (EVER, DRTO)
- Dan Kimball (EVER, DRTO)
- Elsa Alvear (BISC)
- Ian Lundgren (BUIS, SARI)
- Joel Tutein (BUIS, SARI)
- Karen Gustin (BICY)
- Larry West (SERO)
- Mark Lewis (BISC)
- Ron Clark (BICY)
- Thomas Kelley (VIIS)
- Zandy Hillis-Starr (BUIS, SARI))

SFCN Staff
- Matt Patterson
- Jeff Miller
- Andrea Atkinson
- Kevin Whelan
- Brian Witcher
- Rob Waara
- Judd Patterson
- Sasha Wright

Meeting purpose – To review network indicator ranking and achieve agreement on a prioritized list of Vital Sign indicators for the South Florida/Caribbean Network long-term monitoring program.

Meeting Objectives:
1.) Provide update on network activities
2.) Provide overview of indicator development
3.) Review ranking results
4.) Develop and achieve agreement upon a prioritized list of Vital Signs Indicators
5.) Discuss how best to implement Vital Signs monitoring for selected indicators

Handouts
Each attendee received a notebook containing: Workshop Agenda, Ranking Methodology, Ranking Results (7 tables), Draft SFCN Timeline, Phase 3 Report Outline, Park-specific Conceptual Models (BUIS only presented), SFCN Briefings - Handouts on SFCN informational presentations, Indicator Worksheets

An additional handout was made during the workshop showing indicators first sorted by ranking and then organized under general topics.

Results from the online indicator ranking

Results from the online indicator ranking for Ecological Significance and Feasibility were presented. The primary ranking index proposed was the "EF Index"

EF Index = 2 * (Average Ecological Significance score) + (Average Feasibility Score)

An alternate index was also presented

EFML Index = EF Index + Management Score + Legal Score

SFCN staff recommended using the EF index because

- The Management Significance and Legal Mandate scores had only received minimal review from the parks due to a limited review window
- Legal Mandate played a large role in changes in the index, moving threatened species, endangered species and water quality indicators higher on the list
- Management Significance played a small role in changes in the index with over 2/3 of the indicators ranking as "High" or "Very High"
- The primary purpose of the program is to monitor ecosystem condition rather than legal mandates

The meeting participants agreed to use the EF Index as the initial ranked list and the basis for further discussion.

Various methods of looking at the indicator lists were presented:

- Distribution of scores and indicators that had widest variance in rankings
- Separation of Bay & Marine Indicators from Uplands & Wetlands Indicators
- Rankings of Florida indicators (by Florida-only specialists) compared with rankings of USVI Indicators (by Caribbean-only specialists)
- NPS staff rankings compared with non-NPS staff
- Park-specific queries which included only indicators checked for each park
- Effects of people who only ranked < 10 indicators

Participants were told that SFCN plans to use the ranked list to build the best I & M program possible by following ranks as much as possible, but also looking for:

- Opportunities to collaborate (e.g., CERP, parks listed-species monitoring, NOAA)
- Opportunities where co-location or other techniques can reduce costs
- Suites of indicators that provide added value (e.g., vegetation plots with herpetofauna sampling)

Indicators will be reported to Park Management, Congress, Public (and Scientific Community was added by participants)

Meeting participants were then asked:

- Is anything important missing?
- Is there anything missing from top 20?
- What (if anything) should be shifted?

These questions formed the basis for further discussion.

Combining indicators

Concerns were expressed that some indicators overlap and perhaps should be lumped. SFCN agreed to review the water quality indicators (#5, #7, #11, #12, #18, and #25), exotic fauna indicators (#17, #20), sea turtle indicators (#27, #34) and marine fish communities indicators (#21, #36, #42, #46, #50) and make recommendations regarding combining indicators (see Table 1).

SFCN staff reviewed the indicators and on day 2 of the workshop recommended combining the marine fish communities-bays/mangroves indicators (#21, #36, #42, #46, and #50) as these all relate to the same indicator but show different methods. SFCN staff did not recommend combining the other indicators, especially the water quality indicators, as they referred to very different things with very different methodologies. Combining these indicators would not simplify the list as the costs of monitoring would remain the same.

Superintendents agreed that they were basically happy with the top 20 listed indicators.

Moving indicators below the top 20

For indicators below the top 20, each superintendent was asked to propose 3 indicators they would like to see moved higher on the list. These indicators were listed and each superintendent was asked to vote twice for those indicators they felt most strongly about. After the votes were tallied, the indicators were discussed regarding moving them on the list, why, why not, what other indicators should be moved down, combined, etc.

Initial rank	Indicator name	# votes
30	Benthic Communities (mapping)	3
67	USVI Bats	2
26	Long-term within-community vegetation plots	2
40	Landbirds-Residential & Migratory	2
25	Contaminants	2
68	Butterflies	1
61	USVI Amphibians	1
23	Periphyton	1
21	Marine Fish Communities – Bays & Mangroves	1
52	Mudbanks, berms	0
64	USVI Reptiles	0
43	Location of hammock/pineland ecotones	Combined with #22 before voting

Comments from the group :
Indicator "Location of hammock/pineland ecotones" (initial rank=43) was combined with "Location of Critical Ecotones – field plots/transects" (initial rank=22). Location of Hammock/pineland ecotones is an important indicator for BICY.

"Landbirds-Residential and migratory" (initial rank=40) was moved to rank 31. Migratory and residential birds are in the enabling legislation of several of the parks (EVER, BICY, DRTO). Birds are also of high interest to many visitors. In addition, there needs to be more "terrestrial" indicators higher in the list. Birds are early indicators of change and monitoring protocols are available. With climate change, migratory bird arrival date can be expected to change.

USVI amphibians (initial rank=61) were combined with "South Florida amphibians" (initial rank=37) into a network-wide "Amphibians – South Florida and USVI" indicator and moved to a revised rank of 32. It was felt that the combined indicator would have ranked higher than the separately listed indicators if it had originally been listed that way.

Spiny Lobster (initial rank=31) was combined with "Exploited invertebrates" (initial rank=13) (this came up when the group was deciding which indicators to move down).

The other indicators listed were discussed, but their order on the list was left unchanged.

"USVI Bats" (initial rank=67) generated discussion as this was considered an important indicator for VIIS. However it was agreed that this was primarily a VIIS issue and would remain where it was on the list. VIIS is hiring a new biological technician who could initiate bat monitoring, but would appreciate guidance from SFCN.

Butterflies (initial rank=68) were discussed. Butterflies could be indicators of vegetation composition, mosquito control impacts and whether fire regimes are successful. However SFCN staff brought up the fact that butterflies are difficult to monitor well and that 7 of 9 other networks which had initially identified butterflies eventually dropped them as too difficult to monitor well.

BICY wanted to see the Periphyton indicator (initial rank-23) expanded into their park. It is a CERP indicator and will be monitored in EVER. Ranking was left the same.

Meeting participants agreed that the Contaminants (initial rank= 25) indicator is important but with current funding I&M can't approach funding this indicator; SFCN should instead focus on collaborating with other agencies and networks and not funding additional contaminants work at this time.

Other comments on indicators
Concerns were expressed that there were so many water quality indicators in the top 20.

A question was raised regarding where sea level rise and tidal stage are accounted for. These parameters are included under hydrology (initial rank=3) as well as under indicators "Location of critical ecotones - field plots/transects" (initial rank=22), "Ecotone shifts along wetland boundaries - Mangrove to marsh to cypress- Aerial photography" (initial rank=32), "Sediment elevation in mangroves and mud banks (FL Bay) Salt Ponds (USVI) and Mangroves fringes" (initial rank=33), and "Physical drivers of mangrove-marsh ecotones" (initial rank=35).

The value of sea turtles (initial rank=27) as an ecosystem indicator was questioned. While a popular species, sea turtle nesting is only an indicator of itself rather than system health. Juvenile sea turtle monitoring however, might be a good indicator for local ecological health (BUIS is piloting a program).

Meeting participants felt the closed circles indicating sufficient monitoring for Exotic Plants was overstating the case and more monitoring was needed, especially in the USVI parks, but all parks mentioned need for improvement.

BICY wanted to make sure that Visitor Use included ORV use as this is an important issue for their park.

Bob Sobzyak's method of reporting hydrology data for BICY was liked by the superintendents and it was recommended that SFCN explore this approach for other indicators.

Importance for each park
The meeting participants ranked the importance of each of the first 32 indicators for each park as High (H), Low (L), or not applicable (-).

Final Ranks
The final rankings are presented in the attached Table 1.

Other issues
State of the Parks Reports
Park superintendents commented that they are receiving repeated requests for information for various types of "State of the Parks" reports such as the Watershed Condition Assessment. They asked if they could direct such requests to I&M to supply data. Network Coordinator, Matt Patterson agreed and said SFCN would be happy to collaborate.

Permits & Access
Matt Patterson requested that SFCN staff be dealt with as park staff for the purpose of working in the parks rather than having to apply for permits like non-NPS researchers. The superintendents agreed but emphasized that SFCN staff would have to go through the same in-house procedures that park staff did. Matt requested that this be put into writing and will draft an agreement/memo for the group to look at. Dan Kimball (EVER Superintendent) asked Matt to set up a meeting at EVER. Ron Clark recommended contacting Nancy Russell, Museum Curator for the South Florida Collection Management Center, about the South Florida Accessions Charter.

SFCN Vital Signs Ranking Meeting Agenda

Meeting purpose – To review network indicator ranking and achieve agreement on a prioritized list of Vital Sign indicators for the South Florida/Caribbean Network long-term monitoring program.

Meeting Objectives:

1.) Provide update on network activities
2.) Provide overview of indicator development
3.) Review ranking results
4.) Develop and achieve agreement on a prioritized list of Vital Signs Indicators
5.) Discuss how best to implement Vital Signs monitoring for selected indicators

Tuesday – May 9, 2006

8:30-9:00 AM	Coffee and time for informal introductions
9:00-9:15 AM	Opening remarks\Welcome from Superintendent Joel Tutein
9:15-9:45 AM	Overview of agenda & housekeeping issues Indicator Development Process - Overview of Vital Signs Program - Indicator Workshops - Ranking Process
9:45-10:30 AM	Indicator Ranking Review Overall Ranks (Mgmt, Legal, Ecological, Feasibility)
10:30-10:45 AM	Break
10:45-11:00 AM	Presentation: Coral Monitoring – Jeff Miller
11:00-12:00 PM	Indicator Ranking Review -Does ranking change with different queries? (S FL Vs USVI; Internal/External; Combos)
12:00-1:00 PM	Lunch
1:00-1:15 PM	Presentation: GIS synthesis – Sasha Wright
1:15-1:45 PM	Participants review information and identify indicators to discuss
1:45 – 2:00 PM	Break
2:00-2:15 PM	Presentation: NOAA fish & mapping – Rob Waara
2:15-3:00 PM	Indicator Ranking – Discussion - Clarification on indicators & rankings - What's missing? - Is there anything missing from top 20? What should be shifted?
3:00-3:15 PM	Break
3:15-4:00 PM	Continue Discussion
4:00-4:30 PM	Day 1 Wrap-up

Optional – Demonstration of coral monitoring at beach

Wednesday – May 10, 2006

8:30-9:00 AM	**Coffee**
9:00	**Presentation: LIDAR – Judd Patterson** **Review Day 1 and goals for Day 2** **Continue Discussion on Indicators**
10:30-10:45 AM	**Break**
10:45-11:00 AM	**Presentation: Water Quality – Kevin Whelan**
11:00-12:00 PM	**Continue Discussion on Indicators** **Agreement on prioritized list of indicators**
12:00-1:00 PM	**Lunch**
***12:30-1:00 PM**	**Alternative (invertebrate) Vital Signs selection project at the Mermaid Restaurant. All meeting participants are encouraged to join us.**
1:00-1:15 PM	**Presentation: Vegetation Mapping – Andrea Atkinson**
1:15-2:00 PM	**Overview of Phase 3 process** **- overview, outline, timeline** **- strategies/tools for making it all fit w/examples**
2:00-2:15 PM	**Break**
2:15-2:30 PM	**Presentation: Data management –Brian Witcher** **Continue Phase 3 Process presentation** **- data analysis & reporting w/examples** **- user friendly conceptual models** **- what we need from them** **o review time** **o permits** **o cooperation on existing monitoring** **Discussion on Phase 3 process** **Questions? Opportunities? Concerns? Needs (e.g., prioritizing issues to help GMP process)**
4:00-4:30 PM	**Meeting wrap up and action items – Thank you**

****

Table 1. SFCN Vital Signs indicators sorted in priority order plus rating of importance by park and estimates of levels of existing monitoring estimated to be currently occuring for each indicator by park.

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

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			Importance to Park							Estimated level of existing monitoring						
Original Rank	Revised Priority Rank	Indicator	BICY	BISC	BUIS	DRTO	EVER	SARI	VIIS	BICY	BISC	BUIS	DRTO	EVER	SARI	VIIS
1	1	Coral Communities	-	H	H	H	L	H	H		◑	◑	◑	○	○	◑
2	2	Exploited Fish Assemblage - Grouper, Snapper, (parrotfish, surgeonfish in USVI)- population structure, status, and trends	-	H	H	H	H	H	H		◑	◑	◑	◑	◑	◑
3	3	Hydrology = water stage, flow, timing, and duration.	H	H	L	L	H	H	L	●	●	○	○	●	○	○
4	4	Seagrass and other SAV cover and community composition	-	H	H	H	H	H	H		◑	○	◑	●	○	◑
5	5	Water Quality- Nutrients characteristics of the marine water bodies	-	H	L	H	H	H	H		●	○	◑	●	○	●
6	6	Invasive exotic plants	H	H	L	H	H	L	H	●	●	◑	◑	●	◑	◑
7	7	Freshwater Inputs to Estuaries	L	H	-	-	H	L	-	○	●			◑	○	
8	8	Marine Invertebrates - Rare, threatened, and endangered species - *Acropora, Diadema, Antipathes*	-	H	H	H	L	H	H		○	◑	○	○	○	◑
9	9	Shape, orientation, location, and coverage of vegetation community types	L	H	L	H	H	L	H	◑	◑	○	○	●	○	○
10	10	Wading birds - Regional South Florida - Systematic Reconnaissance Flights	H	-	-	-	H	-	-	●				●		
11	11	Spatial and Temporal Salinity Patterns	-	H	-	-	H	L	L		◑			◑	○	○
12	12	Surface Water Quality- physiochemical surface water characteristics at specific locations.	L	H	-	-	H	L	L	◑	○			●	○	○
13, 31	13	Exploited Inverts (Lobster, Conch, Crabs, Shrimp, Stone Crab, Blue Crab, Clams, Oysters, Sponges, Whelks)	-	H	L	H	H	L	H		◑	◑	◑	◑	◑	◑
14	14	Land Development inside/outside the park (within 5 mile radius for USVI parks, radius may be expanded to 75 miles in South Florida)	H	H	L	-	H	H	H	◑	◑	◑		◑	◑	◑
15	15	Marine Fish Communities - Coastal Shelf / Deep oceanic - Status, structure, trends	-	H	H	H	H	L	H		●	●	●	●	●	●
16	16	Colonial Nesting Birds (e.g. Least terns, pelicans, boobies, roseatte terns, egrets, storks, herons)	H	H	L	H	H	L	H	●	●	●	●	●	○	●
17	17	Invasive exotic fauna	H	L	L	L	H	L	H	○	◑	◑	◑	◑	○	○
18	18	Nutrient Loading and Sediment Loading	L	H	L	-	H	H	H	◑	●		○	●	○	◑

Table 1. SFCN Vital Signs indicators sorted in priority order plus rating of importance by park and estimates of levels of existing monitoring estimated to be currently occuring for each indicator by park.

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			Importance to Park							Estimated level of existing monitoring						
Original Rank	Revised Priority Rank	Indicator	BICY	BISC	BUIS	DRTO	EVER	SARI	VIIS	BICY	BISC	BUIS	DRTO	EVER	SARI	VIIS
19	19	Visitor Use (Both commercial and individual/personal use)	H	H	H	H	H	H	H	◑	◑	◑	◑	◑	○	◑
20	20	Early detection, status, and trends of non-indigenous aquatic species.	L	L	-	-	H	L	L	○	○			◑	○	○
21,36,42,46,50	21	Marine Fish Communities - Bays/Mangroves - Status, structure, trends	L	H	-	H	H	L	H	○	◑		○	◑	○	○
~~21~~		~~Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Visual Assessment~~								~~○~~	~~◑~~		~~○~~	~~◑~~	~~○~~	~~○~~
22, 43	22	Location of critical ecotones - field plots/transects	H	H	L	H	H	L	H	◑	○	◑	○	◑	◑	◑
23	23	Periphyton	H	L	-	-	H	-	-	○	○			●		
24	24	Freshwater fish and large macro-invertebrates in wet prairies and marshes	H	-	-	-	H	-	L	◑				●		○
25	25	Contaminants in water column, organisms, and sediments.	H	H	L	L	H	H	H	◑	◑	○	○	◑	○	○
26	26	Long-term, within-community vegetation shifts using permanent plots	L	L	H	L	H	L	H	◑	○	○	○	◑	○	●
27	27	Sea Turtles	-	H	H	H	L	L	H		◑	●	●	○	○	●
28	28	American crocodile (*Crocodylus acutus*)	L	H	-	L	H	-	-	○	●		○	●		
29	29	American alligator (*Alligator mississippiensis*)	H	-	-	-	H	-	-	●				●		
30	30	Benthic community spatial & temporal changes in extent and distribution -remote sensing	-	H	H	H	H	H	H		◑	◑	◑	◑	◑	◑
~~31~~		~~Spiny lobster - population structure, status, and trends~~									~~◑~~	~~◑~~	~~◑~~	~~○~~	~~○~~	~~○~~
40	31	Land Birds - residential and migratory	L	H	H	H	H	H	H	○	◑	◑	○	○	○	◑
37,61	32	Amphibians - South Florida & USVI	H	L	-	-	H	L	H	○	○			○	○	○
32	33	Ecotone shifts along wetland boundaries - Mangrove to marsh to cypress- Aerial photography								○	○			◑		
33	34	Sediment elevation in mangroves and mud banks (Fl Bay) Salt Ponds (USVI) and Mangroves fringes								○	○	○		●	○	○

Table 1. SFCN Vital Signs indicators sorted in priority order plus rating of importance by park and estimates of levels of existing monitoring estimated to be currently occuring for each indicator by park.

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			Importance to Park							Estimated level of existing monitoring						
Original Rank	Revised Priority Rank	Indicator	BICY	BISC	BUIS	DRTO	EVER	SARI	VIIS	BICY	BISC	BUIS	DRTO	EVER	SARI	VIIS
34	35	Marine Vertebrates - Rare, threatened, and endangered species - Crocodiles, Dolphin, Manatee, Sea Turtles, Protected marine mammals.								◑	◑	◑	◑	◑	○	◑
35	36	Physical drivers of mangrove-marsh ecotone									◑			◑		
~~36~~		~~Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Seining~~								⊖	◑		⊖	◑	⊖	⊖
~~37~~		~~Amphibians - South Florida~~								⊖	⊖			⊖	⊖	⊖
38	37	Fire Return Interval Departure								◑				◑		
39	38	Goliath Grouper (Red Hind in VI) - population structure, status, and trends									◑	○	◑	●	○	◑
41	39	Critically Imperiled and Rare Plants:								○	◑	○	○	◑	○	○
~~42~~		~~Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Throw trap~~								⊖	◑	⊖	⊖	◑	⊖	⊖
~~43~~		~~Location of Hammock-Pineland ecotone - field plots/transects~~								⊖				⊖		
44	40	Pink Shrimp population structure, status, and trends									●	○	○	●	○	○
45	41	Aquatic invertebrates in wet prairies and marshes								◑	○			●		
~~46~~		~~Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Trawling~~								⊖	◑		⊖	◑		
47	42	Land birds - Mangrove - population abundance and distribution								○	○	○	○	○	○	○
48	43	Bonnethead, Lemon, Bull, Nurse Sharks - population structure, status, and trends									◑		●	●		
~~49~~	~~44~~	Florida panther								●				●		
~~50~~		~~Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Other trapping~~								⊖	◑	⊖	⊖	◑	⊖	⊖
51	45	Gray Snapper (Schoolmaster in VI)- population structure, status, & trends									●	○	◑	◑	○	◑
52	46	Position and Spatial Extent of Mud Banks, Buttonwood Embankment and Berms								○	○			◑		

Table 1. SFCN Vital Signs indicators sorted in priority order plus rating of importance by park and estimates of levels of existing monitoring estimated to be currently occuring for each indicator by park.

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			Importance to Park							Estimated level of existing monitoring						
Original Rank	Revised Priority Rank	Indicator	BICY	BISC	BUIS	DRTO	EVER	SARI	VIIS	BICY	BISC	BUIS	DRTO	EVER	SARI	VIIS
53	47	Oyster population structure, status, and trends									○			○		
54	48	Spotted Sea Trout - population structure, status, and trends									◑		◑	◑		
55	49	Landbirds - Pine Rockland - population abundance and distribution.								◑				◑		
56	50	Phytoplankton composition and biomass									◑		◑	◑		
57	51	Spatial and temporal changes in extent and distribution of substrate type (marl vs. peat).												○		
58	52	Snook - population structure, status, and trends								○	●		◑	●		
59	53	Infaunal benthic community structure and abundance for animals									○			○		
60	54	Pig Frog (*Rana grylio*)								○	○			○		
~~61~~		~~Amphibians - USVI~~													~~○~~	~~○~~
62	55	Landbirds-Cavity-nesting pine rockland birds - Demographics (Fecundity and Survival)								◑				◑		
63	56	Sawfish- population structure, status, and trends									○		○	◑		
64	57	Reptiles - USVI										○			○	○
65	58	Long-term sediment elevation changes in cypress strands and domes								○				○		
66	59	Florida Box Turtle (*Terrapene Carolina bauri)*								○	○			○		
67	60	Bats - USVI										○			○	○
68	61	Butterflies								○	◑	○	○	◑	○	○
69	62	Island Insects									○	○	○		○	○

Table 8. Indicators sorted by General Category, Sub-Category, then by rank order from Table 1. Top 20 highlighted

General Category	Sub-Category	Indicator	Table 1 Order
Geology & Soils		Sediment elevation in mangroves and mud banks (Fl Bay) Salt Ponds (USVI) and Mangroves fringes	33
		Position and Spatial Extent of Mud Banks, Buttonwood Embankment and Berms	52
		Spatial and temporal changes in extent and distribution of substrate type (marl vs. peat).	57
		Long-term sediment elevation changes in cypress strands and domes	65
Water		Hydrology = water stage, flow, timing, and duration.	3
		Water Quality- Nutrients characteristics of the marine water bodies	5
		Freshwater Inputs to Estuaries	7
		Spatial and Temporal Salinity Patterns	11
		Surface Water Quality- physiochemical surface water characteristics at specific locations.	12
		Nutrient Loading and Sediment Loading	18
		Contaminants in water column, organisms, and sediments.	25
		Phytoplankton composition and biomass	56
Invasive species		Invasive exotic plants	6
		Invasive exotic fauna	17
		Early detection, status, and trends of non-indigenous aquatic species.	20
Bays & Marine	Benthic mapping	Benthic community spatial & temporal changes in extent and distribution -remote sensing	30
	SAV	Seagrass and other SAV cover and community composition	4
	Fish	Exploited Fish Assemblage - Grouper, Snapper, (parrotfish, surgeonfish in USVI)- population structure, status, and trends	2
		Marine Fish Communities - Coastal Shelf / Deep oceanic - Status, structure, trends	15
		Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Visual Assessment	21
		Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Seining	36
		Goliath Grouper (Red Hind in VI) - population structure, status, and trends	39
		Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Throw trap	42
		Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Trawling	46
		Bonnethead, Lemon, Bull, Nurse Sharks - population structure, status, and trends	48
		Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Other trapping	50
		Gray Snapper (Schoolmaster in VI)- population structure, status, & trends	51
		Spotted Sea Trout - population structure, status, and trends	54
		Snook - population structure, status, and trends	58
		Sawfish- population structure, status, and trends	63
	Invertebrates	Coral Communities	1
		Marine Invertebrates - Rare, threatened, and endangered species - Acropora, Diadema, Antipathes	8
		Exploited Inverts (Lobster, Conch, Crabs, Shrimp, Stone Crab, Blue Crab, Clams, Oysters, Sponges, Welks)	13
		Spiny Lobster - population structure, status, and trends	31
		Pink Shrimp population structure, status, and trends	44
		Oyster population structure, status, and trends	53
		Infaunal benthic community structure and abundance for animals	59
	Large Marine Vertebrates (mammals, reptiles)	Sea Turtles	27
		American crocodile (Crocodylus acutus)	28
		Marine Vertebrates - Rare, threatened, and endangered species - Crocodiles, Dolphin, Manatee, Sea Turtles, Protected marine mammals.	34

General Category	Sub-Category	Indicator	Table 1 Order
Wetlands & Uplands	Fire	Fire Return Interval Departure	38
	Vegetation	Shape, orientation, location, and coverage of vegetation community types	9
		Location of critical ecotones - field plots/transects	22
		Periphyton	23
		Long-term, within-community vegetation shifts using permanent plots	26
		Ecotone shifts along wetland boundaries - Mangrove to marsh to cypress- Aerial photography	32
		Physical drivers of mangrove-marsh ecotone	35
		Critically Imperiled and Rare Plants:	41
		Location of Hammock-Pineland ecotone - field plots/transects	43
	Fish	Freshwater fish and large macro-invertebrates in wet prairies and marshes	24
	Invertebrates	Aquatic invertebrates in wet prairies and marshes	45
		Butterflies	68
		Island Insects	69
	Herpetofauna & Mammals	American alligator (Alligator mississippiensis)	29
		Amphibians - South Florida	37
		Florida panther	49
		Pig Frog (Rana grylio)	60
		Amphibians - USVI	61
		Reptiles - USVI	64
		Florida Box Turtle, Terrapene Carolina bauri	66
		Bats - USVI	67
	Birds	Wading birds - Regional South Florida - Systematic Reconnaissance Flights	10
		Colonial Nesting Birds (e.g. Least terns, pelicans, boobies, roseatte terns, egrets, storks, herons)	16
		Land Birds - residential and migratory	40
		Land birds - Mangrove - population abundance and distribution	47
		Landbirds - Pine Rockland - population abundance and distribution.	55
		Landbirds-Cavity-nesting pine rockland birds - Demographics (Fecundity and Survival)	62
Human Use		Land Development inside/outside the park (within 5 mile radius for USVI parks, radius may be expanded to 75 miles in South Florida)	14
		Visitor Use (Both commercial and individual/personal use)	19

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Appendix O.6

Consolidation of 62 Indicators into 42 Vital Signs

Consolidation of 62 Indicators into 42 Vital Signs

The revised list of 62 indicators agreed upon at the Vital Signs Ranking Meeting in May 9-10, 2006 was, in general, more detailed than vital signs identified for other Inventory and Monitoring Program networks. As advised by the Washington program office, the SFCN staff then reviewed the list of 62 indicators, placed them in the National Inventory and Monitoring Program framework, and consolidated the list into 41 more holistic Vital Signs by combining multiple indicators when appropriate (Table O.6-A). A 42nd "Air Quality" vital sign was added at the request of the Washington office as 2 parks have existing air quality monitoring programs receiving funding from the NPS-Air Resources Division. The original indicator details and rankings were retained and used in the development of the final monitoring program (see Appendix O.7).

Table O.6-A. SFCN Vital Signs linked with workshop indicators. 42 SFCN Vital Signs are shown within the National Framework (Level 1, 2, and 3) and linked with the indicators identified in workshops in January - March 2006 and ranked via an online ranking process. The workshop indicators were lumped into more general "Vital Signs" which are more consistent in organization and level of detail with other NPS Inventory and Monitoring Program Network Vital Signs, however, the workshop indicator details will help guide the program. The priority rank for each indicator is also given (1 is highest). Air Quality was added at the request of the Washington office (WASO).

National I & M Program Framework			SFCN Vital Sign	SFCN Workshop Indicators	Priority rank
Level 1	**Level 2**	**Level 3**			
Air and Climate	Air Quality	Wet & Dry Deposition	Air Quality-Deposition	---	---
		Air Contaminants	Air Quality-Mercury	---	---
Geology and Soils	Geomorph-ology	Coastal/ Oceanographic Features and Processes	Coastal Geomorphology	Sediment elevation in mangroves and mud banks (Fl Bay) Salt Ponds (USVI) and Mangroves fringes	34
				Position and Spatial Extent of Mud Banks, Buttonwood Embankment and Berms	46
		Stream/River Channel Characteristics	Wetland substrate	Spatial and temporal changes in extent and distribution of substrate type (marl vs. peat).	51
				Long-term sediment elevation changes in cypress strands and domes	58
Water Biological Integrity	Hydrology	Surface Water Dynamics	Surface Water Hydrology	Hydrology = water stage, flow, timing, and duration.	3
				Freshwater Inputs to Estuaries	7
	Water Quality	Water Chemistry	Estuarine salinity patterns	Spatial and Temporal Salinity Patterns	11
		Nutrient Dynamics	Nutrient Dynamics and Water Chemistry	Surface Water Quality- physiochemical surface water characteristics at specific locations	12
				Water Quality- Nutrients characteristics of the marine water bodies	5
				Nutrient Loading and Sediment Loading	18
		Toxics	Contaminants	Contaminants in water column, organisms, and sediments.	25
		Aquatic Macroinvertebrates and Algae	Periphyton (Freshwater)	Periphyton	23
			Phytoplankton (Marine)	Phytoplankton composition and biomass	50
	Invasive Species	Invasive/Exotic Plants	Invasive/Exotic Plants	Invasive exotic plants	6
		Invasive/Exotic Animals	Invasive/Exotic Animals	Invasive exotic fauna	17
				Early detection, status, and trends of non-indigenous aquatic species.	20
	Focal Species or Communi-ties	Marine Communities	Marine Benthic Communities	Coral Communities	1
				Seagrass and other SAV cover and community composition	4
		Intertidal Communities	Mangrove-Marsh Ecotone	Location of critical ecotones - field plots/transects	22
				Ecotone shifts along wetland boundaries - Mangrove to marsh to cypress- Aerial photography	33
				Physical drivers of mangrove-marsh ecotone	36
		Wetland Communities	Wetland Ecotones and Community Structure	Location of critical ecotones - field plots/transects	22
				Long-term, within-community vegetation shifts using permanent plots	26
		Forest/Woodland Communities	Forest Ecotones and Community Structure	Location of critical ecotones - field plots/transects	22
				Long-term, within-community vegetation shifts using permanent plots	26

National I & M Program Framework			SFCN Vital Sign	SFCN Workshop Indicators	Priority rank
Level 1	Level 2	Level 3			
Biological Integrity (Cont.)	Focal Species or Communi-ties (Cont.)	Marine Invertebrates	Marine Exploited Invertebrates	Exploited Inverts (Lobster, Conch, Crabs, Shrimp, Stone Crab, Blue Crab, Clams, Oysters, Sponges, Whelks)	13
				Pink Shrimp population structure, status, and trends	40
				Oyster population structure, status, and trends	47
			Marine Infaunal Community	Infaunal benthic community structure and abundance for animals	53
		Freshwater Invertebrates	Aquatic invertebrates in wet prairies & marshes	Aquatic invertebrates in wet prairies and marshes	41
		Terrestrial Invertebrates	Butterflies	Butterflies	61
			Island Insects	Island Insects	62
		Fishes (marine)	Marine Fish Communities	Exploited Fish Assemblage - Grouper, Snapper, (parrotfish, surgeonfish in USVI)- population structure, status, and trends	2
				Marine Fish Communities - Coastal Shelf / Deep oceanic - Status, structure, trends	15
				Marine Fish Communities - Bays/Mangroves - Status, structure, trends	21
			Focal Sportfish communities	Goliath Grouper (Red Hind in VI) - population structure, status, and trends	38
				Bonnethead, Lemon, Bull, Nurse Sharks - population structure, status, trends	43
				Gray Snapper (Schoolmaster in VI)- population structure, status, & trends	45
				Spotted Sea Trout - population structure, status, and trends	48
				Snook - population structure, status, and trends	52
		Fishes (freshwater)	Freshwater fish and large macro-invertebrates	Freshwater fish and large macro-invertebrates in wet prairies and marshes	24
		Amphibians and Reptiles	American Alligator	American alligator (*Alligator mississippiensis*)	29
			Amphibians	Amphibians - South Florida & USVI	32
				Pig Frog (*Rana grylio*)	54
			Reptiles-USVI	Reptiles - USVI	57
			Florida Box Turtle	Florida Box Turtle (*Terrapene carolina bauri*)	59
		Birds	Colonial Nesting Birds	Wading birds - Regional South Florida - Systematic Reconnaissance Flights	10
				Colonial Nesting Birds (e.g. Least terns, pelicans, boobies, roseatte terns, egrets, storks, herons)	16
			Landbirds	Land Birds - residential and migratory	31
				Land birds - Mangrove - population abundance and distribution	42
				Landbirds - Pine Rockland - population abundance and distribution.	49
				Landbirds-Cavity-nesting pine rockland birds - Demographics (Fecundity and Survival)	55
		Mammals	Bats-USVI	Bats - USVI	60
	At-risk Biota	T&E Species and Communities	Marine Invertebrates-RTE	Marine Invertebrates - Rare, threatened, and endangered species - *Acropora, Diadema, Antipathes*	8
			Sea Turtles	Sea Turtles	27
			American crocodile	American crocodile (*Crocodylus acutus*)	28

National I & M Program Framework			SFCN Vital Sign	SFCN Workshop Indicators	Priority rank
Level 1	Level 2	Level 3			
Biological Integrity (Cont.)	At-risk Biota (Cont.)	T&E Species and Communities (Cont.)	Protected Marine mammals	Marine Vertebrates - Rare, threatened, and endangered species - Crocodiles, Dolphin, Manatee, Sea Turtles, Protected marine mammals.	35
			Imperiled & Rare Plants	Critically Imperiled and Rare Plants	39
			Florida panther	Florida panther	44
			Sawfish	Sawfish- population structure, status, and trends	56
Human use	Visitor and Recreation Use	Visitor Use	Visitor Use	Visitor Use (Both commercial and individual/personal use)	19
Land-scapes (Eco-system Pattern and Processes)	Fire and Fuel Dynamics	Fire and Fuel Dynamics	Fire Return Interval Departure	Fire Return Interval Departure	37
	Landscape Dynamics	Land Cover and Use	Vegetation Communities Extent & Distribution	Shape, orientation, location, and coverage of vegetation community types	9
			Benthic Communities Extent & Distribution	Benthic community spatial & temporal changes in extent and distribution -remote sensing	30
			Land Use Change	Land Development inside/outside the park (within 5 mile radius for USVI parks, radius may be expanded to 75 miles in South Florida)	14

Appendix O.7

SFCN Indicator Worksheets

Table of Contents

Geology and Soils
Position and Spatial Extent of Mud Banks, Buttonwood Embankment and Berms..... 4
Sediment elevation in mangroves and mud banks (Fl Bay) Salt Ponds (USVI) and Mangrove fringes 6
Spatial and temporal changes in extent and distribution of substrate type (marl vs. peat). 8
Long-term sediment elevation changes in cypress strands and domes 10
Water
Hydrology = water stage, flow, timing, and duration 12
Spatial and Temporal Salinity Patterns 14
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A. *Position and Spatial Extent of Mud Banks, Buttonwood Embankment and Berms*

Which conceptual model(s) is this indicator linked to?

☑ Mangroves ☑ Florida Bay ☑ Biscayne Bay

Parks where monitoring would be conducted

☑ BICY ☑ BISC ☑ EVER

Indicator:	Position and Spatial Extent of Mud Banks, Buttonwood Embankment and Berms
Monitoring Question(s):	How do berms, embankments and mud banks influence circulation and water flows and how will they respond to everglades restoration and climate changes?
Justification:	Berms, embankments, and mud banks in Florida and Biscayne Bays have substantial influence on water exchange and the general circulation patterns between the near shore estuaries and oceanic water bodies. Monitoring the position and spatial extent of these structures is critical to understand the connectivity of the water bodies for processes like: larval recruitment, export of dissolved organic matter, salinity, nutrient patterns, etc. Everglades restoration, water delivery, large storm events, and sea level rise could all affect these ecosystem structures. Long-term resource management will need to understand the change in position and spatial extent to properly understand changes within the system.
Metric:	- Location and spatial extent (historically and at present) - Change in location and extent - Elevation (see Sediment elevation in mangroves and mud banks (Fl Bay) Salt Ponds (USVI) and Mangroves fringes)
Method:	- Historic maps, charts, and air photos - Recent air photos, bathy mapping, GIS analysis
Frequency:	Every 2-3 years
Timing:	Airphotos with no clouds
Scale of Collection:	Regional (incl. areas outside parks), Multiple Parks Multiple NPS units, FWS units, and state/local parks have SETS- Those are in multiple biogeographic regions.
Scale of Operation:	Regional (incl. areas outside parks), Multiple Parks, Site specific Processes affecting elevation occur over multiple scales.
Scale of Analysis:	Regional (incl. areas outside parks), Multiple Parks
Basic Assumptions:	Physical features such as mudbanks both affect water movement and will themselves be affected by CERP (QQTD) and climate.
Research Needs:	Understanding natural rates of change
Management Goal:	No net change (?) What does management do if you discover that basins are filling in naturally?

Threshold Target:	Insufficient knowledge
Response:	See Management goals above
Constraints:	Better understanding of mudbank dynamics as related to upstream inflows
Status:	All of the above. An excellent map of historic bathymetry for Fl Bay has been compiled (contact Bob Halley) The FATHOM hydrology model uses the best available bathymetry Have "good" data for Buttonwood embankment and Fl Bay and BISC NEED data for 10,000 Islands from Everglades City to NW Cape Sable
Estimated Cost:	- 150K- bathymetric survey of 10,000 Islands - 200K Resurveys with air photos and GIS analysis
References:	Hal Wanless (UM), Bob Halley (USGS), Kim Yates (USGS St. Pete), Bill Buttle, Jim Fourqurean (FIU), Mike Robblee (USGS @ EVER)- last three worked on FATHOM model

B. *Sediment elevation in mangroves and mud banks (Fl Bay) Salt Ponds (USVI) and Mangroves fringes*

Which conceptual model(s) is this indicator linked to?

☑ Island Interior ☑ Mangroves ☑ Florida Bay

Parks where monitoring would be conducted

☑ BICY ☑ BISC ☑ BUIS ☑ EVER ☑ SARI ☑ VIIS

Indicator:	Sediment elevation in mangroves and mud banks (Fl Bay) Salt Ponds (USVI) and Mangroves fringes
Monitoring Question(s):	How does sediment dynamics (accretion, subsidence and erosion) in mangroves, mud-banks, salt ponds respond to: 1) hydrology (Quality, quantity, timing and duration), 2) Sea-level, 3) Storms / hurricanes, and 4) upland erosion.
Justification:	Sediment dynamics (the build up or loss of) is a basic process that can have far reaching impacts on the ecosystem. It is especially important in mangroves, mud-banks, and salt ponds. In South Florida, hydrology, sea-level rise and storms have been found to affect mangrove and mud bank sediment elevation. Everglades restoration of regional hydrology is expected to impact this issue. In the U.S. Virgin Islands, sediment filling of ephemeral guts and salt ponds from upland development is an important issue.
Metric:	- Measure relative elevation, elevations change, accretion/erosion at "sentinel" sites.
Method:	- Use Surface Elevation Tables (SETs) and marker horizons. See Whelan *et al.* (2005), Estuaries 28(6) and References there in (esp. Cahoon *et al.*, 2002). - Do in conjunction with vegetation monitoring and surface and ground water monitoring.
Frequency:	quarterly- mangroves at first, maybe able to drop back to biannual (Wet and Dry) - sample after storm events
Timing:	Need to be able to respond rapidly to an "event"- a hurricane, fire, and flood.
Scale of Collection:	Regional (incl. areas outside parks), Multiple Parks Multiple NPS units, FWS units, and state/local parks have SETS- Those are in multiple biogeographic regions.
Scale of Operation:	Regional (incl. areas outside parks, Multiple Parks, Park-wide, Site Specific, Processes affecting elevation occur over multiple scales
Scale of Analysis:	Multiple parks, Site Specific
Basic Assumptions:	Sediment Elevation Table (SET) pipe is a benchmark and does not move (Surveys of the SET pipes can be done to make sure this is the case) Other assumptions from the Scale of Process above
Research Needs:	- Role of ground-water (see Whelan *et al.*, 2005) - Nutrient impacts role of ground-water (see Whelan *et al.*, 2005) - Nutrient impacts on below ground production - More work on role of storms- they can add sediment or kill vegetation leading to sediment loss ("peat collapse") - Role of fire along the mangrove- marsh ecotone

Management Goal:	Trend support management goals for no human influences on trends (upwards or downwards depending on system) -
Threshold Target:	Slope is zero or positive +/- 10-20% Relate ground elevation to lowest seaward berm height (VIIS) Accumulation of sediment in Salt Ponds and guts tied to natural process (and rates) and not to anthropogenic run off.
Response:	Replant mangroves after disturbance If not "keeping pace"- add phosphorous Upland sediment reduction measures for erosion runoff into salt ponds
Constraints:	- Known to work very well in coastal (tidal) wetlands and mud-banks (Fl Bay) - Has not been used in US VI
Status:	Ongoing: - SETS are widely used. 3 networks are present in ENP. TJ Smith has sites along Shark and Lostmans. R. Halley has SETS on mud-banks in Fl bay (5 sites). F. Sklar (2) has SETS in the Taylor Sough/ C 111 area. - Smith is funded starting Feb 2006 by Coe/Recover Sediment dynamics are a Comprehensive Everglades Restoration Plan (CERP) Monitoring and Assessment Plan (MAP) indicator.
Estimated Cost:	For SETs, marker horizons, hydrology sampling (surface and ground water) and vegetation- ALL at the site ~25K/year
References:	For mangroves and Fl. Bay mudbanks see Bob Halley USGS and MIT looking at sedimentation inputs into salt ponds (in 1970's).

C. *Spatial and temporal changes in extent and distribution of substrate type (marl vs. peat).*

Which conceptual model(s) is this indicator linked to?

☑ Freshwater Wet Prairies and Marshes

Parks where monitoring would be conducted

☑ EVER

Indicator:	Spatial and temporal changes in extent and distribution of substrate type (marl vs. peat).
Monitoring Question(s):	What is the status of substrate types at landscape scales over time? Are abnormal changes occurring?
Justification:	Many of the biogeochemical process that are critical in nutrient cycling and sediment generations in the fresh water Everglades is dependent on substrate type (marl vs. peat). Understanding the regional pattern of peat and marl and changes between these substrates is critical to interpret other process occurring with in the fresh water marshes. The extended hydroperiods proposed through Everglade's restoration may promote conversion from marl to peat substrates.
Metric:	Changes in large-scale patterns and extent of associated vegetation communities determined from aerial photography. Changes in surficial substrate physiochemical characteristics such as organic matter/ash content and depth and duration of flocculent detrital material determined from soil samples taken along predetermined transects.
Method:	Using vegetation maps and aerial photography, sites for soil transects will be determined and revisited at predetermined intervals.
Frequency:	Every 5 years, quarterly transect sampling during first year to determine possible rates of change then determine future visits.
Timing:	Not season specific, as determined from evaluation of vegetation maps and aerial photography. Quarterly (seasonal) transect sampling during first year to determine possible rates of change then determine future visits.
Scale of Collection:	Multiple Parks, Site Specific: after baseline verified, frequency determined
Scale of Operation:	Regional (incl. areas outside parks), Along transitional gradients (peat to marl)
Scale of Analysis:	Park-wide, Site specific along transitional gradients.
Basic Assumptions:	The underlying assumption is that hydrology affects the balance between organic matter production and respiration with longer hydroperiods leading to increasingly organic systems. Therefore changes in hydrologic conditions are important links to this process.
Research	Understand sources of change (baseline conditions) in substrate types.

Needs:	
Management Goal:	To maintain a healthy balance between peat and marl substrate systems.
Threshold Target:	Insufficient Knowledge
Response:	Modification of water management regime to hydroperiods that maintain desired substrate balance.
Constraints:	Should link extent and changes to alterations/variation in hydroperiod including depth and duration of inundation.
Status:	Course-scale vegetation mapping currently underway by SFWMD and NPS.

Estimated Cost:

References:

D. *Long-term sediment elevation changes in cypress strands and domes*

Which conceptual model(s) is this indicator linked to?

☑ Freshwater Wet Prairies and Marshes ☑ Forest Uplands and Wetlands

Parks where monitoring would be conducted

☑ BICY ☑ EVER

Indicator:	Long-term sediment elevation changes in cypress strands and domes
Monitoring Question(s):	Does soil surface elevation change in cypress strands and domes over time? What are the processes in the soil profile that dictate these changes?
Justification:	The change in soil surface elevation in cypress strand and domes dictate the hydroperiod which drives the cypress community dynamics (seedling recruitment, survival, decomposition). Long-term resource management of the forest wetlands requires an understanding of how the soil surface elevation changes in response to seasonal wetting, shrink-swell of soils, and fire.
Metric:	Documenting elevation change and processes associated with elevation change in cypress strands and domes of south Florida. This must include actual elevation change as well as subsidence, vertical accretion, and erosion, and should include at least some idea of deep vs. shallow subsidence/elevation change.
Method:	Establish a network of deep and shallow sedimentation-elevation tables (SET) for a statistically valid (i.e., using power analysis from past variation estimates) number of representative locations in cypress strands and domes in BICY and EVER. Perhaps include external locations within the BICY and EVER region?
Frequency:	Every 5-10 years (approximate interval), Quarterly - must be a sampling design that is sensitive to the seasonality of south Florida.
Timing:	Easiest to measure SETs during low-water periods; however, all periods should be considered. Vertical accretion sampling is also difficult under water.
Scale of Collection:	Regional (incl. areas outside parks) Note: Including refuge lands (e.g., Florida Panther NWR) May be good in order to include a larger assessment region along multiple Tamiami Trail crossings.
Scale of Operation:	Regional (incl. areas outside parks)
Scale of Analysis:	Regional (incl. areas outside parks)
Basic Assumptions:	Elevational processes associated with SET location are indicative of the larger community and can be linked appropriately to hydrological changes, fire, and shrink-swell events.
Research Needs:	Determine how elevation changes in south Florida cypress swamps are affected by seasonal wetting, anthropogenic water manipulations, and other landscape drivers (e.g., fire).
Management Goal:	Use management tools to the extent possible to maintain soil elevation as static as possible. This metric will provide an indication of soil elevation loss due to organic

	matter oxidation or combustion, as well as due to mineral sedimentation processes (directly or indirectly). This assumes that much of the cypress zone is currently at an elevation state that is acceptable as a target condition. SETs will also assist with defining this target condition.
Threshold Target:	Small changes in elevation over time become less of a problem as the time interval of monitoring increases. Consult Donald Cahoon and Phillippe Hensel (USGS-Patuxant) for specifics and long-term statistical analyses of these ideas. For instance, a 2 mm elevation change over 1 year becomes 20 mm over 10 years. If the first trend is not real, the longer term trend will not be found.
Response:	Increase water flow to limit soil oxidation processes or prolong the fire return interval to the system. On the flip side, these data may support a shorter fire return interval if elevation is unaffected by repetitive fires.
Constraints:	Standardizing sampling techniques over time with personnel turnover and budget changes. This is especially important for SET measurements. Again, consult Donald Cahoon, Philippe Hensel, or Kevin Whelan about potentials for sample error with personnel changes associated with SET readings.
Status:	SETs are currently being used in several south Florida mangrove areas. None, to my knowledge, are being used in cypress swamps.
Estimated Cost:	SET tables and sampling equipment can be purchased for about $3000 per device, but with pipes and supplies an estimate of $5000 for an entire set-up can be assumed. After the initial set-up, the per-SET price increases considerably. My guess is that $40-50K, as a one-time allocation would be sufficient for installing a fairly robust network over BICY, EVER, or Florida Panther NWR within the cypress swamps. This estimate excludes personnel costs and costs associated with re-measurement (probably $8-10K per annum for the latter??).
References:	Kevin Whelan is an excellent source for how this type of sampling might be accomplished. Don Cahoon, Phillippe Hensel, and Jim Lynch (USGS-Patuxant) would be good sources for exact costs associated with this sort of monitoring.

E. *Hydrology = water stage, flow, timing, and duration.*

Which conceptual model(s) is this indicator linked to?

☑ Freshwater Wet Prairies and Marshes ☑ Forest Uplands and Wetlands

☑ Island Interior ☑ Mangroves ☑ Florida Bay ☑ Biscayne Bay

Parks where monitoring would be conducted

☑ BICY ☑ BISC ☑

DRTO ☑ EVER ☑ SARI ☑ VIIS

Indicator:	Hydrology = water stage, flow, timing, and duration.
Monitoring Question(s):	What is the hydrology (quantity, timing, duration, flow) of the current system?
Justification:	Hydrology is an important driver in most ecosystems. Understanding the quantity, timing, duration, and flow of the hydrology allows a basic comprehension of how this major process affects the ecosystem. Additionally, a general understanding of hydrology is a necessary covariate to interpret other indicators. Everglades restoration is fundamentally expected to affect South Florida regional hydrology.
Metric:	Water quantity, depth, timing, and duration = hydroperiod (stage/depth of water at a specific location) - preemptive with management as additional trigger
Method:	Continuous measurement of stage at appropriate sites upstream to and in appropriate locations. Periodic measures of water velocity in concert with stage.
Frequency:	Continuous
Timing:	Continuous
Scale of Collection:	Regional (incl. areas outside parks), Site Specific
Scale of Operation:	Regional (incl. areas outside parks), Site Specific-During releases upstream
Scale of Analysis:	Regional (incl. areas outside parks), Site Specific-During releases upstream
Basic Assumptions:	Loadings can be calculated using stage/flow/concentration.
Research Needs:	Determine flow volume related to stage and flow velocity at specific points in EVER, VIIS, etc.
Management Goal:	Appropriate stages for the health of the wetland, meeting water quality criteria for wetlands (upstream and receiving bodies). Reduce adverse nutrient flow into FL Bay. Reduce nutrient flow into salt ponds and receiving water bodies.
Threshold Target:	Insufficient knowledge - depends upon what desired characteristics are being controlled for (ridge/slough patterning, SAV, periphyton, nutrient concentrations, flow rates, etc.)

Response:	Work with Water Management Districts to modify water releases, water redirection, and possibly implement buffer wetlands etc.
Constraints:	Dependent on continuous availability of upstream stage data, rainfall volume data, etc.
Status:	Contingent also on Surface Water Quality monitoring effort. Hydrology monitoring is a major focus in Comprehensive Everglades Restoration Program (CERP) Monitoring and Assessment Plan (MAP).
Estimated Cost:	Stage gauges for EVER-$1K per site?
References:	

F. *Spatial and Temporal Salinity Patterns*

Which conceptual model(s) is this indicator linked to?

☑ Mangroves ☑ Florida Bay ☑ Biscayne Bay ☑ Coastal Shelf/Deep Oceanic

Parks where monitoring would be conducted

☑ BISC ☑ BUIS ☑ EVER ☑ SARI ☑ VIIS

Indicator:	Spatial and Temporal Salinity Patterns
Monitoring Question(s):	What is the spatial and temporal distribution of physical characteristics (Salinity, Conductivity, pH, Dissolved Oxygen, Temperature, Redox) throughout the marine water bodies (Coastal Embankments, Central Bay, "open" bay).
Justification:	Physical characteristics of marine water bodies establish the environmental constraints within which other organisms must survive. Understanding the spatial and temporal distribution of the physical characteristics within marine water bodies allows more complete interpretation of other indicators. For example, historically salinity monitoring has been correlated with benthic community monitoring, productivity analysis, fish and other organismal sampling.
Metric:	Salinity, Temp, Depth
Method:	Salinity mapping (shipboard, e.g., NOAA/AOML, SFWMD) Use instrumentation to continuously measure salinity. QAQC procedures to calibrate and post calibrate meters. Determine corrections that would be applied for instrumental deterioration. See USACE/ BISC project/ CERP
Frequency:	Continuous- potential for selected parameters Supplemented "grab" samples, seasonal and event mapping.
Timing:	All Year
Scale of Collection:	Regional (incl. areas outside parks), Multiple Parks, Park-wide, Site Specific
Scale of Operation:	Regional (incl. areas outside parks), Multiple Parks, Park-wide, Site Specific
Scale of Analysis:	Regional (incl. areas outside parks)
Basic Assumptions:	Salinity is a controlling factor in the survival, distribution, health, and patterning on the water column, biotic community and in the benthic community
Research Needs:	Palioecologic studies to determine historical salinities Salinity tolerance and requirements of various mangrove fish or fish communities as well as benthic communities. Effects of salinity in mangrove communities. Effects of High Salinity discharge from RO water plants into near shore Bay.
Management Goal:	Salinity conditions to support historic communities At minimum support productive diverse communities
Threshold Target:	Use the following: CERP, BBCW, C111

	Southeast Estuaries Performance Measures (CERP, RECOVER AT- MAP; ET FBFKFS). Minimize rapid decreases in salinity
Response:	Review and recommendations/ DOI to water managers to improve water flow and distribution
Constraints:	Parks have very little control over inflows, salinity is subject to water availability and distribution which is a highly political process
Status:	- USACE/ BISC- Continuous/ ongoing - DERM/ SFWMD- Salinity profiles, NE Fl Bay Embankments, BISC Bay- Monthly- ongoing - FIU/SFWMD- Monthly grab samples BISC and Fl Bay
Estimated Cost:	
References:	Sarah Bellmund (BISC), Joe Boyer (FIU), Joe Serafy (NOAA), Rick Alleman (SFWMD), Susan Markley (DERM), Chris Crawford, Viletta Mayor (DPNR)

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G. *Freshwater Inputs to Estuaries*

Which conceptual model(s) is this indicator linked to?

☑ Mangroves ☑ Florida Bay ☑ Biscayne Bay ☑ Coastal Shelf/Deep Oceanic

Parks where monitoring would be conducted

☑ BICY ☑ BISC ☑ EVER ☑ SARI

Indicator:	Freshwater Inputs to Estuaries
Monitoring Question(s):	What are the spatial and temporal patterns of freshwater input (surface, groundwater and atmospheric) to estuaries?
Justification:	Freshwater input, coupled with hydrodynamics and evaporation, determines spatial and temporal salinity patterns. Freshwater input is a major estuarine ecosystem driver. Anthropogenic alteration of freshwater input is a major estuarine ecosystem stressor, likely the most important for Biscayne Bay, Florida Bay, and Gulf coast estuarine ecosystems. Specifically, this indicator concentrates effort at tracking the hydrological inputs from the territorial system into the near shore marine environments making this a more precise indicator than the general hydrology indicator (Hydrology = water stage, flow, timing, and duration).
Metric:	Surface water inflow volume: flow rate, water level or stage Ground water flow volume (if practical) Precipitation (rainfall).
Method:	Standard surface water and precipitation collection methodology currently being used in EVER and BICY, and elsewhere by SFWMD and USGS. Standard methods for groundwater flow measurements (Consult groundwater hydrologists.)
Frequency:	Continuous
Timing:	Year round
Scale of	Multiple Parks

Collection:	
Scale of Operation:	Regional (incl. areas outside parks)
Scale of Analysis:	Multiple Parks
Basic Assumptions:	
Research Needs:	Groundwater monitoring and modeling development. Integrated surface, groundwater, atmospheric water budget model. Evaporation/transpiration (ET) measurements were needed for water budget determination and modeling.
Management Goal:	EVER, BISC, BICY (?) mission/strategic goals and CERP goals and objectives regarding restoring and maintaining more natural freshwater inflows to, salinity patterns in, and ecological "health" of estuarine ecosystems.
Threshold Target:	General targets in park mission/strategic goals. CERP salinity targets.
Response:	Comprehensive Everglades Restoration Plan (CERP), Combined Structure Operation Plan (CSOP), has specific sections addressing this concern.
Constraints:	Practicality of groundwater flow monitoring.
Status:	Surface water and precipitation monitoring on-going for much of Florida Bay. Water level/stage continuous monitoring instruments being installed in mangrove zone lakes (West, Seven Palms, Lungs). Need flow meter in Alligator Creek. Much of EVER Gulf coast estuaries have surface water and precipitation monitoring; consult EVER Physical Branch for additional needs. Few, if any, groundwater flow monitoring stations. A complete assessment is needed.
Estimated Cost:	
References:	EVER Physical Branch scientists; local USGS hydrologists and coastal scientists; SFWMD scientists.

H. *Water Quality- Nutrients characteristics of the marine water bodies*

Which conceptual model(s) is this indicator linked to?

☑ Mangroves ☑ Florida Bay ☑ Biscayne Bay ☑ Coastal Shelf/Deep Oceanic

Parks where monitoring would be conducted

☑ BISC ☑ BUIS ☑ DRTO ☑ EVER ☑ SARI ☑ VIIS

Indicator:	Water Quality- Nutrients characteristics of the marine water bodies
Monitoring Question(s):	What is the spatial and temporal distribution of nutrients characteristics throughout the water bodies (i.e.. Coastal Embankments, Central Bay, "open" bay, Coral Bay).
Justification:	Nutrients within the marine ecosystem drive primary production and when unbalanced can have deleterious effects on the marine ecosystem. Understanding the spatial and temporal distribution of nutrients within the marine water bodies allows more complete interpretation to other indicators. Nutrients can change due to upstream/upland development, agricultural inputs, malfunctioning septic systems, boat discharges, atmospheric deposition, as well as internal cycling.
Metric:	Dissolved Inorganic Nitrogen (DIN) Dissolved Inorganic Phosphorous (DIP) Dissolved ammonia (NH4) Dissolved Organic Material (DOM) Dissolved Organic Carbon (DOC) Dissolved Organic Nitrogen (DON) Total Nitrogen (TN) Soluble Reactive Phosphorous (SRP) Total Nitrates (NO2 + NO3) Total Phosphorous (TP) Total suspended solids (TSS) Turbidity SECCHI Photosynthetically active radiation Fecal coliform Escherichia coli
Method:	- EMAP - Existing NPS and Territorial SOPS. - Grab sampling @ consistent depth (e.g., 1m depth) utilizing EPA/SM analysis - Continuous measures (e.g., SARI Crews Station, NOAA cruises) -limited parameter suite? - Utilizing historic sampling stations (DERM/ FIU) or establish protocol for network
Frequency:	Monthly, Event specific (high/low flow events- e.g., tropical systems/ drought)
Timing:	All Year
Scale of Collection:	Regional (incl. areas outside parks), Site Specific: nearshore gradients/ Fl Bay emphasized
Scale of Operation:	Regional (incl. areas outside parks), Park-wide: BISC, Site Specific
Scale of Analysis:	Regional (incl. areas outside parks), Park-wide, Site Specific: meter square to 10-100 hectares
Basic	- Circulation/ current patterns can result in localized effects of nutrient inputs, as well

Assumptions:	as distribute inputs throughout the water body
Research Needs:	Synergistic effects of dissolved organic and inorganic (broad scope nutrients) on primary production (eutrophication) Bioavailability/ decomposition of Dissolved Organic Matter Water quality model development Internal cycling rates (denitrification, N2 fixation)
Management Goal:	Appropriate levels and ratios to support primary productivity of SAV and phytoplankton, while limiting eutrophication and algal blooms
Threshold Target:	Meet all local, state, and federal water quality standards and criteria. Consider P:N ratios relative to "redfield ratio" - Specific dissolved/ total/ inorganic/ organic nitrogen targets - Light sufficient to sustain Benthic Habitat
Response:	Feasibility of upstream control? Review/ evaluation of "operations"/ flow patterns
Constraints:	- Limited control of inputs from upstream - Balance between needed water volume/ flow and water quality/ nutrient loading - Station matrix representation of site/ park/ regional scales
Status:	- SFWMD/ DERM- BISC bay/ Miami-Dade Co. canals (monthly grab sample) - SFWMD EVER WQ monitoring in eastern (general) EVER - SFWMD/FIU Biscayne Bay/ Fl Bay- Fl Bay month grab - NOAA Biscayne Bay/ Fl Bay "continuous" measure monthly cruises - Utilize/ augment existing programs
Estimated Cost:	
References:	David Rudnick (SFWMD), Trisha Stone (SFWMD), Susan Markley (DERM), Joe Boyer (FIU), Peter Ortner (NOAA)

I. *Nutrient Loading and Sediment Loading*

Which conceptual model(s) is this indicator linked to?

☑ Island Interior ☑ Mangroves ☑ Florida Bay ☑ Biscayne Bay ☑ Coastal Shelf/Deep Oceanic

Parks where monitoring would be conducted

☑ BISC ☑ EVER ☑ SARI ☑ VIIS

Indicator:	Nutrient Loading and Sediment Loading
Monitoring Question(s):	What is the nutrient loading and sediment loading to the estuary from all sources? What is the distribution of loading (location of load sources) along the coast? What is sediment loading to the guts and standing ephemeral pools at St. John only?
Justification:	This indicator builds on calculations from the "Surface Water Quality- physiochemical surface water characteristics at specific locations" and the "Hydrology = water stage, flow, timing, and duration", with the goal being calculations of nutrient and sediment loads for specific areas.
Metric:	- Discharge measures (flow) from major inputs (sloughs/ canals), surface, ground, overland - Associated concentration of nutrients for flow. Dissolved Inorganic Nitrogen (DIN) Dissolved Inorganic Phosphorous (DIP) Dissolved ammonia (NH4) Dissolved Organic Material (DOM) Dissolved Organic Carbon (DOC) Dissolved Organic Nitrogen (DON) Total Nitrogen (TN) Soluble Reactive Phosphorous (SRP) Total Nitrates (NO2 + NO3) Total Phosphorous (TP) Total suspended solids (TSS) Turbidity SECCHI Photosynthetically active radiation - Other nutrient sources and sinks (estimate atmospheric, oceanic, internal)
Method:	- Flow weighted WQ samples (nutrients) to capture short term (first flush) and longer period flow characteristics - Flow measures in a time step sufficient to characterize short and long-term flows - Atmospheric (dry and wet fall) - Offshore/ onshore - Groundwater estimates (may need models) - Knowledge of internal cycling - Guts in St. John, Inputs to SARI
Frequency:	Continuous- for overland/ creek/ discharge canal, Event based- sufficient to characterize varied flow regimes that occur "normally" and during events.
Timing:	Year
Scale of Collection:	Regional (incl. areas outside parks), Site Specific: Point sources (e.g.. Rivers, canals)
Scale of	Regional (incl. areas outside parks), Park-wide, Site Specific

Operation:	
Scale of Analysis:	Regional (incl. areas outside parks), Park-wide, Site Specific
Basic Assumptions:	Loads at samples points are characteristic of major nutrient inputs, or minimally can be utilized to establish a relationship for "input" locations and loads.
Research Needs:	Modeling of transport and flux Waterbody specific nutrient response, rate, and transport
Management Goal:	Loads maintained at levels to allow compliance with local/state/federal WQ standards and criteria and/or ecological optimum
Threshold Target:	A research Question Note: eventual determination TMDL Criteria
Response:	Same as WQ- nutrients
Constraints:	- Reliability of automated sampling equipment - Sampling interval to allow characterization of short and long term loading - Equipment cost (number of sites needing monitoring)- flow meters and automated samplers - Non-point sources- groundwater, sheet flow, ocean, etc.- diffuse, variable
Status:	- SFWMD, flow weighted sampling in (?Eastern), Ongoing (?) Everglades - USGS Studies on nutrient loading to BISC Bay (Past) - SFWMD/ USGS ongoing flow monitoring in Fl Bay (Ongoing) - SFWMD- Doppler flow measurements @ control structures (verification of rating curves) - Model under development
Estimated Cost:	Potentially large, at least until calibrated/verified models can be used
References:	Clinton Hittle (USGS), Dan Childers, Rick Alleman (SFWMD), Stephen Blair (DERM)

J. *Surface Water Quality- physiochemical surface water characteristics at specific locations.*

Which conceptual model(s) is this indicator linked to?

☑ Freshwater Wet Prairies and Marshes ☑ Forest Uplands and Wetlands ☑ Mangroves

Parks where monitoring would be conducted

☑ BICY ☑ BUIS ☑ EVER ☑ SARI ☑ VIIS

Indicator:	Surface Water Quality- physiochemical surface water characteristics at specific locations.
Monitoring Question(s):	What are the spatial and temporal distributions of nutrients and physical characteristics at specific sites in the wet prairies and marshes and into tidal areas?
Justification:	Nutrients and physical characteristics within the water body drive primary production and when unbalanced can have deleterious effects. Understanding the distribution of nutrients and physical characteristics allows more complete interpretation of other indicators. Many sites have had continuous sampling at specific locations for a number of years. Nutrient enrichment in freshwater and brackish areas has occurred primarily due to agricultural inputs (South Florida, US Virgin Is) with some impacts due to malfunctioning septic systems (US Virgin Is.). Everglades restoration is expected to reduce nutrient inputs to the Greater Everglades system.
Metric:	Total and soluble nutrients and pH, dissolved oxygen, conductivity, temperature, selected metals, salinity and chlorophyll, turbidity, photosynthetically active radiation (PAR), light extinction, etc.
Method:	- Grab sampling utilizing EPA/SM analysis - Continuous measures - limited parameter suite by Hydrolab-type units - Utilizing historic sampling stations and/or establish protocols and networks where needed.
Frequency:	Continuous- potential for selected parameters - Hydrolab-type, Event specific (high/low flow events- e.g., tropical systems/ drought, triggers based on abnormalities for example during periods of water ascension/recession).
Timing:	All Year
Scale of Collection:	Regional (incl. areas outside parks)
Scale of Operation:	Park-wide: EVER, BICY, Site Specific
Scale of Analysis:	Park-wide: EVER, BICY, Site Specific
Basic Assumptions:	Water flow patterns can result in localized effects of nutrient concentrations.
Research Needs:	Synergistic effects of dissolved organic and inorganic (broad scope nutrients) on primary production (eutrophication).

	Bioavailability/ decomposition of Dissolved Organic Matter and subsequent release of nutrients. Water quality model development and downstream loading determination Internal cycling rates (P sequestration, denitrification, N2 fixation)
Management Goal:	Appropriate levels and ratios to maintain historic vegetation patterns and trophic structure.
Threshold Target:	Meet all local, state, and federal water quality standards and criteria. - Specific dissolved/ total/ inorganic/ organic phosphorus, carbon, and nitrogen targets
Response:	Feasibility of upstream control? Review/ evaluation of "operations"/ flow patterns
Constraints:	- Limited control of inputs from upstream - Balance between needed water volume/ flow and water quality/ nutrient loading - Station matrix representation of site/ park/ regional scales
Status:	- SFWMD EVER WQ monitoring - SFWMD Stage and rainfall monitoring - Utilize/ augment existing programs
Estimated Cost:	Hydrolab Datasonde ($2K each) Sample analysis (nutrients) $60 each
References:	Len (FIU), Tom (SFWMD), Brian (NPS). Jim Hendee (Coral List guy - NOAA) Cruis station at Salt River.

K. *Contaminants in water column, organisms, and sediments.*

Which conceptual model(s) is this indicator linked to?

☑ Freshwater Wet Prairies and Marshes ☑ Forest Uplands and Wetlands ☑ Island Interior ☑ Mangroves ☑ Florida Bay ☑ Biscayne Bay ☑ Coastal Shelf/Deep Oceanic

Parks where monitoring would be conducted

☑ BICY ☑ BISC ☑ BUIS ☑ DRTO ☑ EVER ☑ SARI ☑ VIIS

Indicator:	Contaminants in water column, organisms, and sediments.
Monitoring Question(s):	What are the distribution, range, variability, concentrations of contaminants - including EPOCS (PPCP's - Pharmaceuticals and Personal Care Products), Endocrine disruptors and metals in the water column, organisms, and sediments (surface and core)?
Justification:	Point source and non-point source contaminants are a growing concern in most natural areas. Determining a proper monitoring protocol to establish a baseline and determine trends in contaminants is critical for proper resource management, especially in regards to modifications of water management from Everglades Restoration. Mercury bioaccumulation in particular is serious concern in the greater Everglades system.
Metric:	- Concentrations of conventional contaminants Hg (Total/Methyl); Metals, Hydrocarbons, PAHs, Pesticide/Herbicide/Insecticide, PCB's - Concentrations of EPOCs (Pharms, Caffeine, Estrogen/hormone related), non-regulated contaminants (vessel anti-fouling paint) - Grain size dependant
Method:	- Tissue analysis for conventional contaminants - Water Quality grab samples (in association with fish tissue sampling locations) for EPOCS - Tissue analysis should include resident (high site fidelity) and more broadly ranging species - Grab samples of water and sediment analyzed for contaminants - look at EPA EMAP SOP's o Sediment toxicity evaluations - Stratified random sampling (coastal inputs to open bay) - U.S. FWS or NOAA QA/QC and methods may be good starting point
Frequency:	Annual- Water Quality- Every 2 years for EPOCs, Every 4 years for sediment/ tissue analysis, Sampling frequency dependant on what is initially found
Timing:	Same time of year Across sampling periods - look at major use times (Columbus Day Regatta, Lobster Mini season, look at when partners are sampling
Scale of Collection:	Regional (incl. areas outside parks), Park-wide

Scale of Operation:	Regional (incl. areas outside parks), Site Specific: Basin?
Scale of Analysis:	Regional (incl. areas outside parks), Park-wide, Other (Please specify): Episodic
Basic Assumptions:	- Assessed organisms bioaccumulate contaminants of concern - Sediments serve as a sink for contaminants - Sediments contaminant levels are a surrogate of past exposure - Chemicals analyzed are the ones causing the greatest problems
Research Needs:	Effects of EPOCs and mode of action of EPOC's on animals, transient effects of EPOC's and contaminants What are biological thresholds for contaminants of concern
Management Goal:	No contaminants in Natural Waters or organisms, less than benchmark of concern for contaminants in water or sediment - look to level that causes no harm
Threshold Target:	- Meet all state/federal WQ and SQC standards - Reduction of contaminant in tissues sufficient to remove "fish consumption" limits, to protect biological/ecological integrity
Response:	Determine/mitigate to extent possible Source of Problem
Constraints:	- Sediments are spatially variable- sample number and location sufficient to adequately describe extent and pattern of contaminant levels - Selection of appropriate species for - Expensive! - Variability - Sample preservation, and analysis logistics
Status:	- DERM- County-wide canal sediment contaminants and toxicity (ongoing- every 5 years) - NOAA Biscayne Bay Sediment " (1995) -CCMA in Carib. - SFWMD/DERM County-wide and Bay Surface water Quality (ongoing) - SFWMD- Quarterly pesticide of canals entering the Bay - USDA- Surface Water- bimonthly?- pesticides/herbicides o South Dade "transects" from Everglades to Elliott Key - NPS- CESI- study EVER, BISC, BICY, various contaminants - USGS- EPOCs study (200 4/5)
Estimated Cost:	EPOC's ~$1400/sample Contaminants ~$1000/sample
References:	Susan Markley (DERM), Clint Lietz (USGS), Richard Pieffer (SFWMD), Ramona (USDA), Piero Gardinelle (NPS), NOAA CCMA, USFWS website, John Christiansen, Bill Loftus, Joel Trexler, Tina Ugarte, Roy Irwin

L. *Phytoplankton composition and biomass*

Which conceptual model(s) is this indicator linked to?

☑ Mangroves ☑ Florida Bay ☑ Biscayne Bay ☑ Coastal Shelf/Deep Oceanic

Parks where monitoring would be conducted

☑ BISC ☑

☑ DRTO ☑ EVER

Indicator:	Phytoplankton composition and biomass
Monitoring Question(s):	Is anthropogenic nutrient enrichment or other human associated disturbances causing algal blooms? Are blooms causing light extinction that is harmful to benthic habitat? Are blooms toxic/harmful (red tides)?
Justification:	Phytoplankton community composition and biomass reflect water quality, especially nutrient loading and water clarity. They are important primary producers in aquatic food webs, which when unbalanced by excessive nutrients respond quickly with algal blooms that reduce dissolved oxygen and cause light extinction that harms benthic habitat and fish. Some algal species can be especially harmful as in western Florida where harmful red tides have occurred and in the Florida keys where "black water" events have occurred.
Metric:	Primary - Chlorophyll a, other pigments (taxonomic indicator), microscopic validation of pigment indicator, possible bioassay for red tide (?), location, light extinction Secondary - From related program, nutrients (concentration and loading), DO variability, salinity - Cyanobacteria and red tide species as indicators of harmful algal blooms
Method:	Fluorometry, HPLC, (remote sensing of chlorophyll a?), in vivo field surveys; extracted fluorometry Microscopy
Frequency:	Monthly, also with events (higher frequency)
Timing:	N/A
Scale of Collection:	Regional (incl. areas outside parks)
Scale of Operation:	Regional (incl. areas outside parks)
Scale of Analysis:	Regional (incl. areas outside parks)
Basic Assumptions:	Pigments are good indicators of biomass and composition
Research Needs:	Attributing anthropogenic vs. natural forcing? Capability of red tide bioassays? Water quality model development Causes of bloom dynamics

	Information of limiting nutrients, (N, P, Si, Fe)
Management Goal:	Minimize anthropogenically driven blooms, especially as indirect consequence of environmental management
Threshold Target:	Varies with location (see RECOVER and Fl Bay and Keys Feasibility Study performance measures)
Response:	Improved nutrient treatment?
Constraints:	-See research needs regarding cause and effect -Frequency of blooms (high variability) -Model capability
Status:	-SFWMD/FIU WQ monitoring -DERM/SFWMD -Mote/ FKNMS/EPA/FIU -FWRI- (HAB) -NOAA/AOML/RSMAS- Mapping -SFWMD Model development
Estimated Cost:	Included in overall water quality monitoring = $1M- $20M, but extra ~$200,000 for detailed composition non-chlor pigments (best guess)
References:	Joe Boyer, Karen Steidinger, Gary Hitchcock, Gabe Vango, Ed Philips, Cindy Heil

M. *Invasive exotic plants*

Which conceptual model(s) is this indicator linked to?

☑ Freshwater Wet Prairies and Marshes ☑ Forest Uplands and Wetlands

☑ Island Interior ☑ Mangroves

Parks where monitoring would be conducted

☑ BICY ☑ BISC ☑ BUIS ☑

DRTO ☑ EVER ☑ SARI ☑ VIIS

Indicator:	Invasive exotic plants
Monitoring Question(s):	Are invasive exotic plants increasing in extent or are new invasive species becoming established in or near the park with potential to become invasive?
Justification:	Invasive plants are one of the most serious threats to maintaining ecosystem integrity in the South Florida and Caribbean parks. Not only is tracking the distribution, rate of spread and control of known invasive species important to assessing the health of the system for supporting native species, but detecting new species with the potential to become invasive while they are still in small controllable populations is important to cost-effective management of this problem. Executive Order 13112 deals with the introduction, spread, control, and monitoring of invasive species on federal lands.
Metric:	Number of species established Areal extent of invasion by species Vegetation types invaded Number of new species near or in park Risk factor for invasion of a new species
Method:	See Science Coordination Group development of invasive plant indicator There are gaps in coverage of the SCG indicator. It does not cover BISC, or western BICY
Frequency:	Annual
Timing:	Winter after leaf fall for deciduous species
Scale of Collection:	Multiple Parks
Scale of Operation:	Regional (incl. areas outside parks)
Scale of Analysis:	Regional (incl. areas outside parks)
Basic Assumptions:	Invasive species are continuing to spread and invade and are altering native ecosystem properties and functions
Research Needs:	Development of a risk assessment tool for south Florida plants and animals and a detailed listing of species that may pose future threats in order to do a risk assessment. Need an understanding of the biology of individual species and work for biocontrol of species (see USDA and SFWMD)

Management Goal:	No new species invading, reduction in extent of existing invasive species
Threshold Target:	No exotic species present or contraction in extent of existing species and no new species
Response:	Active management program to reduce populations
Constraints:	Need to determine invasive risk potential of a species new to the area. Need to determine how to kill a species and prevent its further spread.
Status:	Some work is being done, See EPA REMAP, SFWMD-USFWS-NPS SRF, SCG indicator, SFWMD tree island survey and SFWMD Vegetation mapping project. Also Florida Exotic Pest Plant Council and the COE Master Invasive Species Plan.
Estimated Cost:	Varies but see different existing projects Synthesis of existing information and filling spatial and temporal gaps in existing projects
References:	LeRoy Rodgers, Ken Rutchey SFWMD, John Volin FAU, Jenny Richards & Tom Philippi & Bob Doren FIU, Tony Pernas, Jonathan Taylor, Skip Snow NPS

N. *Invasive exotic fauna*

Which conceptual model(s) is this indicator linked to?

☑ Freshwater Wet Prairies and Marshes ☑ Forest Uplands and Wetlands ☑ Island Interior ☑ Mangroves ☑ Florida Bay ☑ Biscayne Bay ☑ Coastal Shelf/Deep Oceanic

Parks where monitoring would be conducted

☑ BICY ☑ BISC ☑ BUIS ☑ DRTO ☑ EVER ☑ SARI ☑ VIIS

Indicator:	Invasive exotic fauna
Monitoring Question(s):	What exotic animal species are present in the parks and which ones are considered invasive or otherwise problematic? What is the distribution of the species and level of control and how is this changing? Are new invasive species becoming established in or near the park? How are they affecting native species and habitats?
Justification:	Invasive fauna are one of the most serious threats to maintaining ecosystem integrity in the South Florida and Caribbean parks. At least 61 exotic species are currently found within the network parks. Some of the most problematic include pythons, hogs, rats, mice, mongoose, Mayan cichlid, Cuban tree frogs, loose and feral livestock, lac lobate scale, and fire ants. Tracking the distribution and level of control of known invasive species is important to assessing the health of the system for supporting native species. In addition, detecting new species with the potential to become invasive while they are still in small controllable populations is important to cost-effective management. Island food-webs are particularly susceptible to invasive species, but also offer some of the best opportunities for successful control. Executive Order 13112 deals with the introduction, spread, control, and monitoring of invasive species on federal lands. Note: Indicator "Early detection, status, and trends of non-indigenous aquatic species" is similar but has a more specific focus on non-indigenous aquatic species in south Florida and detailed methodology.
Metric:	Number of species established Locations/distribution where detected Trends in distribution of established species Vegetation types invaded Number of new species detected near or in park Risk factor for invasion of a new species
Method:	• Monitor for new species at likely entry points (park boundaries, boundary canals, areas of high commercial or recreational boat traffic). • Record new sightings detected during other monitoring and management activities. • As problematic species are identified, target methods to that species to assess distribution and/or abundance and assess changes as appropriate (for species whose distribution is park-wide and no control exists, detailed monitoring is not recommended as it yields no useful information).
Frequency:	Annual

Timing:	As appropriate by species
Scale of Collection:	Multiple Parks, Site Specific
Scale of Operation:	Regional (incl. areas outside parks)
Scale of Analysis:	Regional (incl. areas outside parks), Multiple Parks, Site Specific
Basic Assumptions:	Some invasive species are established (e.g., pythons, hogs, rats, mice, mongoose, Mayan cichlid, Cuban tree frogs, loose and feral livestock, lac lobate scale, and fire ants) and are already altering native ecosystem properties and functions. New invasive species could establish due to released pets, ornamental plant trade, exotic food trade, fishing bait, boats hulls, ship ballast water releases, and freak accidents during hurricanes and tropical storms both within and outside the parks.
Research Needs:	Development of a risk assessment tool for south Florida plants and animals and a detailed listing of species that may pose future threats in order to do a risk assessment. Need an understanding of the biology of individual species and work for biocontrol of species (see USDA and SFWMD)
Management Goal:	No new species invading, reduction in extent of existing invasive species
Threshold Target:	No exotic species present or contraction in extent of existing species and no new species
Response:	Active management program to reduce populations
Constraints:	Need to determine invasive risk potential of a species new to the area. Need to determine how to remove a species and prevent its further spread.
Status:	Project-specific monitoring - i.e. elimination of mongoose, rats, and mice on Buck Island; control efforts for pythons in Everglades; rats at DRTO; monitoring at BISC for Mexican red-bellied squirrel
Estimated Cost:	Varies but see different existing projects Synthesis of existing information
References:	Tony Pernas (NPS-EPMT), Skip Snow (NPS-EVER), Jeff Kline (NPS-EVER)

O. *Early detection, status, and trends of non-indigenous aquatic species.*

Which conceptual model(s) is this indicator linked to?

☑ Freshwater Wet Prairies and Marshes ☑ Forest Uplands and Wetlands

☑ Mangroves

Parks where monitoring would be conducted

☑ BICY ☑ EVER

Indicator:	Early detection, status, and trends of non-indigenous aquatic species.
Monitoring Question(s):	1. The early detection of non-indigenous species outside of NPS boundaries in support of management actions to prevent the introduction and establishment of

	non-native species with NPS boundaries. 2. The early detection of non-indigenous species within NPS boundaries to facilitate management actions to prevent establishment. 3. Tracking the status and trends of non-indigenous populations both within and outside of NPS boundaries.
Justification:	There are over 100 non-indigenous aquatic species that have been introduced in South Florida. Establishment and displacement of native fauna is a real management concern. In addition some invasive non-indigenous species have the potential for greatly changing aquatic food web functioning. Detecting new species with the potential to become invasive while they are still in small controllable populations and/or outside park boundaries is important to cost-effective management of this problem. Executive Order 13112 deals with the introduction, spread, control, and monitoring of invasive species on federal lands.
Metric:	Number of non-indigenous species both within and along the boundary of NPS lands. Changes in non-native species composition outside ENP boundaries. Changes in numbers and population sizes of non-native species within ENP.
Method:	Common fisheries survey techniques: Electrofishing, trapping, netting. Methods chosen should be proven to collect a large diversity of species to increase the probability of detecting new species in the system.
Frequency:	Annual
Timing:	Annually at a minimum. During the dry season when fishes are concentrated in canals along the border. During the wet season within ENP boundaries to detect populations on the marsh surface.
Scale of Collection:	Other (Please specify): Includes both within NPS boundaries lands and canals bordering.
Scale of Operation:	Other (Please specify): Includes both within NPS boundaries lands and canals bordering.
Scale of Analysis:	Other (Please specify): Includes both within NPS boundaries lands and canals bordering.
Basic Assumptions:	The S. Florida canal system is key source of aquatic non-indigenous species within ENP.
Research Needs:	Research techniques for delivering water without delivering non-indigenous species.
Management Goal:	Reduce the rate of increase in numbers of new non-indigenous species entering and becoming established within NPS lands. Reduce the total number of non-indigenous species established within NPS lands. Monitoring that provides early detection and changes in the distribution of non-native species to support management actions that prevent the spread into ENP lands and tracks the distribution of species once introduced.
Threshold Target:	No new non-indigenous species within NPS lands. Use existing numbers of species to base changes against.
Response:	Determine if there are viable alternatives to how water delivery is accomplished. Facilitate cooperation between state and federal agencies to meet the mandates of federal lands where non-indigenous species are concerned.
Constraints:	South Florida Parks need water and it seems that there will always be canals with non-indigenous species in South Florida.
Status:	Some monitoring exists within Everglades National Park boundaries. There is no consistent monitoring effort in the border canals and lands to ENP.

Estimated Cost:
References:

P. *Coral Communities*

Which conceptual model(s) is this indicator linked to?

☑ Coastal Shelf/Deep Oceanic

Parks where monitoring would be conducted

☑ BISC ☑ BUIS ☑ DRTO ☑ SARI ☑ VIIS

Indicator:	Coral Communities
Monitoring Question(s):	How do coral communities change over time within parks and outside of park? How are percent cover, species diversity, rugosity, abundance, spatial extent, recruitment, disease, mortality, calcification, structure, and algal community structure changing? How do communities compare among areas with differing management regimes?
Justification:	The coral reef communities within the South Florida / Caribbean Network represent some of the best examples of Caribbean and Western Atlantic Coral reefs within the National Park Service. The enabling legislation and/or presidential proclamations for VIIS, BUIS and DRTO specifically mention coral reefs within these park units as significant environmental communities. The reefs support incredible diversity, including endangered sea turtles, conchs and lobsters. Monitoring coral reefs was identified as a national priority by President Clinton's Executive Order 13089 establishing the Coral Reef Initiative. These coral reefs are negatively impacted by unusually high water temperatures that cause "bleaching", coral disease, overfishing, vessel scarring, major storms, and in some cases by sedimentation and nutrient enrichment.
Metric:	Percent cover, species diversity, rugosity, abundance, spatial extent, recruitment, disease, mortality, calcification, structure, bio-erosion, episodic assaults (bleaching)
Method:	Video transects, quadrats (photo/visual), colonies, area surveys.
Frequency:	Annual, episodic, to be determined
Timing:	consistent dates.
Scale of Collection:	Regional, Multi-park, site specific, external to park
Scale of Operation:	Regional
Scale of Analysis:	Regional, park, site specific
Basic Assumptions:	Independence or linkage Monitoring reflects the population- appropriate timing and methodology Revisit during protocol development.
Research Needs:	- Relation of demographics to observable information - Determine a threshold target - species specific - Identify sensitive species - Larval transport - Inventory of deep.

	- Microbial communities.
Management Goal:	Coral community integrity Sustainable recreation Sustainable fisheries Sustainable water quality
Threshold Target:	
Response:	- sound alarm - organize task force - education/outreach - mitigation
Constraints:	Is this sampling design appropriate in predicting population estimates? [precision] Costs of high precision sampling design Uncertainty in estimates Number of qualified research experts. Decadal processes limit ability to show trend.
Status:	Ongoing (NOAA, FWC, NPS, USGS, EPA, Universities, NGO's, etc)
Estimated Cost:	Park/Method/Intensity specific
References:	Contact: Jeff Miller, Caroline Rogers, Chris Jeffries.

Q. *Seagrass and other SAV cover and community composition*

Which conceptual model(s) is this indicator linked to?

☑ Mangroves ☑ Florida Bay ☑ Biscayne Bay ☑ Coastal Shelf/Deep Oceanic

Parks where monitoring would be conducted

☑ BISC ☑ BUIS ☑

☑ DRTO ☑ EVER ☑ SARI ☑ VIIS

Indicator:	Seagrass and other SAV cover and community composition
Monitoring Question(s):	What is the location, distribution, extent, habitat quality of SAV habitat? How does SAV habitat vary along onshore-offshore, longshore gradients over time and depths? How is community composition changing over time?
Justification:	Communities of seagrass and other submerged aquatic vegetation (SAV) cover large portions of 6 parks within the South Florida / Caribbean Network. These habitats support a wide diversity of vertebrate and invertebrate life and provide connectivity pathways between nearshore and offshore habitats. They are also important nursery areas for many marine species. Community composition is related to salinity levels, light extinction, the distribution of soft-bottom and hard-bottom sediments, nutrient enrichment, water quality (e.g., sulfides, redox), disease, level of disturbance, and succession. The 1987 seagrass die-off in Florida Bay had cascading effects on the ecosystem.
Metric:	Primary: Modified Braun- Blanquet cover index, species composition (including both seagrass and macroalgae), location, depth, salinity, sediment depth, canopy height.

	density Secondary (from related programs)- light extinction, nutrients, N:P ratio in Thallasia blades, epiphytes, sulfide toxicity, redox, slime mold disease
Method:	See RECOVER (Durako and Fourqurean)- Diver Potential for video transects Belts, Quadrats. See also NPS protocol
Frequency:	Monthly- min. semi-annual (all sites) Quarterly (subset of all sites), Annual
Timing:	Wet season, dry season (focus on salinity min/max)
Scale of Collection:	Regional (incl. areas outside parks), multiple parks, site specific
Scale of Operation:	Regional (incl. areas outside parks)
Scale of Analysis:	Regional (incl. areas outside parks), Site Specific: meter square to 10-100 hectares
Basic Assumptions:	-Sensitive to stressors -Relevant to food web -Braun Blanquet methodology is sufficiently quantitative -Coordinated with salinity and other measurements
Research Needs:	Effects of macro-nutrients on species composition. Effects of salinity variance on species comp. Video transect Braun Blanquet calibration/ verification. Interspecific species competition relationships. Relationship of importance of habitat quality to upper trophic levels. E.g., Diversity, etc)
Management Goal:	At a minimum, maintain marshes, seagrass species abundance, and distribution. Rehabilitate a diverse and sustainable habitat
Threshold Target:	General target of high cover where SAV can grow (e.g., with sediments), moderate density, high diversity. "Threshold" level undetermined at this time.
Response:	Insufficient knowledge, but salinity and nutrient management are likely focus for action
Constraints:	Semi-quantitative nature of Braun-Blanquet Calibration among sampling teams/ field workers Continued model development (in progress) Larger scale spatial relationships (need for remote sensing, mapping)
Status:	Some existing monitoring exists in Fl Bay and BISC Bay by Miami- Dade DERM and FIU, UNCW (Duracho). (RECOVER, SFWMD funding) USVI on-going In Comprehensive Monitoring Restoration Plan (CERP) Monitoring and Assessment Plan (MAP) and is an Interim Goals indicator.
Estimated Cost:	$500,000/ yr
References:	Jim Fourqurean (FIU), Penny Hall (FWRI), Duraco (UNCW), S. Blair (MD DERM), B. Miller, Chris Jeffery

R. *Benthic community spatial & temporal changes in extent and distribution - remote sensing*

Which conceptual model(s) is this indicator linked to?

☑ Florida Bay ☑ Biscayne Bay ☑ Coastal Shelf/Deep Oceanic

Parks where monitoring would be conducted

☑ BISC ☑ BUIS ☑ DRTO ☑ EVER ☑ SARI ☑ VIIS

Indicator:	Benthic community spatial & temporal changes in extent and distribution -remote sensing
Monitoring Question(s):	What are the baseline conditions in the extent and distribution of major benthic communities and how are they changing (e.g., hardbottom, soft-bottom, dense Thallasia sp. seagrass, sparse seagrass, etc)? Where are areas of impact occurring (visitor use, canal discharges)? Are abnormal/episodic changes occurring?
Justification:	The extent, distribution, and composition of major benthic communities (e.g., hardbottom, soft-bottom, dense Thallasia sp. seagrass, sparse seagrass, etc.) across bays and marine areas are a strong influence on the fish, invertebrate, and larger vertebrate communities (e.g., sea turtles, manatees) they support. These can change with alterations in location, quantity and quality of freshwater and sediment inputs (e.g., Comprehensive Everglades Restoration Plan), nutrient levels, major storm events, and heavy visitor use (e.g., repeated boat groundings, scarring, and anchoring damage). Analysis of remotely-sensed data provides the spatial extent and composition of major benthic communities across relevant areas of marine parks allowing tracking of changes in large-scale patch size and shape at a broader scale than site-specific studies.
Metric:	Changes in large-scale patch size and shape with field sampling to ground-truth species composition of benthic patches
Method:	GIS low level aerial imagery or submerged georeferenced imagery polygons that are analyzed for shape, size, and spatial relationships Example: Underwater georeferenced videos, diver surveys, acoustic
Frequency:	To be determined
Timing:	To be determined
Scale of Collection:	Regional (incl. areas outside parks), Site Specific
Scale of Operation:	Regional (incl. areas outside parks), Park-wide, may also be local in relation to events or inputs- e.g., Canals or boat groundings
Scale of Analysis:	Regional (incl. areas outside parks), Park-wide
Basic Assumptions:	The underlying assumption is that there is some characteristic suite of benthic communities that exist in relation to each other in some characteristic or consistent way that may change if faced with a significant perturbation or abnormal conditions.
Research	This information is needed to verify a seagrass model

Needs:	Understand sources of change (baseline conditions) in various benthic communities
Management Goal:	To maintain a mosaic of natural benthic habitats.
Threshold Target:	Insufficient Knowledge
Response:	Determine source of change. Once source of change is known, act on it if possible.
Constraints:	Must sample with enough frequency to clearly characterize a baseline condition. Best if also used in conjunction with a detailed complex seagrass model. This could be used to look at influences on changes in macro-algal communities, shifts in hardbottom, and increases in mud bottoms.
Status:	-Some sampling is currently funded for submerged imaging within BISC and some reef sampling. SWAP's in BISC Bay by UM RSMAS -FDEP/MAP-CERP currently developing benthic map of entire BISC and Fl Bay area. Not used in fine scale -Benthic habitat maps, fine-scale in-situ data collection on-going. - USVI -Side-Scan Sonar, Multi-beam and ROV work ongoing. - USVI
Estimated Cost:	
References:	

S. *Marine Fish Communities - Coastal Shelf / Deep oceanic - Status, structure, trends*

Which conceptual model(s) is this indicator linked to?

☑ Coastal Shelf/Deep Oceanic

Parks where monitoring would be conducted

☑ BISC ☑ BUIS ☑ DRTO ☑ EVER ☑ SARI ☑ VIIS

Indicator:	Marine Fish Communities - Coastal Shelf / Deep oceanic - Status, structure, trends
Monitoring Question(s):	How do fish communities change over time within parks outside of parks? Does the species integrity persist? What is the location and integrity of spawning aggregations? How do communities compare among areas with differing management regimes? How do juvenile communities change over time?
Justification:	Fish communities in the coastal shelf and oceanic areas are an important higher trophic level of the marine system that are additionally valued by humans as fisheries. Community status, structure and trends reflect changes in marine habitat quality, connectivity, fishing pressure, and long-term ecosystem resilience. The status of fish communities also affects seabird communities and large marine vertebrates. Balancing resource extraction with sustainability is a key management concern. The impacts of fishery management tools such as "no-take" zones are of high interest to resource management and the public. Several fish species within parks are at or near local or regional extirpation.
Metric:	Fish community recruitment, abundance, size, species, species composition, fishing pressure, biomass Spawning aggregation characteristics
Method:	Fishery dependent- monitoring recreational and commercial catch Fishery independent- visual census, acoustics, optics, nets, trawls, traps Methods may need to be focused to answer targeted spp questions?
Frequency:	Annual to quarterly; lunarly.
Timing:	Depending on seasonal spatial distribution.
Scale of Collection:	Regional, Multi-park
Scale of Operation:	Regional/ Multi-park
Scale of Analysis:	Multi-park/ Park/ Habitat
Basic Assumptions:	Independence or linkage Monitoring reflects the population- appropriate timing and methodology
Research Needs:	To better understand the sustainability of the community: Natural History/Demographics of non-exploited species Connectivity

Management Goal:	Fish community integrity Sustainable fishing and other recreation Viable spawning aggregations
Threshold Target:	Increased predator base Increased herbivores To be determined
Response:	Reduce impacts of principal stressors: Collaborate with other agencies Internal response
Constraints:	Is this sampling design appropriate in predicting population estimates? [precision] Costs of high precision sampling design We know the measurement generally reflects population changes, the level of accuracy and precision is cost dependent.
Status:	Ongoing (NOAA, FWC, NPS, Universities, NGO's, etc)
Estimated Cost:	Park/Method/Intensity specific
References:	Contact: J. Bohnsack, J. Ault, C. Menza

T. *Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Throw trap*

Which conceptual model(s) is this indicator linked to?

☑ Freshwater Wet Prairies and Marshes ☑ Mangroves ☑ Florida Bay ☑ Biscayne Bay

Parks where monitoring would be conducted

☑ BICY ☑ BISC ☑ BUIS ☑ DRTO ☑ EVER ☑ SARI ☑ VIIS

Indicator:	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Throw trap
Monitoring Question(s):	What are baseline conditions, variability, and trends in nearshore and estuarine fish communities?
Justification:	Fish communities in nearshore estuaries are a critical component of the ecosystem. Community status, structure and trends reflect changes in marine habitat quality, connectivity, fishing pressure, and long-term ecosystem resilience. Several fish species within parks are at or near local or regional extirpation. Differing sampling methodologies target different portions of the fish community. Our fisheries experts advocate using consistent methodologies across the region for increased data comparability, but recommended evaluating them independently through this ranking process. This indicator refers to "throw trap" methods. "Visual assessment", "seining", "trawling", and "other trapping" are covered in other indicator worksheets.
Metric:	Taxonomic composition, T. Richness, T. Diversity, T. Evenness, habitat and sediments (?), T. dominance (spatial and temporal distribution), trophic classification, index of trophic complexity
Method:	Throw trap
Frequency:	Monthly- pilot, seasonal after pilot
Timing:	To be determined, dependent on pilot
Scale of Collection:	Multiple Parks
Scale of Operation:	Park-wide, Site Specific
Scale of Analysis:	
Basic Assumptions:	- Consistency in sampling design and sampling methods - Consistency in protocol - Consistency of data collection and data quality control
Research Needs:	- Hydrographic dynamics and monitoring - Literature review/ research, analysis of historical data and literature to look for trophic classification by species as well as size class
Management	Optimal diverse and productive community

Goal:	
Threshold Target:	Will be determined by baseline analysis
Response:	Will be determined by baseline analysis
Constraints:	Funding, continuous and long-term Support Skilled man power
Status:	Ongoing in BISC and EVER through MAP
Estimated Cost:	~$250k/park/year MAP covers BISC and EVER
References:	Joe Serafy Joan Browder Mike Robblee Todd Hopkins

U. *Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Trawling*

Which conceptual model(s) is this indicator linked to?

☑ Freshwater Wet Prairies and Marshes ☑ Mangroves ☑ Florida Bay

☑ Biscayne Bay

Parks where monitoring would be conducted

☑ BICY ☑ BISC ☑ DRTO

Indicator:	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Trawling
Monitoring Question(s):	What are baseline conditions, variability, and trends in nearshore and estuarine fish communities??
Justification:	Fish communities in nearshore estuaries are a critical component of the ecosystem. Community status, structure and trends reflect changes in marine habitat quality, connectivity, fishing pressure, and long-term ecosystem resilience. Several fish species within parks are at or near local or regional extirpation. Differing sampling methodologies target different portions of the fish community. Our fisheries experts advocate using consistent methodologies across the region for increased data comparability, but recommended evaluating them independently through this ranking process. This indicator refers to "trawling" methods. "Visual assessment", "seining", "throw traps", and "other trapping" are covered in other indicator worksheets.
Metric:	Taxonomic composition, T. Richness, T. Diversity, T. Evenness, habitat and sediments (?), T. dominance (spatial and temporal distribution), trophic classification, index of trophic complexity
Method:	Trawling
Frequency:	Monthly- pilot, seasonal after pilot
Timing:	To be determined, dependent on pilot
Scale of Collection:	Multiple Parks
Scale of Operation:	Park-wide, Site Specific
Scale of Analysis:	
Basic Assumptions:	- Consistency in sampling design and sampling methods - Consistency in protocol - Consistency of data collection and data quality control
Research Needs:	- Hydrographic dynamics and monitoring - Literature review/ research, analysis of historical data and literature to look for trophic classification by species as well as size class
Management	Optimal diverse and productive community

Goal:	
Threshold Target:	Will be determined by baseline analysis
Response:	Will be determined by baseline analysis
Constraints:	Funding, continuous and long-term Support Skilled man power
Status:	Ongoing in BISC and EVER through MAP
Estimated Cost:	~$250k/park/year MAP covers BISC and EVER
References:	Joe Serafy Joan Browder Mike Robblee Todd Hopkins Ron Hill (NIMPS) Texas worked in St. John not in mangroves Ivan Mateo (U of Rhode Island) Sea Nimph project at Salt River. Otoliths (ear bone chemistry) for connectivity.

V. *Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Seining*

Which conceptual model(s) is this indicator linked to?

☑ Freshwater Wet Prairies and Marshes ☑ Mangroves ☑ Florida Bay

☑ Biscayne Bay

Parks where monitoring would be conducted

☑ BICY ☑ BISC ☑ BUIS ☑ DRTO ☑ EVER ☑ SARI ☑ VIIS

Indicator:	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Seining
Monitoring Question(s):	What are baseline conditions, variability, and trends?
Justification:	Fish communities in nearshore estuaries are a critical component of the ecosystem. Community status, structure and trends reflect changes in marine habitat quality, connectivity, fishing pressure, and long-term ecosystem resilience. Several fish species within parks are at or near local or regional extirpation. Differing sampling methodologies target different portions of the fish community. Our fisheries experts advocate using consistent methodologies across the region for increased data comparability, but recommended evaluating them independently through this ranking process. This indicator refers to "seining" methods. "Visual assessment", "trawls", "throw traps", and "other trapping" are covered in other indicator worksheets.
Metric:	Taxonomic composition, T. Richness, T. Diversity, T. Evenness, habitat and sediments (?), T. dominance (spatial and temporal distribution), trophic classification, index of trophic complexity
Method:	Seining
Frequency:	Monthly- pilot, seasonal after pilot
Timing:	To be determined, dependent on pilot
Scale of Collection:	Multiple Parks
Scale of Operation:	Park-wide, Site Specific
Scale of Analysis:	
Basic Assumptions:	- Consistency in sampling design and sampling methods - Consistency in protocol - Consistency of data collection and data quality control
Research Needs:	- Hydrographic dynamics and monitoring - Literature review/ research, analysis of historical data and literature to look for trophic classification by species as well as size class
Management	Optimal diverse and productive community

Goal:	
Threshold Target:	Will be determined by baseline analysis
Response:	Will be determined by baseline analysis
Constraints:	Funding, continuous and long-term Support Skilled man power
Status:	Ongoing in BISC and EVER through MAP
Estimated Cost:	~$250k/park/year MAP covers BISC and EVER
References:	Joe Serafy Joan Browder Mike Robblee Todd Hopkins Ron Hill (NIMPS) Texas worked in St. John not in mangroves Ivan Mateo (U of Rhode Island) Sea Nimph project at Salt River. Otoliths (ear bone chemistry) for connectivity.

W. *Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Visual Assessment*

Which conceptual model(s) is this indicator linked to?

☑ Freshwater Wet Prairies and Marshes ☑ Mangroves ☑ Florida Bay

☑ Biscayne Bay

Parks where monitoring would be conducted

☑ BICY ☑ BISC ☑ BUIS ☑

DRTO ☑ EVER ☑ SARI ☑ VIIS

Indicator:	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Visual Assessment
Monitoring Question(s):	What are baseline conditions, variability, and trends in nearshore and estuarine fish communities?
Justification:	Fish communities in nearshore estuaries are a critical component of the ecosystem. Community status, structure and trends reflect changes in marine habitat quality, connectivity, fishing pressure, and long-term ecosystem resilience. Several fish species within parks are at or near local or regional extirpation. Differing sampling methodologies target different portions of the fish community. Our fisheries experts advocate using consistent methodologies across the region for increased data comparability, but recommended evaluating them independently through this ranking process. This indicator refers to "visual assessment" methods. "Seining", "trawls", "throw traps", and "other trapping" are covered in other indicator worksheets.
Metric:	Taxonomic composition, T. Richness, T. Diversity, T. Evenness, habitat and sediments (?), T. dominance (spatial and temporal distribution), trophic classification, index of trophic complexity
Method:	Visual Assessment
Frequency:	Monthly- pilot, seasonal after pilot
Timing:	To be determined, dependent on pilot
Scale of Collection:	Multiple Parks
Scale of Operation:	Park-wide, Site Specific
Scale of Analysis:	
Basic Assumptions:	- Consistency in sampling design and sampling methods - Consistency in protocol - Consistency of data collection and data quality control
Research Needs:	- Hydrographic dynamics and monitoring - Literature review/ research, analysis of historical data and literature to look for trophic classification by species as well as size class

Management Goal:	Optimal diverse and productive community
Threshold Target:	Will be determined by baseline analysis
Response:	Will be determined by baseline analysis
Constraints:	Funding, continuous and long-term Support Skilled man power
Status:	Ongoing in BISC and EVER through MAP
Estimated Cost:	~$250k/park/year MAP covers BISC and EVER
References:	Joe Serafy, Joan Browder, Mike Robblee, Todd Hopkins, Ron Hill (NIMPS) Texas worked in St. John not in mangroves Ivan Mateo (U of Rhode Island) Sea Nimph project at Salt River. Otoliths (ear bone chemistry) for connectivity.

X. *Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Other trapping*

Which conceptual model(s) is this indicator linked to?

☑ Freshwater Wet Prairies and Marshes ☑ Mangroves ☑ Florida Bay

☑ Biscayne Bay

Parks where monitoring would be conducted

☑ BICY ☑ BISC ☑ BUIS ☑ DRTO ☑ EVER ☑ SARI ☑ VIIS

Indicator:	Marine Fish Communities - Bays/Mangroves - Status, structure, trends - Other trapping
Monitoring Question(s):	What are baseline conditions, variability, and trends in nearshore and estuarine fish communities?
Justification:	Fish communities in nearshore estuaries are a critical component of the ecosystem. Community status, structure and trends reflect changes in marine habitat quality, connectivity, fishing pressure, and long-term ecosystem resilience. Several fish species within parks are at or near local or regional extirpation. Differing sampling methodologies target different portions of the fish community. Our fisheries experts advocate using consistent methodologies across the region for increased data comparability, but recommended evaluating them independently through this ranking process. This indicator refers to methods other than "seining", "trawls", "visual surveys", and "throw traps" which are covered in other indicator worksheets.
Metric:	Taxonomic composition, T. Richness, T. Diversity, T. Evenness, habitat and sediments (?), T. dominance (spatial and temporal distribution), trophic classification, index of trophic complexity
Method:	Other trapping
Frequency:	Monthly- pilot, seasonal after pilot
Timing:	To be determined, dependent on pilot
Scale of Collection:	Multiple Parks
Scale of Operation:	Park-wide, Site Specific
Scale of Analysis:	
Basic Assumptions:	- Consistency in sampling design and sampling methods - Consistency in protocol - Consistency of data collection and data quality control
Research Needs:	- Hydrographic dynamics and monitoring - Literature review/ research, analysis of historical data and literature to look for trophic classification by species as well as size class
Management	Optimal diverse and productive community

Goal:	
Threshold Target:	Will be determined by baseline analysis
Response:	Will be determined by baseline analysis
Constraints:	Funding, continuous and long-term Support Skilled man power
Status:	Ongoing in BISC and EVER through MAP
Estimated Cost:	~$250k/park/year MAP covers BISC and EVER
References:	Joe Serafy Joan Browder Mike Robblee Todd Hopkins Ron Hill (NIMPS) Texas worked in St. John not in mangroves Ivan Mateo (U of Rhode Island) Sea Nimph project at Salt River. Otoliths (ear bone chemistry) for connectivity.

Y. *Exploited Fish Assemblage - Grouper, Snapper, (parrotfish, surgeonfish in USVI)- population structure, status, and trends*

Which conceptual model(s) is this indicator linked to?

☑ Mangroves ☑ Coastal Shelf/Deep Oceanic

Parks where monitoring would be conducted

☑ BISC ☑ BUIS ☑ DRTO ☑ EVER ☑ SARI ☑ VIIS

Indicator:	Exploited Fish Assemblage - Grouper, Snapper, (parrotfish, surgeonfish in USVI)- population structure, status, and trends
Monitoring Question(s):	What are baseline conditions, variability, and trends of Nassau Grouper/Snapper/Parrotfish/Surgeonfish? Are there differences among areas with different management regimes? Are no-take zones working?
Justification:	The exploited fish assemblage contains intermediate and higher trophic level piscivores although herbivores are added in heavily fished US Virgin Is. These species are under heavy fishing pressure within and outside SFCN parks boundaries. Community status, structure and trends for exploited fish can reflect changes in marine habitat quality, food-web structure, fishing pressure, and long-term ecosystem resilience. Balancing resource extraction with sustainability is a key management concern. The impacts of fishery management tools such as "no-take" zones are of high interest to resource management and the public. Several fish species within parks are at or near local or regional extirpation.
Metric:	Presence/ absence Spatial/ temporal distribution Density Size Structure Rates (growth, mortality, reproduction, recruitment, immigration/emigration), secondary production, trophic level
Method:	- Creel Surveys - Visual Surveys - Fisheries dependant monitoring - Tagging - Refer to USGS/NOAA/NPS fish monitoring protocol
Frequency:	Annual, Other (Please specify): - pilot, sustained to be determined, dependent on pilot
Timing:	To be determined, dependent on pilot, consistent dates
Scale of Collection:	Regional (incl. areas outside parks), Multiple Parks
Scale of Operation:	Regional (incl. areas outside parks), Park-wide, Site Specific
Scale of Analysis:	Regional (incl. areas outside parks), Park-wide, Site Specific
Basic	- Consistency in sampling methods and design

Assumptions:	- Protocol consistency - Consistency of data collection and data quality control
Research Needs:	Connectivity questions
Management Goal:	Productive and resilient population If exploited species- sustainability
Threshold Target:	Will be determined by baseline analysis
Response:	Will be determined by baseline analysis
Constraints:	Funding, continuous and long-term Support Skilled human power
Status:	Ongoing
Estimated Cost:	$50k/park/year Can be combined with other studies
References:	Joe Serafy, Tom Schmidt, Mike Robblee, Joan Browder, Charlie Menza

Z. *Snook - population structure, status, and trends*

Which conceptual model(s) is this indicator linked to?

☑ Mangroves ☑ Florida Bay ☑ Biscayne Bay ☑ Coastal Shelf/Deep Oceanic

Parks where monitoring would be conducted

☑ BICY ☑ BISC ☑ DRTO ☑ EVER

Indicator:	Snook - population structure, status, and trends
Monitoring Question(s):	What are baseline conditions, variability, and trends of snook?
Justification:	The snook (Centropomus undecimalis) is a euryhaline, diadromous, estuarine-dependent species targeted as a sport fish and for human consumption within and outside SFCN parks boundaries. They are under strong fishing pressure. Prey source varies with life stage (juveniles - small fish, plants; adults -fish, crabs). Community status, structure and trends can reflect changes in marine habitat quality, food-web structure, fishing pressure, and long-term ecosystem resilience. Balancing resource extraction with sustainability is a key management concern.
Metric:	Presence/ absence Spatial/ temporal distribution Density Size Structure Rates (growth, mortality, reproduction, recruitment, immigration/emigration), secondary production, trophic level
Method:	- Creel Surveys - Visual Surveys - Seining
Frequency:	Monthly- pilot project; long-term monitoring frequency to be determined, dependent on pilot
Timing:	To be determined, dependent on pilot
Scale of Collection:	Multiple Parks
Scale of Operation:	Park-wide, Site Specific
Scale of Analysis:	Park-wide, Site Specific
Basic Assumptions:	- Consistency in sampling methods and design - protocol consistency - Consistency of data collection and data quality control
Research Needs:	- Hydrographic dynamics and monitoring - Literature review/ research, analysis of historical data and literature to look for trophic classification by species as well as size class
Management	Productive, resilient, and sustainable populations

Goal:	
Threshold Target:	Will be determined by baseline analysis
Response:	Will be determined by baseline analysis
Constraints:	Funding, continuous and long-term Support Skilled man power
Status:	Ongoing EVER and BISC
Estimated Cost:	~$150k/park/year Can be combined with other studies
References:	

AA. *Bonnethead, Lemon, Bull, Nurse Sharks - population structure, status, and trends*

Which conceptual model(s) is this indicator linked to?

☑ Mangroves ☑ Florida Bay ☑ Biscayne Bay ☑ Coastal Shelf/Deep Oceanic

Parks where monitoring would be conducted

☑ BISC ☑

DRTO ☑ EVER

Indicator:	Bonnethead, Lemon, Bull, Nurse Sharks - population structure, status, and trends
Monitoring Question(s):	What are baseline conditions, variability, and trends in Bonnethead (Sphyrna tiburo), Lemon (Negaprion brevirostris), Bull (Carcharhinus leucas), and Nurse (Ginglymostoma cirratum) sharks?
Justification:	Sharks, as top marine food-web predators, have been fished to such an extent that their numbers are reduced in south Florida and they have been virtually eliminated from the US Virgin Islands. Sharks mature late in life, have slow growth rates and produce few offspring. As top predators they reflect the condition of the marine food web. Larger fish such as these are targets of fisherman, and thus appropriate management for sustainable fisheries is a concern.
Metric:	Presence/ absence Spatial/ temporal distribution Density Size Structure Rates (growth, mortality, reproduction, recruitment, immigration/emigration), secondary production, trophic level
Method:	- Creel Surveys - Long Line
Frequency:	Monthly- pilot project; long-term monitoring frequency to be determined, dependent on pilot
Timing:	To be determined, dependent on pilot
Scale of Collection:	Multiple Parks
Scale of Operation:	Park-wide, Site Specific
Scale of Analysis:	Park-wide, Site Specific
Basic Assumptions:	- Consistency in sampling methods and design - protocol consistency - Consistency of data collection and data quality control
Research Needs:	- Hydrographic dynamics and monitoring - Literature review/ research, analysis of historical data and literature to look for trophic classification by species as well as size class

Management Goal:	Productive, resilient, and sustainable populations
Threshold Target:	Will be determined by baseline analysis
Response:	Will be determined by baseline analysis
Constraints:	Funding, continuous and long-term Support Skilled man power
Status:	Ongoing in DRTO and EVER
Estimated Cost:	~$150k/park/year Can be combined with other studies
References:	Joe Serafy, Mike Robblee, Joan Browder

BB. *Spotted Sea Trout - population structure, status, and trends*

Which conceptual model(s) is this indicator linked to?

☑ Mangroves ☑ Florida Bay ☑ Biscayne Bay ☑ Coastal Shelf/Deep Oceanic

Parks where monitoring would be conducted

☑ BISC ☑

DRTO ☑ EVER

Indicator:	Spotted Sea Trout - population structure, status, and trends
Monitoring Question(s):	What are baseline conditions, variability, and trends of snook?
Justification:	The spotted sea trout (Cynoscion nebulosus) is a bottom-feeding intermediate trophic level species targeted as a sport fish and for human consumption within and outside SFCN parks boundaries. This is the only major sport fish in south Florida that spends its entire life cycle in bays. They are sensitive to hypersaline conditions and thus may respond to changes in south Florida water management restoration. Community status, structure and trends for the spotted sea trout can reflect changes in marine habitat quality, food-web structure, fishing pressure, and long-term ecosystem resilience. Balancing resource extraction with sustainability is a key management concern. Mercury bioaccumulation is also a concern.
Metric:	Presence/ absence Spatial/ temporal distribution Density Size Structure Rates (growth, mortality, reproduction, recruitment, immigration/emigration), secondary production, trophic level
Method:	- Creel Surveys - Small otter trawl - Commercial catch per unit effort
Frequency:	Monthly- pilot project; long-term monitoring frequency to be determined, dependent on pilot
Timing:	To be determined, dependent on pilot
Scale of Collection:	Multiple Parks
Scale of Operation:	Park-wide, Site Specific
Scale of Analysis:	Park-wide, Site Specific
Basic Assumptions:	- Consistency in sampling methods and design - protocol consistency - Consistency of data collection and data quality control
Research Needs:	- Hydrographic dynamics and monitoring - Literature review/ research, analysis of historical data and literature to look for

	trophic classification by species as well as size class
Management Goal:	Productive, resilient and sustainable populations
Threshold Target:	Will be determined by baseline analysis
Response:	Will be determined by baseline analysis
Constraints:	Funding, continuous and long-term Support Skilled man power
Status:	Ongoing in EVER only
Estimated Cost:	~$150k/park/year Combined with other fish creel studies
References:	

CC. *Gray Snapper (Schoolmaster in VI)- population structure, status, & trends*

Which conceptual model(s) is this indicator linked to?

☑ Mangroves ☑ Florida Bay ☑ Biscayne Bay ☑ Coastal Shelf/Deep Oceanic

Parks where monitoring would be conducted

☑ BISC ☑ BUIS ☑ DRTO ☑ EVER ☑ SARI ☑ VIIS

Indicator:	Gray Snapper (Schoolmaster in VI)- population structure, status, & trends
Monitoring Question(s):	What are baseline conditions, variability, and trends of gray snapper/schoolmaster?
Justification:	The gray snapper (Lutjanus griseus)/schoolmaster (Lutjanus apodus) are intermediate trophic level species targeted for human consumption within and outside SFCN parks boundaries. Juveniles predominately reside in nearshore habitats and adults are found in the coastal shelf/reefs. Community status, structure and trends for snapper can reflect changes in marine habitat quality, food-web structure, fishing pressure, and long-term ecosystem resilience. Balancing resource extraction with sustainability is a key management concern.
Metric:	Presence/ absence Spatial/ temporal distribution Density Size Structure Rates (growth, mortality, reproduction, recruitment, immigration/emigration), secondary production, trophic level
Method:	- Visual Census/ Shoreline visual survey - Trawls - Seining - Creel Surveys - Traps
Frequency:	Monthly- pilot project; long-term monitoring frequency to be determined, dependent on pilot
Timing:	To be determined, dependent on pilot
Scale of Collection:	Multiple Parks
Scale of Operation:	Park-wide, Site Specific
Scale of Analysis:	Park-wide, Site Specific
Basic Assumptions:	- Consistency in sampling methods and design - protocol consistency - Consistency of data collection and data quality control
Research Needs:	- Hydrographic dynamics and monitoring - Literature review/ research, analysis of historical data and literature to look for

	trophic classification by species as well as size class
Management Goal:	Productive, resilient and sustainable populations
Threshold Target:	Will be determined by baseline analysis
Response:	Will be determined by baseline analysis
Constraints:	Funding, continuous and long-term Support Skilled man power
Status:	Ongoing in BISC and NE Florida Bay, Previous work at USVI
Estimated Cost:	~$150k/park/year Seasonal Surveys
References:	Schoolmaster- nursery habitat, USVI - Visual and Traps (Rafe)., Large Gray Snapper in Mangroves and large Schoolmaster on Reef in USVI

DD. *Goliath Grouper (Red Hind in VI) - population structure, status, and trends*

Which conceptual model(s) is this indicator linked to?

☑ Mangroves ☑ Florida Bay ☑ Biscayne Bay ☑ Coastal Shelf/Deep Oceanic

Parks where monitoring would be conducted

☑ BISC ☑ BUIS ☑
DRTO ☑ EVER ☑ SARI ☑ VIIS

Indicator:	Goliath Grouper (Red Hind in VI) - population structure, status, and trends
Monitoring Question(s):	What are baseline conditions, variability, and trends of goliath grouper/red hind?
Justification:	Goliath grouper (Epinephelus itajara), a top marine food-web predator, has been over-fished to such an extent that it is now rare and a protected species in the state of Florida. The goliath grouper has all but disappeared in the US Virgin Islands and as such red hind (Epinephelus guttatus) is recommended instead as a top-predator to monitor that is also under heavy fishing pressure. Larger fish such as these are popular targets of fisherman, and thus of particular concern for management and efforts to protect and manage these stocks are often used as indicators of success for marine protected areas.
Metric:	Presence/ absence Spatial/ temporal distribution Density Size Structure Rates (growth, mortality, reproduction, recruitment, immigration/emigration), secondary production, trophic level
Method:	- Creel Surveys - Visual Surveys
Frequency:	Monthly- pilot project; long-term monitoring frequency to be determined, dependent on pilot
Timing:	To be determined, dependent on pilot
Scale of Collection:	Multiple Parks
Scale of Operation:	Park-wide, Site Specific
Scale of Analysis:	Park-wide, Site Specific
Basic Assumptions:	- Consistency in sampling methods and design - protocol consistency - Consistency of data collection and data quality control
Research Needs:	- Hydrographic dynamics and monitoring - Literature review/ research, analysis of historical data and literature to look for trophic classification by species as well as size class

Management Goal:	Productive, resilient, and sustainable populations
Threshold Target:	Will be determined by baseline analysis
Response:	Will be determined by baseline analysis
Constraints:	Funding, continuous and long-term Support Skilled man power
Status:	Ongoing EVER
Estimated Cost:	~$150k/park/year Can be combined with other studies
References:	Joe Serafy, Mike Robblee, Joan Browder

EE. *Sawfish- population structure, status, and trends*

Which conceptual model(s) is this indicator linked to?

☑ Mangroves ☑ Florida Bay ☑ Biscayne Bay ☑ Coastal Shelf/Deep Oceanic

Parks where monitoring would be conducted

☑ BISC ☑

DRTO ☑ EVER

Indicator:	Sawfish- population structure, status, and trends
Monitoring Question(s):	What are baseline conditions, variability, and trends for small-toothed sawfish?
Justification:	Small-toothed sawfish (Pristis pectinata) is a Federally Listed Endangered Species found in Everglades and Biscayne National Parks. This long-lived and large species (record is 18 feet in length) was formerly a fishery before stocks dwindled. Typically is found near and in estuaries, bays, and inlets utilizing seagrass, mud/sand bottom, oyster bars, reefs, and mangroves. Their saw makes them susceptible to entanglement in nets and lines. Little is known about this species, but, like other rays and sharks, they have limited reproductive potential.
Metric:	Presence/ absence Spatial/ temporal distribution Density Size Structure Rates (growth, mortality, reproduction, recruitment, immigration/emigration), secondary production, trophic level
Method:	- Creel Surveys - Long Line - Visual Surveys
Frequency:	Monthly- pilot project; long-term monitoring frequency be determined, dependent on pilot
Timing:	To be determined, dependent on pilot
Scale of Collection:	Multiple Parks
Scale of Operation:	Multiple Parks, Site Specific
Scale of Analysis:	Multiple Parks, Site Specific
Basic Assumptions:	- Consistency in sampling methods and design - protocol consistency - Consistency of data collection and data quality control
Research Needs:	- Hydrographic dynamics and monitoring - Literature review/ research, analysis of historical data and literature to look for trophic classification by species as well as size class
Management	Productive and resilient population

Goal:	
Threshold Target:	Will be determined by baseline analysis
Response:	Will be determined by baseline analysis
Constraints:	Funding, continuous and long-term Support Skilled man power
Status:	Ongoing in EVER
Estimated Cost:	~$150k/park/year Can be combined with other fish surveys
References:	Joe Serafy, Mike Robblee

FF. *Infaunal benthic community structure and abundance for animals*

Which conceptual model(s) is this indicator linked to?

☑ Mangroves ☑ Florida Bay ☑ Biscayne Bay ☑ Coastal Shelf/Deep Oceanic

Parks where monitoring would be conducted

☑ BISC ☑ EVER

Indicator:	Infaunal benthic community structure and abundance for animals
Monitoring Question(s):	What is the distribution and abundance of important indicators and keystone organisms? What is the current distribution of organisms with respect to salinity and nutrient gradients?
Justification:	Infaunal benthic communities include bivalves (clams), worms (polychaetes and oligochaetes), amphipod crustaceans, insect larvae, etc., that live within the marine substrate. They are heavily preyed upon by crabs and fish. Community composition and structure differs with habitat, salinity, and dissolved oxygen. Community composition is sensitive to changes in water quality, particularly contaminants (e.g., pesticides, heavy metals), changing salinity, and dissolved oxygen (related to nutrient and organics enrichment). In addition to indicators of overall estuarine health in Florida and Biscayne Bays, they can potentially be valuable indicators in ecotonal areas or areas of suspected contaminant input. They show a response to the general water quality and contaminant levels at a site through time. However, while these communities have been uses as indices in other areas of the country, a south Florida index has not been developed yet.
Metric:	Sample the benthic communities species composition, abundance, distribution. Species richness/ diversity, number and organisms, species, location. Nutrients, Tp and SRP, DO, turbidity, salinity, temp, depth in sediment, type of sediment for benthic habitat Nutrient WQ sampling to be conducted in accordance with benthic monitoring
Method:	- Grab or core samples - Sediment and sediment sieves grain size, % organics, total organic, total inorganic carbon - Standard nutrient sampling using accepted lowest threshold min detection limits - Continuous salinity recording equipment measuring conductivity temperature in bottom water - Also sample in conjunction with groundwater flow and water quality sampling
Frequency:	Continuous- salinity, Other (Please specify): initially intensive organismal wet season and dry season, weekly for 2 months. Then monthly for 2 years, then possibly quarterly if nothing unusual
Timing:	Wet and Dry season
Scale of Collection:	Regional (incl. areas outside parks), Multiple Parks, Park-wide, Site Specific
Scale of Operation:	Regional (incl. areas outside parks), Park-wide, Site Specific
Scale of	Multiple Parks, Park-wide, Site Specific

Analysis:	
Basic Assumptions:	- Benthic invertebrate community will respond to water and sediment quality
Research Needs:	Salinity stress on SF benthic invertebrates, study of nutrient effects on benthics, variation of infaunal components with physical and chemical constituents (variations associated with contaminants, eutrophication, etc) Relationship of these stresses to changes in community composition and structure
Management Goal:	Maintain water and sediment quality sufficient to minimize or prevent infaunal components indicative of degraded habitats
Threshold Target:	
Response:	
Constraints:	Benthic infaunal assemblages are specific to the desired ecotones (oligo/meso/euryhaline)
Status:	To be developed
Estimated Cost:	
References:	

GG. *Exploited Inverts (Lobster, Conch, Crabs, Shrimp, Stone Crab, Blue Crab, Clams, Oysters, Sponges, Welks)*

Which conceptual model(s) is this indicator linked to?

☑ Mangroves ☑ Florida Bay ☑ Biscayne Bay ☑ Coastal Shelf/Deep Oceanic

Parks where monitoring would be conducted

☑ BISC ☑ BUIS ☑

DRTO ☑ EVER ☑ SARI ☑ VIIS

Indicator:	Exploited Inverts (Lobster, Conch, Crabs, Shrimp, Stone Crab, Blue Crab, Clams, Oysters, Sponges, Welks)
Monitoring Question(s):	Are the range of goals (human uses and preferred ecological states) sustainable? How do invertebrate populations change over time between and within parks?
Justification:	The exploited invertebrate assemblage include herbivores, filter feeders, intermediate feeders, omnivores. These species are under heavy fishing pressure and commercial harvest pressure within and outside SFCN parks boundaries. These species have complicated reproductive cycles that frequently use multiple habitats inside and outside park boundaries and can be affected by regional connectivity and stressors. They are sensitive to fishing pressure and environmental degradation. Balancing resource extraction with sustainability is a key management concern. The impacts of fishery management tools such as "no-take" zones are of high interest to resource management and the public.
Metric:	What is the spatial distribution of the invert population (abundance, size, species)?

Method:	Fishery dependent- monitoring recreational and commercial catch Fishery independent- visual census, acoustics, optics, nets, trawls, traps, Measure size of shells for Welks
Frequency:	Annual to quarterly
Timing:	Depending on seasonal spatial distribution.
Scale of Collection:	Multiple Parks
Scale of Operation:	Regional (incl. areas outside parks), Other (Please specify): Network Wide
Scale of Analysis:	Park-wide, Site Specific: Habitat wide, Network Wide
Basic Assumptions:	Independence or linkage Monitoring reflects the population- appropriate timing and methodology
Research Needs:	NA
Management Goal:	Invert population stability and diversity across exploited species Sustainable fishing and other recreation
Threshold Target:	Approx. 2 standard deviations off the mean.
Response:	Reduce impacts of principal stressors (extraction): Better enforcement for Welks. Collaborate with other agencies Internal response - Close season for regulated locations.
Constraints:	Is this sampling design appropriate in predicting population estimates? [precision] Costs of high precision sampling design We know the measurement generally reflects pop changes, the level of accuracy and precision is cost dependent.
Status:	Ongoing (NOAA, FWC, NPS, Universities, etc)
Estimated Cost:	Park/Method/Intensity specific
References:	Contact: J. Bohnsack, J. Ault, J. Browder, J. Hunt, M. Robblee Welks contact Rafe.

HH. *Pink Shrimp population structure, status, and trends*

Which conceptual model(s) is this indicator linked to?

☑ Mangroves ☑ Florida Bay ☑ Biscayne Bay ☑ Coastal Shelf/Deep Oceanic

Parks where monitoring would be conducted

☑ BISC ☑ BUIS ☑

DRTO ☑ EVER ☑ SARI ☑ VIIS

Indicator:	Pink Shrimp population structure, status, and trends
Monitoring Question(s):	What are baseline conditions, variability, and trends in pink shrimp?

Justification:	Pink shrimp (Farfantepenaeus duorarum) function as both a predatory and prey species within the marine ecosystem and provide a large amount of biomass in Florida and Biscayne Bays. They are sensitive to changes in hydrological modifications, salinity patterns, circulation effects on larval transport. Florida Bay is an important nursery ground for larval recruitment to the Dry Tortugas commercially harvested fishery. Pink shrimp are both recreationally and commercially harvested within Biscayne Bay.
Metric:	Presence/ Absence Spatial/ temporal distribution Density Size Structure Develop relationships with habitat Rates: Growth, mortality, reproduction, recruitment, immigration/emigration, secondary production, trophic level
Method:	Throw trap Trawl Commercial catch per unit effort
Frequency:	Monthly- pilot project; long-term monitoring frequency to be determined, dependent on pilot
Timing:	To be determined, dependent on pilot
Scale of Collection:	Multiple Parks
Scale of Operation:	Park-wide, Site Specific
Scale of Analysis:	Park-wide
Basic Assumptions:	- Consistency in sampling design and sampling methods - Consistency in protocol - Consistency of data collection and data quality control
Research Needs:	- Hydrographic dynamics and monitoring - Literature review/ research, analysis of historical data and literature to look for trophic classification by species as well as size class
Management Goal:	Productive, resilient, and sustainable populations
Threshold Target:	Will be determined by baseline analysis
Response:	Will be determined by baseline analysis
Constraints:	Funding, continuous and long-term Support Skilled man power
Status:	Ongoing in BISC and EVER West Coast Fl
Estimated Cost:	~$250k/park/year, seasonal sampling Can be combined with fish throw trap sampling
References:	

II. *Spiny Lobster - population structure, status, and trends*

Which conceptual model(s) is this indicator linked to?

☑ Mangroves ☑ Florida Bay ☑ Biscayne Bay ☑ Coastal Shelf/Deep Oceanic

Parks where monitoring would be conducted

☑ BISC ☑ BUIS ☑

DRTO ☑ EVER ☑ SARI ☑ VIIS

Indicator:	Spiny Lobster - population structure, status, and trends
Monitoring Question(s):	What are baseline conditions, variability, and trends of spiny lobster?
Justification:	The spiny lobster (Panulirus argus) life cycle includes both a free-swimming larval phase and a benthic adult life stage. Lobsters have complicated reproductive cycles that frequently use multiple habitats inside and outside park boundaries and can be affected by regional connectivity and stressors. Adult spiny lobsters feed mainly on gastropods, chitons, and bivalves. They are under heavy fishing pressure and commercial harvest pressure within and outside SFCN parks boundaries. In 2003, the commercial fishery landed over 4 million pounds in Florida.
Metric:	Presence/ absence Spatial/ temporal distribution Density Size Structure Rates (growth, mortality, reproduction, recruitment, immigration/emigration, secondary production, trophic level) contaminants
Method:	- Lobster pot - Commercial catch per unit effort - Visual Surveys - Pueruli collectors - larval Settlement.
Frequency:	Monthly- pilot project; long-term monitoring frequency to be determined, dependent on pilot
Timing:	To be determined, dependent on pilot
Scale of Collection:	Multiple Parks
Scale of Operation:	Park-wide, Site Specific
Scale of Analysis:	Park-wide, Site Specific
Basic Assumptions:	- Consistency in sampling methods and design - protocol consistency - Consistency of data collection and data quality control
Research Needs:	Hydrographic dynamic monitoring for trophic classification by spp. and size class
Management Goal:	Productive, resilient, and sustainable populations
Threshold Target:	Will be determined by baseline analysis

Response:	Will be determined by baseline analysis
Constraints:	Funding, continuous and long-term Support Skilled man power
Status:	BISC somewhat, MINI season Visual Surveys - Buck Island Pueruli collectors - larval Settlement SeaMap Done every three years, DFW of DPNR (maybe at Buck).
Estimated Cost:	~$150k/park/year Combined?
References:	

JJ. *Oyster population structure, status, and trends*

Which conceptual model(s) is this indicator linked to?

☑ Mangroves ☑ Florida Bay ☑ Biscayne Bay

Parks where monitoring would be conducted

☑ BISC ☑ EVER

Indicator:	Oyster population structure, status, and trends
Monitoring Question(s):	What are baseline conditions, variability, and trends in oysters?
Justification:	Oysters (Crassostrea virginica) are filter feeders and become prey to many species of fish and larger invertebrates. Oysters develop into oyster bar communities which form an extensive habitat along western edge of Everglades National Park. Oysters were once present in greater numbers within Biscayne Bay, but are now rare. Oysters have a strong association with moderate saline conditions and are hence being considered an indicator of proper hydrological flows for Biscayne Bay. Their shell accumulations provide information about the physical, chemical and biological conditions that allow them to flourish.
Metric:	Presence/ absence Spatial/ temporal distribution Density Size Structure Rates (growth, mortality, reproduction, recruitment, immigration/emigration, secondary production, trophic level)
Method:	- Visual Census/ Shoreline visual survey - Tissue Sampling - Tongs - Dredge
Frequency:	Monthly- pilot project; long-term monitoring frequency to be determined, dependent on pilot
Timing:	To be determined, dependent on pilot
Scale of Collection:	Multiple Parks
Scale of Operation:	Park-wide, Site Specific
Scale of Analysis:	Park-wide, Site Specific
Basic Assumptions:	- Consistency in sampling methods and design - protocol consistency - Consistency of data collection and data quality control
Research Needs:	Hydrographic dynamics, monitoring Contaminant Assessment
Management	Establish/ Increase population

Goal:	
Threshold Target:	Will be determined by baseline analysis
Response:	Will be determined by baseline analysis
Constraints:	Funding, continuous and long-term Support Skilled man power
Status:	Proposed in BISC Maybe outside Park Boundaries?
Estimated Cost:	~$150k/park/year Seasonal Surveys
References:	Mike Savasere (Fl Gulf Boast University), Jack Meter (BISC)

KK. *Marine Vertebrates - Rare, threatened, and endangered species - Crocodiles, Dolphin, Manatee, Sea Turtles, Protected marine mammals.*

Which conceptual model(s) is this indicator linked to?

☑ Mangroves ☑ Florida Bay ☑ Biscayne Bay ☑ Coastal Shelf/Deep Oceanic

Parks where monitoring would be conducted

☑ BICY ☑ BISC ☑ BUIS ☑
DRTO ☑ EVER ☑ SARI ☑ VIIS

Indicator:	Marine Vertebrates - Rare, threatened, and endangered species - Crocodiles, Dolphin, Manatee, Sea Turtles, Protected marine mammals.
Monitoring Question(s):	How do rare, threatened, and endangered species change over time between and within parks? Does the species integrity persist?
Justification:	Critically imperiled or rare marine vertebrates are typically large species that are sensitive to the effects of nesting/rearing habitat loss, habitat degradation, contaminant bioaccumulation, and food-web alterations. Recovery from historic hunting/collection pressure and low reproductive fecundity are also issues. These species are wide-ranging, experiencing a wide range of stressors and habitat quality both inside and outside park boundaries. Because of their relatively low numbers they are affected by stochastic impacts on populations such a boat collisions, entanglement in fishing gear, and entrainment in flood control structures which kill individual animals. Disturbance by visitors can also be an issue. Monitoring population status and trends and distribution is used to inform park management about the status of these legally protected species and to assess potential impacts of visitor use activities and management activities.
Metric:	What is the spatial distribution of the rare, threatened, and endangered species (abundance, size, disease, condition)?
Method:	Species dependent- Species independent- visual census, acoustics, optics, nets, trawls, traps, tagging & telemetry
Frequency:	Annual to quarterly.
Timing:	Depending on seasonal spatial distribution.
Scale of Collection:	Multi-park, some regional programs occurring
Scale of Operation:	Regional/ Network-wide
Scale of Analysis:	Network/ Park/ Habitat
Basic Assumptions:	Independence or linkage Monitoring reflects the population- appropriate timing and methodology
Research Needs:	(To better understand the sustainability of the species: Natural History/Demographics of non-exploited species)

Management Goal:	Species integrity
Threshold Target:	
Response:	Reduce impacts of principal stressors: Collaborate with other agencies Internal response
Constraints:	Is this sampling design appropriate in predicting population estimates? [precision] Costs of high precision sampling design We know the measurement generally reflects pop changes, the level of accuracy and precision is cost dependent.
Status:	Ongoing (NOAA, FWC, NPS, Universities, NGO's, etc)
Estimated Cost:	Park/Method/Intensity specific
References:	

LL. *Sea Turtles*

Which conceptual model(s) is this indicator linked to?

☑ Mangroves ☑ Florida Bay ☑ Biscayne Bay ☑ Coastal Shelf/Deep Oceanic

Parks where monitoring would be conducted

☑ BISC ☑ BUIS ☑

☑ DRTO ☑ EVER ☑ SARI ☑ VIIS

Indicator:	Sea Turtles
Monitoring Question(s):	Are populations of sea turtles increasing, decreasing, or stable? Is the number of sea turtle nests and nesting success increasing, decreasing, or stable? What is the status of nesting beaches?
Justification:	Four species of sea turtles nest on beaches within the South Florida / Caribbean Network of parks, all of which are either federally endangered or threatened. The most prevalent are hawksbill, green, and loggerhead sea turtles. Nesting activities on historic turtle nesting beaches reflects both the habitat quality of the nesting beaches as well as population dynamics and presumably health of both local and regional seagrass beds, coral reef areas, and oceanic areas. Sea turtles return to their natal nesting beaches to nest year after year. At least a portion of the juvenile and adult sea turtles are assumed to remain in the general area and so are affected by stressors and management within the park. Currently the greatest threats to sea turtle populations include loss of nesting beaches, degradation in quality of nesting beaches, nest predation, degradation in quality of foraging habitats (sea grass beds, coral reefs, open ocean, etc), collisions with boats, being trapped in fishing gear or trash, and disease. Artificial lighting may be an issue at Virgin Islands National Park, but is not an issue at the other parks.
Metric:	Nest counts, species which nested, distribution of nests, nesting success, nest predation Supplemental monitoring: beach erosion, sand quality, lighting, predators, and mortality will be measured/observed.
Method:	Initial beach assessment will be conducted (e.g., quality, erosion, lighting, etc.). Surveys will be conducted for nests and tracks during the nesting season (May - October). Actual nesting is verified by gently digging by hand into nest (many "false crawls" can occur). Eggs are counted. After baby turtles are assumed to have emerged, nest is re-dug and the number of empty egg-shells, live and dead trapped baby turtles, and unhatched dead eggs are counted. (Live baby turtles are released to sea). Buck Island Reef National Monument is using a more intensive protocol that might be worth exploring.
Frequency:	Annual
Timing:	During the nesting season (May - October).
Scale of Collection:	Regional (incl. areas outside parks), Multiple Parks, Site Specific
Scale of Operation:	Regional (incl. areas outside parks), Multiple Parks, Site Specific

Scale of Analysis:	Regional (incl. areas outside parks), Multiple Parks, Site Specific
Basic Assumptions:	Monitoring numbers of nests and nesting success provides a reliable surrogate for the status of the sea turtle community. At least a portion of juvenile turtles and adult turtles remain in and around the park areas and are affected by local habitat quality and stressors. Any program must be done on a long term basis because we don't understand shorter-term climate cycle effects on these populations
Research Needs:	Relationship between nest counts and nesting success with juvenile and adult populations
Management Goal:	Maintain or increase populations at sustainable levels.
Threshold Target:	Insufficient knowledge. However in general any nest predation or impacts to nesting success or other problems with these highly threatened species that can be identified are typically acted upon immediately (e.g., covering nests to prevent raccoon predation).
Response:	Determine if nesting decline due to identifiable causes and attempt to correct problem (e.g., reducing nest predation, trash on beaches, artificial night lighting).
Constraints:	Sampling and searches are time consuming. Results should be interpreted in a regional as well as local context. Beaches in south Florida national parks are not the heaviest nesting beaches in south Florida and thus changes in sea turtle populations in south Florida will also reflect management at beaches outside park boundaries. Fortunately monitoring is occurring at many of these other beaches. In contrast U.S. Virgin Island national park beaches have heavy nesting within the parks. As another regional issue sea turtles are also killed in fishing nets in the open ocean far outside park boundaries.
Status:	Monitoring is on-going at Biscayne National Park, Dry Tortugas National Park, Buck Island Reef National Monument, and Virgin Islands National Park. No monitoring is occurring that we know of at Everglades National Park, although nesting does occur there. No nesting is known to occur at Salt River Bay National Historical Park and Ecological Preserve, although beaches exist. Intensive sea turtle nest monitoring is occurring at Buck Island with nightly surveys during nesting season and measurements also taken on female size. All nesting females are tagged. A juvenile sea turtle monitoring program is also ongoing.
Estimated Cost:	
References:	Zandy Hillis-Star (Buck Island Reef National Monument), Shelby Moneysmith (Biscayne National Park), Emilie Verdon (IRC)

MM. *American crocodile (Crodylus acutus)*

Which conceptual model(s) is this indicator linked to?

☑ Mangroves ☑ Florida Bay ☑ Biscayne Bay

Parks where monitoring would be conducted

☑ BISC ☑ EVER

Indicator:	American crocodile (Crocodylus acutus)
Monitoring Question(s):	What is the relative distribution, abundance, nesting effort and success, condition, growth and survival of crocodiles in relation to water levels and salinities throughout mangrove estuaries of Everglades National Park and Biscayne National Park? How do these metrics change over time and during Everglades restoration?
Justification:	The American crocodile is a top predator within the estuarine ecosystem. Crocodile population dynamics have been linked to resource management activities, especially water management which has resulted in increased salinities in both estuaries. Habitat alteration and conversion along western Biscayne Bay, disturbance, and road kill are also issues. Crocodiles are an Endangered Species with core nesting areas in Biscayne and Florida Bays.
Metric:	Animals/ shoreline km, Size distribution, Body condition, Annual survival, mm increase in body length, nests/region All metrics are equivalent to those used as performance standards in Comprehensive Everglades Restoration Plan (CERP).
Method:	Distribution and abundance are obtained through night-light survey along established routes throughout the Parks. Condition, growth, and survival are determined from morphometric measurements of captured and released animals encountered during quarterly surveys. Nesting effort and success are determined by inspecting nests found during ground and aerial searches. See Mazzotti and Cherkiss (2003) for justification and protocols. Protocols are also present in Crocodile MAP annual reports as well as CESI Crocodile distribution project reports.
Frequency:	Annual
Timing:	Night-light surveys and captures are currently performed quarterly. Nest searches are conducted during April-August.
Scale of Collection:	Park-wide
Scale of Operation:	Regional (incl. areas outside parks)
Scale of Analysis:	Park-wide, by park region.
Basic Assumptions:	The underlying assumption of this indicator is that the distribution and abundance of crocodiles is strongly influenced by patterns of fresh water flow. All metrics assume that data collection provides estimation of detection probability

	(crocodile eyeshine, nests). This is accomplished through design of monitoring using distance sampling, transect methodology, and/or direct estimation of detection.
Research Needs:	Additional research is needed to reduce the uncertainty regarding the importance of fresh water for growth and survival of hatchling crocodiles. Work is currently underway funded by CESI and MAP to address detection under the various monitoring components.
Management Goal:	Restoration of location of freshwater flow will result in an increase in relative density of crocodiles in areas of restored flow, such as Taylor Slough/Taylor River drainage. Reestablishing the salinity gradient in the estuary will increase growth and survival of juvenile crocodiles throughout the estuary. All of the above will result in increased nesting.
Threshold Target:	Historical data exist to provide estimates of natural annual variation. These data have not been used to set threshold targets.
Response:	Habitat restoration as necessary.
Constraints:	Continued priority of monitoring program.
Status:	On-going. Is an indicator in the Comprehensive Everglades Restoration Plan (CERP) Monitoring and Assessment Plan (MAP) and Interim Goals.
Estimated Cost:	Approximately 6 man-hours per night-light survey (6 per transect per year), 20 man-hours per body condition survey (4 per region monitored per year), About 160 hrs for nest surveys by boat and foot, supplemented by 10-20 hours helicopter time and man-hours per year for nest surveys.
References:	Mazzotti, F. J., and M. S. Cherkiss. 2003. Status and conservation of the American crocodile in Florida: Recovering an endangered species while restoring an endangered ecosystem. Technical Report. 41 pp.

NN. *Marine Invertebrates - Rare, threatened, and endangered species - Acropora, Diadema, Antipathes*

Which conceptual model(s) is this indicator linked to?

☑ Coastal Shelf/Deep Oceanic

Parks where monitoring would be conducted

☑ BISC ☑ BUIS ☑ DRTO ☑ SARI ☑ VIIS

Indicator:	Marine Invertebrates - Rare, threatened, and endangered species - Acropora, Diadema, Antipathes
Monitoring Question(s):	How do rare, threatened, and endangered species change over time between and within parks? Does the species integrity persist?
Justification:	Critically imperiled or rare invertebrate species within the marine community are important indicators and subjects for monitoring, as they are significant drivers/architects of reef community and structure. Elkhorn coral (Acropora palmata), once the primary reef building species, has declined >95% in areas, dramatically effecting many marine and coastal processes. Black spiny sea urchins (Diadema antillarum), once abundant herbivores, have significantly reduced populations, dramatically affecting herbivory of marine algae on coral reefs and subsequent coral reef recruitment and growth processes. Black coral (Antipathes sp.) have been overharvested for jewelery to the point that they are now considered rare.
Metric:	What is the spatial distribution of the rare, threatened, and endangered species (abundance, size, species, condition)?
Method:	Species dependent- Species independent- visual census, acoustics, optics,
Frequency:	Monthly to Annual. Episodic
Timing:	Night surveys for Diadema maybe? Spawning?
Scale of Collection:	Multi-park
Scale of Operation:	Regional/ Network-wide
Scale of Analysis:	Network/ Park/ Habitat
Basic Assumptions:	Independence or linkage Monitoring reflects the population- appropriate timing and methodology
Research Needs:	Connectivity Knowledge about disease pathogens
Management Goal:	species sustainability
Threshold Target:	To be determined
Response:	Reduce impacts of principal stressors:

	Collaborate with other agencies Internal response
Constraints:	Is this sampling design appropriate in predicting population estimates? [precision] Costs of high precision sampling design We know the measurement generally reflects pop changes, the level of accuracy and precision is cost dependent. Pathogens for disease uncertain
Status:	Ongoing (NOAA, USGS, FWC, NPS, Universities, NGO's, TNC, etc)
Estimated Cost:	$20K/year/park
References:	Contact: C. Rogers, NOAA Status Review of Acropora,

OO. *Fire Return Interval Departure*

Which conceptual model(s) is this indicator linked to?

☑ Freshwater Wet Prairies and Marshes ☑ Forest Uplands and Wetlands

Parks where monitoring would be conducted

☑ BICY ☑ EVER

Indicator:	Fire Return Interval Departure
Monitoring Question(s):	Where upon the Landscape does a departure from native fire regimes exist?
Justification:	Fire is a major driver in vegetation community distribution, structure, and composition across the landscape. Maintaining a fire regime that mimics the historical pattern while maintaining public safety is important for maintaining such communities as the pine rocklands from being encroached by hardwood hammocks, marshes from being encroached by forests and mangroves, etc. Monitoring Fire Return Interval Departure is an important tool for assessing the health of the system with respect to this important driver as well as providing key information for fire management decisions.
Metric:	Fire Location. (Lat/Lon) Fire Size expressed in acres Perimeter in digitized shapefile Date(s) of fire event Ignition Source (lightning, human)
Method:	Assemble and historical fire records, develop GIS shape files for fire perimeter, ground truth fire locations (to determine if site is capable of supporting combustion, i.e. non-flammable vegetation-fuel conditions or standing water). Develop departure classification scheme.
Frequency:	Continuous, After each fire event
Timing:	post-fire
Scale of Collection:	Multiple Parks
Scale of Operation:	Regional (incl. areas outside parks)
Scale of Analysis:	Regional (incl. areas outside parks)
Basic Assumptions:	Historic fire records are complete and accurate
Research Needs:	What climate patterns or cycles create conditions for landscape level fire events and when do these occur? Which fire regimes will support or enhance ecosystem restoration? What were the spatial extent of historic fire events?

Management Goal:	Use management practices that ensure ecologically appropriate fire regimes.
Threshold Target:	90% of flammable vegetation National Park Service managed landscape in South Florida receives ecologically appropriate fire treatment within a 20 year period
Response:	Develop landscape level fire management goals and objectives for Everglades and Big Cypress
Constraints:	The capacity and interest of the two park units to work together, share information and resources. Access to elevation and inundation data. Accurate historic fire records
Status:	Retrieval and evaluation of historical has begun Development of GIS based shape files is ongoing by EVER fire staff Organization and display of data base is in development by EVER fire staff
Estimated Cost:	Ground-Truthing and Mapping Flights @ 750.00 per hour, estimated cost 7500.00 per year. Interns for data processing 20,000.00
References:	SEKI has conducted similar monitoring of the Sierra landscape

PP. *Shape, orientation, location, and coverage of vegetation community types*

Which conceptual model(s) is this indicator linked to?

☑ Freshwater Wet Prairies and Marshes ☑ Forest Uplands and Wetlands

☑ Island Interior ☑ Mangroves

Parks where monitoring would be conducted

☑ BICY ☑ BISC ☑ DRTO ☑ EVER

Indicator:	Shape, orientation, location, and coverage of vegetation community types
Monitoring Question(s):	Spatial Patterns of vegetation in wet prairies and marshes, forests, tree islands, mangroves, beaches and tidal wetlands changing? Are these changes related to environmental drivers? Are these changes related to Everglades restoration (e.g., CERP) or other management efforts?
Justification:	The spatial patterns of vegetation in wet prairies and marshes, forests, tree islands, mangroves, beaches and tidal wetlands are expected to show changes due to management regimes (regional hydrology changes by Everglades restoration efforts; fire) as well as natural succession processes, sea level rise, and invasive species. It is important that a baseline as well as a sound monitoring program be established in order to track the impact of these changes at a regional scale. The mosaic and diversity of vegetation communities across the landscape strongly influences animal communities, food web-structure and distribution of rare plants. Such information is also useful from management planning, monitoring planning, and visitor use perspectives.
Metric:	Aerial photography and vegetation mapping of community types (classifications). Metrics: 1. Number of patches by type 2. Location of patches (e.g., mangroves shifting inland, mangrove shifting due to frost, Muhly wet prairie shifting in relation to rehydration) 3. total acreage of patches 4. Size distribution of patches a. avg.-min-max patch size, 5. shape specific to type a. orientation related to flow (wet prairies and marshes, sloughs, tree islands) b. Beach width 6. Potential for determining canopy height from stereo pairs but this may add significantly to the cost and effort
Method:	Comprehensive Everglades Restoration Plan (CERP) mapping project for vegetation methodology for landscape level coverage. Tree Island shape studies from Loxahatchee, see Laura Brandt. This mapping would be done using the CERP mapping aerial imagery but would not be the same product as the CERP mapping effort. This project would require finer scale characterization of boundaries and the development of polygons instead of the

	CERP process of MMU (CERP = 50 X 50 M) classification.
Frequency:	Every 4-6 years (CERP mapping program frequency), Additional sampling should occur within the event boundary in response to large scale disturbance events such as frosts, hurricanes, large fire events (e.g., 100,000 acres), floods, etc.
Timing:	In concert with existing aerial photo programs (CERP, etc.) for use of existing imagery. As imagery is available since time-lags between acquiring images and interpreting images can make accurate determinations more difficult if not impossible.
Scale of Collection:	Same as CERP mapping boundaries: includes EVER, BICY, but DRTO and BISC are not included in CERP mapping effort at this time. All wet prairies, marshes, sloughs, mangroves and tidal wetlands are included. Tidal Creeks are a RECOVER indicator. Consider tidal creeks because an additional indicator for tidal creeks may be developed separately - either include tidal creeks here or develop this concept for tidal creeks elsewhere.
Scale of Operation:	Regional (incl. areas outside parks), Some events operate at a more local scale
Scale of Analysis:	Multiple scales including all the above
Basic Assumptions:	Vegetation patterns reflect environmental drivers and patterning and changes in management. In turn, vegetation patterns drive other environmental factors such as wildlife populations. This indicator looks at the biotic response to drivers; it does not monitor specific drivers (different drivers would elicit different changes), however, the correlations in relation to changes in vegetation pattern need to be able to be established from other monitoring efforts (e.g., hydrology, nutrients, etc.)
Research Needs:	An understanding of historical or existing conditions to be able detect and determine changes. Determining whether CERP classification is capable of identifying specific community classes of special interest such as Schizycharium vs. Muhlenbergia vs. Cladium vs. Eleocharis vs. etc. If CERP mapping effort cannot distinguish this level of type differences then the imagery would have to be used to reclassify polygons for this map product.
Management Goal:	Trend toward decrease in sawgrass and increase in wet prairie and slough without a loss in total diversity of community types and sustained current levels of biodiversity. Mangroves, beaches and tidal wetlands should show little to no inland movement or change in areal extent.
Threshold Target:	Insufficient knowledge, however, once these data are established prior to dramatic hydrologic changes the target would be a sustained level of biodiversity with no loss of any vegetation type. Threshold targets may not be practicable for this indicator until trends in patterns are developed for different eco-regions that are being affected or not, by different management regimen (e.g., fire, water, etc.). Targets would be different for different vegetation types (e.g., mangroves, wet prairies, etc).
Response:	Management responses would depend on management actions and the resultant effects of those actions on the vegetation patterns. For example, changes in fire management in coastal marshes may alter marsh vegetation patterns. A determination of the "relevance" of the change in the pattern and any subsequent change in management actions would be needed (i.e. more research?).
Constraints:	Limitations of aerial photo being able to be used to resolve the different vegetation types and boundaries between types. This includes resolution and scale. If boundaries between marsh and slough areas cannot be delineated from the imagery (e.g., Shark Slough vs. wet prairie), it may be necessary to delineate vegetation types and boundaries within a single large bioregion or Conceptual Ecological Models (e.g., Wet

Prairies and Marshes).

Status: Comprehensive Everglades Restoration Plan / RECOVER is currently creating a vegetation map of CERP-related areas of EVER, BICY, BISC, and the Water Conservation Areas using 1:24000 Color-Infrared Photography. Remapping is currently scheduled every 5 years. (See Ken Rutchey, SFWMD)

NPS-South Florida / Caribbean Network is mapping the remaining areas of BICY and EVER not covered by the CERP effort with a consistent methodology. This is a one-time mapping effort to create a baseline vegetation map.

Estimated Cost: Ken Rutchey (SFWMD) has estimated costs for interpretation on a per acre cost.

References: Ken Rutchey and Kevin Whelan (NPS)

QQ. *Ecotone shifts along wetland boundaries - Mangrove to marsh to cypress- Aerial photography*

Which conceptual model(s) is this indicator linked to?

☑ Freshwater Wet Prairies and Marshes ☑ Forest Uplands and Wetlands

☑ Mangroves ☑ Florida Bay ☑ Biscayne Bay

Parks where monitoring would be conducted

☑ BICY ☑ BISC ☑ EVER

Indicator:	Ecotone shifts along wetland boundaries - Mangrove to marsh to cypress- Aerial photography
Monitoring Question(s):	Are the wetland ecotones changing in aerial size (becoming wider or narrower)? What is the influence of CERP and land use change in EVER, BICY and BISC on ecotones? What are the effects of sea-level rise on ecotones?
Justification:	Tracking the position of mangrove-marsh and mangrove-marsh-cypress ecotones can indicate the long-term trajectory of the wetland ecosystem especially in regards to the ecological forcing from regional water management changes and sea-level rise. This regional process can be effectively monitored by aerial photography. In South Florida at selected sentinel sites, the movement of the ecotone across the landscape historically has been an important indicator of water management, e.g., "White Zone" in southeast Everglades.
Metric:	Track and ground-truth aerial change and movement of ecotone across the landscape at selected sentinel sites, historically and over time (e.g., 10 year intervals). Measure change in area of features, e.g., "White Zone" in southeast Everglades. Units of change would be area (ha) and direction
Method:	Comparison of sequential, geo-referenced, and ground-truthed aerial photographs
Frequency:	Every 3-10 years (approximate interval) depending in part on speed of change
Timing:	Anytime that cloud cover is low and vegetation can be delineated
Scale of Collection:	Multiple Parks
Scale of Operation:	Regional (incl. areas outside parks)
Scale of Analysis:	Regional (incl. areas outside parks), Multiple Parks, Note: consider including partner DOI and State of Florida landholdings (e.g., Ten Thousands Islands NWR; Florida Panther NWR; Fakahatchee Strand State Park)
Basic Assumptions:	Sample assumption is that ecotones can be demarcated well with chrono-repetitive aerial photographs (i.e., area change is great enough to detect differences relative to sampling variation) Method assumption is that shifting ecotones in multiple directions are good indicators of long-term change
Research Needs:	Monitor bi-directional past changes in wetland community shifts from cypress swamps (BICY & EVER) to marsh (BICY & EVER) to mangrove (EVER & BISC).

	Relate to shifts to hydrological manipulations, fire incidence, or elevation loss/gain.
Management Goal:	Determine if ecotone is shifting towards coast as CERP is implemented, or how ecotone is shifting with "natural" hydrological changes associated with climate (e.g., sea-level rise, temperature, fire, freeze, etc....) or hurricanes.
Threshold Target:	Insufficient knowledge
Response:	Identify constrictions to water flow and modify hydrologic releases patterns
Constraints:	There are several "types of mangrove: non-mangrove wetland ecotones- mangroves with a) periphyton-spikerush, b) sawgrass, c)needlerush, d) spartina, e)succulents (botis, seguvium)- and then each of these with cypress - these may respond differently. Determining cypress versus mangrove coverage from aerial photographs in areas of habitat overlap (principally BICY & EVER), especially along dendritic channels (rivulets) in the region can be challenging if the sampling protocol stipulates limited funds for ground-truthing.
Status:	The USGS has mapped mangrove-to-ecotone shifts in EVER from 1927 through at least 1995 (Tom Smith & Ann Foster - USGS-FISC; Tom Doyle - USGS-NWRC). USGS has been conducting the EVER Historical Air Photo project (EHAP), scanning old air photos. Need to develop GIS layers. "White Zone" has been mapped on one occasion. Cypress-to-marsh habitats have been largely ignored as a temporal component of mapping efforts. Ecotone mapping has been useful at verifying systems landscape models for predicting shifts and sensitive elements of shifts in EVER (contact Tom Doyle - USGS-NWRC, 337-266-8647). There is also a strong desire from the larger scientific community to expand our understanding of which drivers are most responsible for dictating ecotonal dynamics through the use of landscape ecological simulation models. In other words, consider linking mapping efforts with modeling efforts for individual parks.
Estimated Cost:	Approximately $100-$120 K per year for at least a two-to-three-year focal period every 10 years, for example. Budget would have to include salary, travel, and photo acquisition costs for a GIS Specialist. Project costs would be lower if NPS has a GIS Specialist on permanent salary; overall program costs, of course, remain the same. Costs exclude modeling efforts
References:	Contact Tom Smith and Tom Doyle, See Smith *et al.* (2002), Open-file Report 02-207, Open-file Report 02-236, on sofia.usgs.gov

RR. *Location of critical ecotones - field plots/transects*

Which conceptual model(s) is this indicator linked to?

☑ Freshwater Wet Prairies and Marshes ☑ Forest Uplands and Wetlands

☑ Island Interior ☑ Mangroves

Parks where monitoring would be conducted

☑ BICY ☑ BISC ☑ BUIS ☑
DRTO ☑ EVER ☑ SARI ☑ VIIS

Indicator:	Location of critical ecotones - field plots/transects
Monitoring Question(s):	Are ecotones shifting due to physical conditions e.g., Hydrology, climate change, anthropogenic factors, sea level rise, fire, episodic metrological and storm wave events etc.
Justification:	Ecotones are transition zones between habitats and are generally dynamic locations for flora and fauna. Due to the sharp transition between habitats, tracking the position of ecotones can indicate the long-term trajectory of the habitats. Understanding the physical conditions which are driving the change in the ecotone location will be critical for proper resource management. Examples of ecotones include mangrove-tidal marsh ecotones; tidal wetlands (mangrove/tidal marsh)-freshwater marsh ecotones; sawgrass ridge-slough-tree island ecotones; marl prairie-sawgrass marsh ecotones; pine-marl prairie ecotones. Ecotones are expected to move, for example, in response to changes in water management, sea level rise, and fire management.
Metric:	Species composition and physical structure of vegetative community or habitat.
Method:	Transects/plots from one ecosystem to another. Possible overlap with CERP marl prairie to slough methodology and other existing monitoring. St. John program - beach profile
Frequency:	Every 3-5 years, VIIS quarterly for beach program.
Timing:	Varies by logistics, but same time each sampling period once initiated. Need to be able to respond rapidly to an "event"- a hurricane, fire, flood
Scale of Collection:	Multiple Parks
Scale of Operation:	Regional (incl. areas outside parks), Multiple Parks, Site Specific
Scale of Analysis:	Regional (incl. areas outside parks), Multiple Parks, Park-wide
Basic Assumptions:	Ecotones move in response to changes in environment. Ecotone shifts reflect changes in environment.
Research Needs:	
Management Goal:	Changes in ecotones will occur via natural means. Non-natural, controllable changes will be minimized.
Threshold Target:	Varies by community, but any shifts thought to be due to non-natural events will be reported to management.
Response:	Determine if change in ecotone is due to non-natural process. Minimize influence of non-natural process, if possible, e.g., change fire regime, restore hydrological patterns, and control exotic and undesirable native vegetation.
Constraints:	Monitoring unconstrained.
Status:	Some monitoring ongoing (vegetation mapping, transects in pine-prairie ecotones, transects in prairie-slough (CERP), CSSS work may apply, Raccoon point monitoring may apply, BISC and BICY inventory work may apply, ground truthing in ENP and BICY may apply. VIIS beach profile program (Rafe), Salt River site specific monitoring.

Estimated Cost: Determined by chosen methodology, location. Estimated $60,000/sampling period for each unit.

References: Resource management staff at related park units, USGS staff, university staff, local non-profits.

SS. *Location of Hammock-Pineland ecotone - field plots/transects*

Which conceptual model(s) is this indicator linked to?

☑ Forest Uplands and Wetlands

Parks where monitoring would be conducted

☑ BICY ☑ EVER

Indicator:	Location of Hammock-Pineland ecotone - field plots/transects
Monitoring Question(s):	Are ecotones between pineland and hammock shifting due to physical conditions, e.g., fire, hydrology, climate change, anthropogenic factors, sea level rise, etc.
Justification:	Both hammocks and pinelands (esp. pine rocklands) are important habitats for rare and endemic plant species and for wildlife, with different species occurring in each. Hammocks are spatially limited vegetation community occurring within a matrix of pinelands in south Florida. Pinelands are fire adapted whereas hammock species are less so. In the absence of fire, hammock species expand into pinelands. However fire can reduce or even eliminate hammocks. Thus appropriate fire management is critical to maintaining a balance of both these habitats. Invasive species could also impact these relationships. Long-term monitoring will detect changes in the position of the ecotone allowing management changes to be made if necessary.
Metric:	Plant species composition, physical structure of vegetative community (canopy height; density at different strata), soil depth to and including A horizon and O horizon
Method:	Transects/plots from hammock to pineland. Permanent plots will be established along a belt transect which runs across the ecotone and into mature portions of each community. In each plot the following data will be recorded: Canopy height, vegetative cover of each plant species, canopy cover in each stratum (canopy, herb layer, shrub layer, etc), O horizon depth, and A horizon depth. Data will be analyzed to determine if species composition, soils, and vegetation structure are changing along transects over time.
Frequency:	Every 3-5 years
Timing:	Same time each sampling period once initiated. Timing not critical.
Scale of Collection:	Multiple Parks
Scale of Operation:	Multiple Parks, Site Specific
Scale of Analysis:	Regional (incl. areas outside parks)
Basic Assumptions:	Hammock-pineland ecotones shift in response to environmental changes, especially hydrology and fire conditions (seasonality, and intensity).
Research Needs:	Identification of baseline or reference condition from aerial photography. Coordination with burn monitoring programs necessary. Information on management decisions that identify how systems should be maintained. Information on concurrent hydrological changes in study areas.

Management Goal:	Maintain an appropriate balance of pinelands and hammocks in healthy condition across the landscape and conservation of rare and endemic species within them.
Threshold Target:	Any shifts thought to be due to non-natural events will be reported to management.
Response:	Determine if change in ecotone is due to non-natural process. Minimize influence of non-natural process, if possible. e.g., Change fire regime, restore hydrological patterns, control exotic and undesirable native vegetation.
Constraints:	Monitoring unconstrained.
Status:	No current monitoring known within parks specific to this issue, but Raccoon Point monitoring data may be applicable.
Estimated Cost:	Estimated $20,000-40,000/sampling period for each unit.
References:	Resource management staff at related park units, USGS staff, university staff, local non-profits.

TT. *Physical drivers of mangrove-marsh ecotone*

Which conceptual model(s) is this indicator linked to?

☑ Freshwater Wet Prairies and Marshes ☑ Mangroves

Parks where monitoring would be conducted

☑ BISC ☑ EVER

Indicator:	Physical drivers of mangrove-marsh ecotone
Monitoring Question(s):	How are climate change and modifications in freshwater input impacting the coastal gradient?
Justification:	There is a sharp transition between the mangrove-marsh ecotone which maybe a result of the interaction of freeze/fire events and sea level rise/ water management. Tracking the position of mangrove-marsh ecotones can indicate the long-term trajectory of the mangrove ecosystem especially in regards to the ecological forcing from regional water management and sea-level rise. However, to properly interpret mangrove-marsh ecotonal movement, porewater salinity monitoring to show how the salinity gradient is changing coupled with accounting for rare freeze/fire events is necessary in addition to aerial photography.
Metric:	1. Porewater salinity across this gradient 2. Winter low temperatures across this gradient 3. Low-level photography to assess concurrent shift in vegetation with ground-truthing
Method:	See Metric above; Across spatial networks, I-button temperature sensors, salinity in distilling wells
Frequency:	Salinity & temperature continuously; vegetation every 3 years
Timing:	See above
Scale of Collection:	Regional (incl. areas outside parks)
Scale of Operation:	Regional (incl. areas outside parks)

Scale of Analysis:	Regional (incl. areas outside parks), Multiple Parks, Park-wide, Site Specific
Basic Assumptions:	If salinity & winter freezes didn't affect encroachment of mangroves
Research Needs:	1. modeling of porewater salinity with salinity in adjacent marine waters 2. salinity & freeze stress response of major plant species 3. characterize species variability in microclimate in landscape
Management Goal:	Mitigate continued encroachment of mangroves as much as possible
Threshold Target:	Insufficient knowledge
Response:	N/A
Constraints:	Other drivers may be important in some locales
Status:	TIME modeling addresses coastal marshes to some degree. Ongoing salinity monitoring programs in USGS are not geographically comprehensive. Existing temperature monitoring programs are not adequate.
Estimated Cost:	Economics of scale make this difficult to estimate
References:	Tom Smith, Mike Ross, Robert Twilley, Victor Rivera-Monsoy, Gordon Anderson, Kevin Whelan

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UU. *Long-term, within-community vegetation shifts using permanent plots*

Which conceptual model(s) is this indicator linked to?

☑ Freshwater Wet Prairies and Marshes ☑ Forest Uplands and Wetlands

☑ Island Interior ☑ Mangroves

Parks where monitoring would be conducted

☑ BICY ☑ BISC ☑ BUIS ☑ DRTO ☑ EVER ☑ SARI ☑ VIIS

Indicator:	Long-term, within-community vegetation shifts using permanent plots
Monitoring Question(s):	Are there changes in plant community dominant species, structure, composition, and quality over time within communities (e.g., forest, marsh, mangroves)?
Justification:	Plants are important primary producers and dominant physical structure components in terrestrial natural systems. They are the quintessential primary focus component of almost all natural land resource management agencies. Long-term, within community changes in vegetation community composition and structure provides important information for management and may indicate transformation of successional state, time since disturbance, eutrophication, hydro-pattern (including groundwater), water quality, fire regime, disease or insect outbreak effects, changes in relative cover by native/non-native species (etc).
Metric:	Species composition in multiple strata, percent cover (native and exotic), density, species richness. In forested areas, forest inventory (e.g., basal area, height, tree density), including overstory and understory composition, assessment of

	regeneration, presence and cover of exotic plants, and herbaceous plant surveys within fixed plots. [Soil depth, type and simple soil nutrients could be measured at the same time.]
Method:	Establish permanent, fixed radius (e.g., 13 m radius) or fixed-edge (e.g., 20 x 50 m) plots from which plant community structure is monitored with established protocols periodically. Established protocols will include main plots, sub-plots, and smaller plots of herbaceous vegetation and regeneration. Attributes to monitor will include tree DBH, tree height, herbaceous plant coverage, seedling density, soil depth, soil type, and soil nutrients. Note: these should not be confused with ecotone questions or belt transect techniques. Those techniques are structured to determine fundamentally different things.
Frequency:	Every 3-10 years (approximate interval), Other (Please specify): Longer frequency in forested habitats (5-10 years). Shorter frequency in herbaceous habitats (3-5 years). Additional sampling following catastrophic events such as hurricanes, intense fires, hydrologic alteration.
Timing:	Late dry season or early wet season for the wetlands, but timing may be driven more by access (e.g., airboats, lack of mosquitoes for mangroves) than plant phenology. Same time each sampling period once initiated. Initiation of sampling in some communities (e.g., Fire dependent) may require a specific season. Cloud cover should be low so that vegetation can be delineated
Scale of Collection:	Multiple Parks, Site Specific, community specific
Scale of Operation:	Regional (incl. areas outside parks), Multiple Parks, Site Specific, community specific
Scale of Analysis:	Regional (incl. areas outside parks), Multiple Parks, community specific
Basic Assumptions:	Plots will be located by protocol to facilitate identifying its exact location along 10 year sample intervals, for example, even after hurricane disturbance or lightning damage. Techniques should include GPS locations to identify general areas, but must include witness trees and establishment of plot centers/plot corners to ID exact plot boundaries. Location of plots are representative of the larger community and indicate habitat change, especially in reference to loss of dominant species and colonization by invasive plants. Plant species composition both responds to environmental drivers and in turn drives other species responses at smaller changes than conversion between vegetation types (e.g., cape sable seaside sparrow populations respond to Muhlenbergia density).
Research Needs:	Identification of existing baseline data. Identification of communities most likely to reflect changes in the ecology of the system. Calibration of individual species responses to hydrology, soil type and soil nutrients. Determine how vegetation communities are persisting over time in light of their individual stress gradients. All parks will be influenced by hurricanes and sea-level rise, while only a few will be influenced by human-mediated hydrologic changes, for example.
Management Goal:	Maintain structure and regeneration patterns found in the initial survey (??), with the understanding that the initial structure surveyed may not be a climax association or

	the best indicator of historic habitat. Change, hence, may be rated as good, bad, or neutral through this documentation process. Determine method of establishing appropriate community structure, species composition, and dominance.
Threshold Target:	Insufficient knowledge, but variation in community structural change over time is likely to be high in some communities, especially in a hurricane-prone region. Any shifts thought to be due to non-natural events will be reported to management. Background data on current conditions (e.g., REMAP) exist.
Response:	Variable. Determine if change in community structure, species composition, and dominance is due to non-natural process. Minimize influence of non-natural process, if possible. e.g., Change fire regime, restore hydrological patterns, control exotic and undesirable native vegetation. If native dominant species are being lost, suggest plantings. If species are rare, suggest propagation programs. In general, however, the latter topic (rare plants) should be included as a separate monitoring plan.
Constraints:	Standardizing sampling techniques over time with personnel turnover and budget changes.
Status:	Permanent plots are currently located in several of the parks within the region. BICY and EVER are at least two. Raccoon Point monitoring data may be applicable. This format would, for the first time, propose an among-park permanent sampling scheme that can easily be integrated with existing permanent plots. This technique will offer an excellent way to communicate with all other I&M programs along the lines of data comparison. Permanent plots already occurring in St. John. Monitoring of this form has been tentatively proposed as a component of CERP landscape monitoring (Philippi 2005), although it is not currently in development.
Estimated Cost:	Sampling will likely need to be staggered from year-to-year from among the parks in the I&M Network. Best guess, excluding personnel costs, $50K per annum for forest plots as a continuous allotment (assuming that permanent survey personnel are located in south Florida). Get ballpark estimates from Mike Ross. Similar REMAP vegetation sampling cost ~$100 for soil samples plus personnel and transportation costs (helicopter, airboat).
References:	Kevin Whelan (NPS), Keith Bradley (IRC), George Gann (IRC), Mike Barry (USFWS) Philippi T. 2005. Final Report to SFWMD CP040131 Stohlgren, T. J., A. J. Owen, and M. Lee. 2000. Monitoring shifts in plant diversity in response to climate change: a method for landscapes. Biodiversity and Conservation 9:65-86. There is a huge literature base for this, especially from the tropics. Resource management staff at related park units, USGS staff, university staff, local non-profits.

VV. *Critically Imperiled and Rare Plants:*

Which conceptual model(s) is this indicator linked to?

☑ Forest Uplands and Wetlands ☑ Island Interior

Parks where monitoring would be conducted

☑ BICY ☑ BISC ☑ BUIS ☑
DRTO ☑ EVER ☑ SARI ☑ VIIS

Indicator:	Critically Imperiled and Rare Plants:
Monitoring Question(s):	Are population sizes of rare plants increasing, decreasing, or stable
Justification:	Critically Imperiled or Rare plant species are important indicators and subjects for monitoring for the following reasons: they will be the first plants to become extirpated if habitat quality declines; they are sensitive to changes in ecosystem processes, such as disruption of pollinator populations, or increases or decreases in hydrology; they are either endemic to the study region or are at the geographical limits of their ranges and extirpation would result in extinction or a contraction in the species' global range; and if endemic they may be host plants for other rare or endemic organisms, such as invertebrates.
Metric:	Demography and distributions of each rare plant species, including annual population sizes, mortality, recruitment, and extent of habitat occupied. Focal species: All Critically Imperiled plants of Long Pine Key, Everglades National Park Species of the East Everglades - Anemia wrightii, Phyla stoechadifolia, Vanilla barbellata Species of the EVER coastal area - Cheilanthes microphylla, Chromolaena frustrata, Kosteletzkya depressa, Malachra urens, Oncidium undulatum, Pavonia paludicola, Peperomia humilis, Rhipsalis baccifera, Species of BICY - Burmannia flava, Calopogon multiflorus, Dalea carthagenensis var. floridana, Quercus nigra, Trichomanes holopterum, Viola palmata Species of BISC - Aristolochia pentandra, Eugenia rhombea, Guajacum sanctum, Opuntia corallicola, Pavonia paludicola, Phoradendron rubrum, Pseudophoenix sargentii, Rhynchosia swartzii, Vallesia antillana Species of DRTO - Cenchrus myosuroides Species of VIIS, SARI, and BUIS - to be determined
Method:	Areas with rare plant populations will be surveyed on foot. The extent of habitat occupied by each rare plant species will be mapped. Individuals of each rare plant will be tagged and mapped. For each individual several attributes will be recorded, including plant size (e.g., height, canopy diameter), flowering and fruiting activity, life history stage (e.g., seedling, juvenile, reproductive adult). Plants will be monitored annually to track long term changes in population numbers and extent.
Frequency:	Annual, every 3-5 years, Species specific - depending on life history. Trees may be monitored less frequently than herbs.
Timing:	Species specific
Scale of Collection:	Multiple Parks, Site Specific
Scale of Operation:	Regional (incl. areas outside parks), Multiple Parks, Site Specific
Scale of Analysis:	Regional (incl. areas outside parks), Multiple Parks, Site Specific

Basic Assumptions:	Any program must be done on a long term because we don't understand shorter-term climate cycle effects on populations
Research Needs:	Data mining for baseline data on species occurrences
Management Goal:	Maintain populations at sustainable levels
Threshold Target:	Long term populations need to be stable or increasing
Response:	Determine if population decline is due to anthropogenic causes or other and utilize adaptive management to correct problem (e.g., change fire, hydrology, or augment population sizes)
Constraints:	Demographic sampling is time consuming
Status:	A five year monitoring program of critically imperiled plants of Long Pine Key, Everglades National Park is in its third year.
Estimated Cost:	$5K -20k per species per sampling year
References:	Jimi Sadle (BICY), Keith Bradley (IRC), George Gann (IRC), Emilie Verdon (IRC), Craig Smith (EVER), Tom Phillipi (FIU), Andrea Atkinson for sampling design issues (NPS-SFCN), Jim Burch (BICY)

WW. *Periphyton*

Which conceptual model(s) is this indicator linked to?

☑ Freshwater Wet Prairies and Marshes ☑ Forest Uplands and Wetlands

☑ Mangroves ☑ Florida Bay ☑ Biscayne Bay

Parks where monitoring would be conducted

☑ BICY ☑ BISC ☑ EVER

Indicator:	Periphyton
Monitoring Question(s):	Is periphyton cover, distribution, biomass, productivity and composition changing in response to alterations in water quality, hydrology and related habitat changes?
Justification:	Periphyton is a critical primary producer base of the food web in South Florida wetlands and estuarine areas. Periphyton production can exceed phytoplankton; it stabilizes the sediments, controls nutrient upwelling, and changes compositionally in direct response to salinity and water management (quality, quantity, timing, duration).
Metric:	Aerial Cover Structure Biomass Productivity Organic/Inorganic (Calcite) content Nutrient content Species composition
Method:	Aerial Cover - photographs of fixed quadrats (m2) and aerial image analysis (km2) Structure - substrate-specific cover estimates (benthic, epiphytic, metaphytic) Biomass - dry weight, ash-free dry weight and chlorophyll a scaled to m2 using cover estimates Productivity - on a subset of sites by BOD incubation Organic/Inorganic (Calcite) content - ratio of ash-free dry mass to dry mass Nutrient content - total phosphorus (nitrogen and carbon) per gram dry mass Species composition - relative abundances of algal taxa
Frequency:	Annual
Timing:	Samples should be collected in the late wet season (August-November) and from a sub-set of sites during the dry season (Feb-April).
Scale of Collection:	Regional (incl. areas outside parks)
Scale of Operation:	Regional (incl. areas outside parks), Site Specific
Scale of Analysis:	Regional (incl. areas outside parks)
Basic Assumptions:	Periphyton responds in structure, productivity and composition to habitat alterations.
Research	1. Can periphyton be investigated at the landscape-scale through aerial image

Needs:	analysis? 2. How do short-term disturbance events (hurricanes, fire, prolonged drought) affect periphyton response to longer-term changes?
Management Goal:	1. Ridge and Slough - restoring ridge and slough topography will increase contrast in periphyton abundance between the two habitat types (high in slough, low in ridge). Increased water depth will shift mats to the water column (metaphyton) and increase the organic and TP content, green algae and diatoms. Inherent increased nutrient delivery will shift these qualities further in the same direction but may also decrease overall biomass. 2. Marl Prairie/Rocky Glades - increased hydroperiod in the severely dry end of this gradient will increase periphyton production while lengthening beyond 365 days will reduce it. There may be a shift to increasing metaphyton production (relative to benthic and epiphytic), increased organic and TP content, green algae and diatoms. Inherent increased nutrient delivery will shift these qualities further in the same direction but may also decrease overall biomass. 3. Estuaries - altered freshwater and nutrient delivery to the coastal zone will radically shift composition of periphyton communities.
Threshold Target:	1. Ridge and Slough (except LNWR) Cover - mean 60-100 % Structure - metaphytic > epiphytic > benthic Dry Biomass - mean 100-1000 dry g/m2 Percent Calcite - mean 30-70% TP Content - mean 100-200 ug/g dry mass Composition - by multivariate analysis of difference over time Productivity - insufficient knowledge 2. Marl Prairie/Rocky Glades Cover - mean 70-100% Structure - epiphytic > benthic > metaphytic Dry Biomass - mean 800-1500 dry g/m2 Percent Calcite - mean 60-80% TP Content - mean 100-150 ug/g dry mass Composition - by multivariate analysis of difference over time Productivity - insufficient knowledge 3. Estuaries Cover - mean 0-50% Structure - epiphytic > benthic > metaphytic Dry Biomass - mean 100-1000 dry g/m2 Percent Calcite - mean 50-90% TP Content - mean 100-200 ug/g dry mass Composition - by multivariate analysis of difference over time Productivity - insufficient knowledge
Response:	1. Examination of time series of change at site (did excedence values follow extreme disturbance event?) 2. Abatement of nutrient loading 3. Increased clean freshwater delivery
Constraints:	Periphyton needs to be monitored on appropriate spatial scale to detect change over time, and sampling needs to coincide with consumer, plant and water quality monitoring to address effects of correlated variables.
Status:	1. Periphyton is being monitored at a large scale in the MAP in conjunction with invertebrate and fish collections (food web component). 2. The current MAP food web project does not sample dry habitats and therefore severely under-represents the marl prairie/rocky glades.

3. There is no continuous monitoring of periphyton in the estuary/coastal zone of Biscayne or Florida bays even though periphyton production exceeds phytoplankton there, stabilizes the sediments and controls nutrient upwelling, and changes compositionally in direct response to salinity.

Estimated Cost: $100,000 per year per 100 sites

References: Evelyn Gaiser

Davis, S. M., W. F. Loftus, E. E. Gaiser and A. E. Huffman. 2006. Southern marl prairies conceptual ecological model. Wetlands 25: 821-831

Gaiser, E. E., J. H. Richards, J. C. Trexler, R. D. Jones and D. L. Childers. 2006. Periphyton responses to eutrophication in the Florida Everglades: Cross-system patterns of structural and compositional change. Limnology and Oceanography 51: 617-630.

XX. *Freshwater fish and large macro-invertebrates in wet prairies and marshes*

Which conceptual model(s) is this indicator linked to?

☑ Freshwater Wet Prairies and Marshes ☑ Forest Uplands and Wetlands

Parks where monitoring would be conducted

☑ BICY ☑ EVER

Indicator:	Freshwater fish and large macro-invertebrates in wet prairies and marshes
Monitoring Question(s):	What are the status and trends in community composition, abundance, size structure, and distribution of fish and large macro-invertebrate assemblages in the wet prairies and marshes?
Justification:	Regional populations of wet prairies and marsh fishes and other aquatic fauna reflect regional hydrology (water depth, timing, duration, quantity, quality) and in turn are the prey base for wading birds and other higher consumers in the Greater Everglades and Big Cypress ecosystem. Water diversions and altered water management practices have resulted in declines in regional populations of fish and aquatic invertebrates with cascading impacts on higher food web levels. The Comprehensive Everglades Restoration Plan will be rehabilitating system hydrology and is expected to affect these populations.
Metric:	Community composition, Abundance (density and relative abundance), size structure
Method:	Throw traps in sparse vegetation habitats such as wet prairies. Not a proven method in thick vegetation (ie. Sawgrass) or karst topography (ie. Rocky Glades). Qualitative sampling gear in addition to quantitative methods to increase number of species collected.
Frequency:	Multiple samples that emphasize important seasonal dynamics.
Timing:	
Scale of Collection:	Regional (incl. areas outside parks)
Scale of Operation:	Multiple Parks
Scale of Analysis:	Multiple Parks
Basic Assumptions:	Sampling biases associated with each collection gear. Throw trap valid only for small fishes (<80mm) and large macroinverterates (e.g., crayfish, prawns, dragonflies). Qualitative sampling gear collections may not represent actual abundances.
Research Needs:	Sampling efficiency in forested and short hydroperiod karst wetlands. Partitioning effect of nutrient additions and hydroperiod.

Management Goal:

Threshold Target:

Response:

Constraints:

Status: On-going:
CERP-MAP (Trexler: throw trap); EVER long-term sites (Kline and Trexler: throw trap); CESI (Kline: throw trap and minnow trap; Loftus: minnow traps, minnow trap arrays, and throw traps); LTER (Trexler: Throw trap); REMAP (Trexler: throw trap)

NOTE: The Comprehensive Everglades Restoration Plan (CERP) and has "Aquatic Fauna Regional Populations in Everglades Wetlands" and "System-Wide Wading Bird Nesting Patterns" as CERP Interim Goals Indicators and monitoring variables in the CERP Monitoring and Assessment Plan.

Estimated Cost:

References: See "Status" above.

YY. *Aquatic invertebrates in wet prairies and marshes*

Which conceptual model(s) is this indicator linked to?

☑ Freshwater Wet Prairies and Marshes ☑ Forest Uplands and Wetlands

Parks where monitoring would be conducted

☑ BICY ☑ BISC ☑ EVER

Indicator:	Aquatic invertebrates in wet prairies and marshes
Monitoring Question(s):	What shifts are occurring in aquatic invertebrate community composition and structure as indicators of hydrological patterns and water quality in the wet prairies and marshes?
Justification:	Aquatic invertebrate communities reflect water quality and hydrology (water depth, timing, duration, quantity) and are frequently used in indices (i.e. Macroinvertebrate Biological Integrity Index (MBI)) as early warning response indicators of change. These invertebrates in turn are the prey base for fish, large macro-invertebrates (e.g., crayfish), herpetofauna, and wading birds in the Greater Everglades and Big Cypress ecosystem. Water diversions and altered water management practices have resulted in changes in aquatic invertebrate community composition and abundance. The Comprehensive Everglades Restoration Plan will be rehabilitating system hydrology and water quality which should in turn affect aquatic invertebrate communities and consequently higher trophic levels.
Metric:	Community composition, Abundance (density and relative abundance) these are incorporated in the Macroinvertebrate Biological Integrity Index (MBI) SEE Pinar
Method:	Dip net, Benthic cores (note expensive), Funnel Traps Rick Jacbson Midget Pupal Exuvia - USGS contractor. Ryan King - Invert work in WCA's Turner and Trexler (Inverts in Marshes)
Frequency:	Multiple samples that emphasize important seasonal dynamics.
Timing:	Biannual Wet and Dry season
Scale of Collection:	Regional
Scale of Operation:	Regional, Multiple Parks
Scale of Analysis:	Regional, Multiple Parks
Basic Assumptions:	Sampling biases associated with each collection gear. Development of MBI for these marshes specifically / regionally. Qualitative sampling gear collections may not represent actual abundances.
Research	Development of MBI for these marshes specifically / regionally

Needs:	MBI may differ among habitats. Partitioning effect of nutrient additions and hydroperiod.
Management Goal:	
Threshold Target:	insufficient knowledge
Response:	insufficient knowledge
Constraints:	Requires massive collaboration across the following institutions SFWMD, DEP, Joel Trexler's CESI IOP assessment project.
Status:	On-going: CESI-IOP (Trexler: throw trap and DIP net); SWFMD (research on invertebrates - Robert Shoufford in Marsh Ecology Everglades Division) DEP (Northern Marshes Fraidomburg, Greg Graves)
Estimated Cost:	Expensive to unknown
References:	CESI-IOP (Trexler: throw trap and DIP net); SWFMD (research on invertebrates - Robert Shoufford in Marsh Ecology Everglades Division) DEP (Northern Marshes Fraidomburg, Greg Graves)

ZZ. *Butterflies*

Which conceptual model(s) is this indicator linked to?

☑ Forest Uplands and Wetlands ☑ Island Interior

Parks where monitoring would be conducted

☑ BICY ☑ BISC ☑ BUIS ☑ DRTO ☑ EVER ☑ SARI ☑ VIIS

Indicator:	Butterflies
Monitoring Question(s):	What are the status and trends in abundance and distribution of butterflies?
Justification:	Butterflies are important pollinators that reflect changes in plant communities, caterpillar host plants, butterfly nectar plants, and pesticide use. Schaus Swallowtail (Papilio aristodemus ponceanus) and the Miami blue butterfly (Hermiargus thomasi benthunebakeri) in south Florida parks are federally listed (former) or candidates for listing (later). Information could also be useful in directing park mosquito control activities in areas of rare butterflies.
Metric:	Population abundance and distribution
Method:	Visual surveys, mark-recapture
Frequency:	Monthly
Timing:	Each month, annually
Scale of Collection:	Multiple Parks
Scale of Operation:	Site Specific, Regional (incl. areas outside parks)
Scale of Analysis:	Park-wide
Basic Assumptions:	Stressors that cause changes in plant communities influence butterfly populations
Research Needs:	Better understanding of causes of population declines for rare endemic butterflies Relationship of fire management and abundance and distribution of butterflies Metapopulation dynamics of butterflies
Management Goal:	Maintain or increase butterfly population levels Prevent extirpation of rare butterflies
Threshold Target:	Self-sustaining populations of butterfly species
Response:	Reduce pesticide spraying in the parks to avoid killing rare butterfly species
Constraints:	Social and political restraints related to pesticide spraying
Status:	EVER staff and volunteers are currently monitoring butterflies using visual surveys EVER biological and Fire staff are monitoring affects of fire on host and nectaring plants

Estimated Cost: Travel cost and technician salary

References: Consult Sue Perry (NPS), Ricardo Zambrano (FFWCC), Cindy Schulz (USFWS)

AAA. *Island Insects*

Which conceptual model(s) is this indicator linked to?

☑ Island Interior ☑ Mangroves

Parks where monitoring would be conducted

☑ BISC ☑ BUIS ☑ DRTO ☑ SARI ☑ VIIS

Indicator:	Island Insects
Monitoring Question(s):	What is the composition and distribution of major insect groups? e.g., beetles, pollinators. What invasive species are present and what is their distribution?
Justification:	Small islands have very simple food webs compared with mainland areas or large islands (e.g., Puerto Rico). It is assumed that insects are important in these island communities, e.g., beetles are important to nutrient recycling and as prey base; bees are susceptible to invasive species; etc.
Metric:	To be determined
Method:	To be determined
Frequency:	
Timing:	To be determined
Scale of Collection:	Multiple Parks, Site Specific
Scale of Operation:	Regional (incl. areas outside parks)
Scale of Analysis:	Multiple Parks, Site Specific
Basic Assumptions:	Insects are important in these island communities e.g., beetles are important to nutrient recycling and as prey base. Bees are susceptible to invasive species.
Research Needs:	Comprehensive inventory. Requires research first to determine what species are critical to maintain ecosystem function? E.g., beetles, pollinators
Management Goal:	
Threshold Target:	
Response:	
Constraints:	
Status:	A beetle inventory was completed at Buck Island.
Estimated Cost:	
References:	

BBB. *Amphibians - USVI*

Which conceptual model(s) is this indicator linked to?

☑ Island Interior

Parks where monitoring would be conducted

☑ SARI ☑ VIIS

Indicator:	Amphibians - USVI
Monitoring Question(s):	What are the distribution and proportion of area occupied of native and non-native amphibian species at Virgin Islands National Park and Salt River Bay National Historical Park and Ecological Preserve? What habitats are they using?
Justification:	Amphibians are an important component in the Virgin Islands terrestrial ecosystems. They comprise a large amount of the resident vertebrate biomass and generally are a strong intermediate link in the food web. Amphibians have been used as a biological indicator for many environmental variables and are sensitive to changes in breeding habitat quality, invasive species, and contaminants.
Metric:	Proportion of area occupied
Method:	Visual encounter surveys and vocalization surveys coupled with proportion of area occupied (PAO) analysis. A protocol developed by Kenneth G. Rice *et al.* (2005) of USGS may be suitable.
Frequency:	2-3 visits per sampling year to estimate occupancy. Initially sample ever year for first 4-5 years to create baseline, then reduce frequency to once every 1-5 years as appropriate depending on data variability.
Timing:	To be determined
Scale of Collection:	Multiple Parks
Scale of Operation:	Regional (incl. areas outside parks)
Scale of Analysis:	Park-wide
Basic Assumptions:	The protocol developed by USGS is biased towards areas along roads and trails. Either the protocol will need to be adapted to assess amphibian populations across the park or park managers must be willing to accept that the inference will only be for populations along roads and trails.
Research Needs:	Is the Puerto Rican crested toad, Bufo lemur present on the island? It was not found during the USGS inventory and only known from one previous sighting with no voucher in existence. What are the optimum sampling times during the years and level of sampling effort required to appropriately sample this community?
Management Goal:	Reduction or elimination of introduced species. Sustainable maintenance of native populations.
Threshold	Insufficient knowledge.

Target:	
Response:	Control of invasive species. Habitat restoration as necessary. Mitigation of sources of contaminants.
Constraints:	See assumptions.
Status:	USGS completed an inventory and pilot monitoring protocol for St. John in 2001-2003. No long-term monitoring is underway.
Estimated Cost:	
References:	Rice, Kenneth G., J. Hardin Waddle, Marquette E. Crockett, Raymond Carthy, H. Franklin Percival. 2005. Herpetofaunal Inventories of the National Parks of South Florida and the Caribbean: Volume II. Virgin Islands National Park. U.S. Geological Survey Technical Report. USGS, Florida Integrated Science Center, UF-FLREC, 3205 College Av., Ft. Lauderdale, FL 33314, USA

CCC. *Amphibians - South Florida*

Which conceptual model(s) is this indicator linked to?

☑ Freshwater Wet Prairies and Marshes ☑ Mangroves

Parks where monitoring would be conducted

☑ BICY ☑ BISC ☑ EVER

Indicator:	Amphibians - South Florida
Monitoring Question(s):	What is the distribution and proportion of area occupied by native and non-native amphibian species at Everglades National Park, Biscayne National Park, and Big Cypress National Preserve? Are new invasions of exotic species occurring? Are local extinctions and/or colonizations of native species occurring?
Justification:	Amphibians are an important component in South Florida ecosystems. They comprise a large amount of the resident vertebrate biomass and generally are a strong intermediate link in the food web. Amphibians have been used as a biological indicator for many environmental variables and are sensitive to changes in breeding habitat quality, hydrology, invasive species, and contaminants.
Metric:	Proportion of area occupied, species presence
Method:	Visual encounter surveys and vocalization surveys coupled with proportion of area occupied (PAO) analysis. A protocol developed by Kenneth G. Rice *et al.* (2004-2006) of USGS may be suitable.
Frequency:	12-15 visits per plot per sampling year to estimate occupancy. Sample frequency of 3-10 years as appropriate (depends on required ability to detect change).
Timing:	Spring-Fall. See Rice *et al.* (2004-2006) for appropriate months by Park.
Scale of Collection:	Multiple Parks
Scale of Operation:	Regional (incl. areas outside parks)
Scale of Analysis:	Park-wide

Basic Assumptions:	If a species is present, the models assume that detection probability is greater than 0. Also, within-year sampling is closed to local colonization and extinction.
Research Needs:	How can the individual species occupancies be combined into community-based monitoring? For example, since South Florida amphibian species are fairly ubiquitous, monitoring of relative occupancies across groups of species (communities) might result in a better monitoring tool.
Management Goal:	Reduction or elimination of introduced species. Sustainable maintenance of native populations.
Threshold Target:	Use of previously collected data could be used to obtain targets. However, this work has not been initiated.
Response:	Control of invasive species. Habitat restoration as necessary.
Constraints:	See assumptions.
Status:	USGS completed an inventory and pilot monitoring protocol for each Park during 2001-2004. No long-term monitoring is underway.
Estimated Cost:	Approximately 1 man-hour required per sample in the field, no laboratory requirements.
References:	Rice, K.G., J.H. Waddle, M.E. Crockett, B.M. Jeffrey, and H.F. Percival. 2004. Herpetofaunal inventories of the National Parks of South Florida and the Caribbean: Volume I. Everglades National Park. U.S. Geological Survey, Open-File Report 2004-1065, Fort Lauderdale, Florida. 144pp. Rice, K.G., J.H. Waddle, B. Jeffries, and H.F. Percival. 2005. Herpetofaunal Inventories of the National Parks of South Florida and the Caribbean: Volume III. Big Cypress National Preserve. USGS Open-File Report. Fort Lauderdale, FL. Rice, K.G., J.H. Waddle, B. Jeffries, and H.F. Percival. 2006. Herpetofaunal Inventories of the National Parks of South Florida and the Caribbean: Volume IV. Biscayne National Park. USGS Open-File Report. Fort Lauderdale, FL.

DDD. *Pig Frog (Rana grylio)*

Which conceptual model(s) is this indicator linked to?

☑ Freshwater Wet Prairies and Marshes ☑ Forest Uplands and Wetlands

Parks where monitoring would be conducted

☑ BICY ☑ BISC ☑ EVER

Indicator:	Pig Frog (Rana grylio)
Monitoring Question(s):	What is the pig frog population structure in specific wetlands within Everglades National Park and Big Cypress National Preserve?
Justification:	The Pig Frog, Rana grylio, makes up a large amount of the vertebrate biomass in freshwater wetlands. They are both a prey source and a major predator. The Pig Frog life cycle (eggs and tadpoles, adults) is directly and intimately related to the marsh hydrology (immediate and moderate time period hydroperiod). Shifts in population

	structure are related to general wetland health and pig frogs have been shown to bioaccumulate some contaminants (e.g., mercury).
Metric:	Synoptic Population Structure sampling. Abundance (density and relative abundance)
Method:	Hand Grab sampling at night (Ugarte 2004) Large regional Scale synoptic night light surveys for abundance using double-observer methodology. The difference in detection can be calculated for different areas (Ugarte 2004).
Frequency:	Multiple samples that emphasize important seasonal dynamics.
Timing:	Biannual Wet and Dry season
Scale of Collection:	Regional (incl. areas outside parks), Multiple Parks
Scale of Operation:	Regional (incl. areas outside parks), Multiple Parks
Scale of Analysis:	Regional (incl. areas outside parks), Multiple Parks
Basic Assumptions:	Sampling biases associated with collection may miss extremely young individual; however, this is believed to be a minimal issue from a prior study. Qualitative sampling (four nights of repeated sampling) may not represent actual abundances.
Research Needs:	pending
Management Goal:	pending
Threshold Target:	pending
Response:	Large annual variation not tied to site specific hydrological issues should be investigated.
Constraints:	None
Status:	Prior work occurred with in EVER and WCA 3 A and WCA3 B
Estimated Cost:	Moderate to inexpensive
References:	Ugarte, C. A. 2004. PhD dissertation Human impacts on Pig Frog populations in South Florida wetlands: Harvest, water management and mercury contamination. Ugarte, C. A., *et al*. 2005. Variation of total mercury concentrations in Pig Frogs, Rana Grylio, across the Florida Everglades, USA. Science of the Total Environment. (345) 51-59.

EEE. *Reptiles - USVI*

Which conceptual model(s) is this indicator linked to?

☑ Island Interior ☑ Mangroves

Parks where monitoring would be conducted

☑ BUIS ☑ SARI ☑ VIIS

Indicator:	Reptiles - USVI
Monitoring Question(s):	What is the distribution and proportion of area occupied by native and non-native reptile species at Virgin Islands National Park and Salt River Bay National Historical Park and Ecological Preserve? What is the status of the Virgin Islands Tree Boa, Epicrates monensis granti, and the St. Croix Ground Lizard, Ameiva polops, if introduced to Buck Island Reef National Monument?
Justification:	Reptiles are an important top predator on the U.S. Virgin Islands. Reptiles as a group are not as transient as birds, the other top island predator; therefore, understanding the status of the island reptiles should indicate if overall terrestrial island management is appropriate for the higher trophic species. Additionally, Virgin Islands Tree Boa and the St. Croix Ground Lizard are listed species due to habitat destruction and over collection.
Metric:	Abundance or proportion of area occupied by species
Method:	Visual encounter surveys, live trapping, and/or mark/recapture. The St. Croix Ground lizard populations are estimated directly via counts in their known locations. Estimates of the Virgin Islands Tree Boa likewise will need special counting procedures, assuming the few remaining populations exist within NPS boundaries.
Frequency:	Monthly, Will require several sampling periods per year to estimate occupancy.
Timing:	To be determined
Scale of Collection:	Regional (incl. areas outside parks), Multiple Parks, Park-wide, Site Specific
Scale of Operation:	Regional (incl. areas outside parks), Site Specific
Scale of Analysis:	Park-wide, Site Specific
Basic Assumptions:	Assumption that visual encounter surveys, live trapping or other protocol provides an estimate of relative abundance or proportion of area occupied that is a reasonable surrogate for actual abundance or occupancy.
Research Needs:	What are the optimum sampling times during the years and level of sampling effort required to appropriately sample this community?
Management Goal:	Reduction or elimination of introduced species. Sustainable maintenance or increase of native population size and distribution.
Threshold Target:	To be determined.
Response:	Control of invasive species. Habitat restoration as necessary. Introduction of rare species to new locations on cays to reduce risk due to catastrophic events (hurricanes) and invasive species introductions.
Constraints:	Community monitoring will likely need a different approach from the two rare species listed.
Status:	Monitoring is underway for the St. Croix Ground Lizard and may be occurring for the

Boa.

Estimated Cost:

References:

Rice, Kenneth G., J. Hardin Waddle, Marquette E. Crockett, Raymond Carthy, H. Franklin Percival. 2005. Herpetofaunal Inventories of the National Parks of South Florida and the Caribbean: Volume II. Virgin Islands National Park. U.S. Geological Survey Technical Report. USGS, Florida Integrated Science Center, UF-FLREC, 3205 College Av., Ft. Lauderdale, FL 33314, USA

U.S. Virgin Islands Department of Planning and Natural Resources Division of Fish and
Wildlife. 2005. Comprehensive Wildlife Conservation Strategy for the U. S. Virgin Islands. June 1. 2005. 216 pages. URL:
http://www.vifishandwildlife.com/Wildlife/05F01WildlifePlan/Part%201%20Introduction/table%20of%20contents.htm

FFF. *Florida Box Turtle, Terrapene Carolina bauri*

Which conceptual model(s) is this indicator linked to?

☑ Freshwater Wet Prairies and Marshes ☑ Forest Uplands and Wetlands

Parks where monitoring would be conducted

☑ BICY ☑ BISC ☑ EVER

Indicator:	Florida Box Turtle, Terrapene Carolina bauri
Monitoring Question(s):	What are the population status, trends and distribution of Florida Box Turtles? Are they increasing, decreasing, or stable?
Justification:	T. c. bauri is an abundant turtle in south Florida and in some cases is called the "common" box turtle. The species is long-lived and reflects long-term habitat conditions at a site and region. They are very susceptible to habitat loss and fragmentation, roadkill (cars, farm equipment, lawn-mowers), intense fires, collection as pets, and dog and cat injury and predation. They utilize a diverse selection of upland and seasonally-flooded habitats throughout the year and play a key ecological role, serving as both predators and prey, contributing to the cycling of nutrients, and acting as seed dispersers for many native plants. As an abundant species that may be on the decline, changes in the population may be a better indicator of ecosystem health than monitoring an already endangered species.
Metric:	Demography and distributions of T. c. bauri populations, including annual population sizes, population structure, mortality, recruitment, and extent of habitat occupied.
Method:	Plots will be established for monthly mark/recapture surveys to estimate population size and searches will be conducted primarily during the wet season months when box turtles are most active as well as after prescribed fires to detect mortality. Plots will be placed in freshwater prairies, marshes, forest uplands, and wetlands, preferable 3 in wetland habitat and 3 in upland habitat. In addition, box turtles will be collected by visually searching open areas, roads, leaf litter, under vegetation, and through opportunistic collecting throughout the study area. Each box turtle will be marked permanently for future identification by filing notches on the marginal scutes (Cagle, 1939). Gender will be determined by the presence (male) or absence (female) of a plastral indentation. Age is nearly impossible to determine, therefore age will be classified by carapace length as either juvenile (< 11 cm) or adult (> 11 cm) following Dodd *et al.* (1994). Total population size estimates, sex-ratios, minimum number of turtles known to be alive, recapture rates, apparent survival parameters, growth, and mean morphological characteristics such as carapace length and weight will be computed.
Frequency:	Annual
Timing:	During the Wet/Rainy Season when box turtles are more active and more likely to be observed (April - November). In addition, searches will be conducted immediately after prescribed burns.
Scale of	Multiple Parks, Site Specific

Collection:	
Scale of Operation:	Regional (incl. areas outside parks), Multiple Parks, Site Specific
Scale of Analysis:	Regional (incl. areas outside parks), Multiple Parks, Site Specific
Basic Assumptions:	Any program must be done on a long term basis because we don't understand shorter-term climate cycle effects on these populations
Research Needs:	Data mining for baseline data on species occurrences.
Management Goal:	Maintain populations at sustainable levels.
Threshold Target:	Long term populations need to be stable or increasing.
Response:	Determine if population decline is due to anthropogenic causes or other and utilize adaptive management to correct problem (e.g., change fire, hydrology, or augment population sizes).
Constraints:	Demographic sampling and searches are time consuming.
Status:	Monitoring is proposed.
Estimated Cost:	$6K per replicate per sampling year with 6 replicates with additional searches outside of the plot area = ~$40K per sampling year
References:	Emilie Verdon (IRC) Kenneth Dodd (USGS) - expert on the genus Terrapene Verdon, E . 2004. Activity patterns, habitat use, and home range of the Florida box turtle (Terrapene carolina bauri) in the lower Florida Keys. M.S. Thesis. Florida International University. Miami. 129 pp. Verdon, E., and M.A. Donnelly. 2005. Population structure of Florida Box Turtles (Terrapene carolina bauri) at the southernmost limit of their range. Journal of Herpetology 39(4).

GGG. *American alligator (Alligator mississippiensis)*

Which conceptual model(s) is this indicator linked to?

☑ Freshwater Wet Prairies and Marshes ☑ Mangroves

Parks where monitoring would be conducted

☑ BICY ☑ EVER

Indicator:	American alligator (Alligator mississippiensis)
Monitoring Question(s):	What is the relative distribution, abundance, body condition, alligator hole occupancy, nesting level, and demographic structure of alligators in various habitats in relation to water levels and salinities throughout Everglades National Park and Big Cypress National Preserve? How do these metrics change over time and during Everglades restoration?
Justification:	The American alligator is considered an ecosystem engineer in the Greater Everglades

	due to it role in maintaining alligator holes (aquatic refugia in the dry season). Additionally, it is a top predator and can influence many other species. Alligators have been monitored as a keystone species in the Everglades for over the last 20 years trying to link their population dynamics to resource management activities; especially to water management.
Metric:	Animals/km, Sex ratio, Size distribution, Body condition index, alligators per hole, nests/km2, All metrics are equivalent to those used as performance standards in Comprehensive Everglades Restoration Plan (CERP).
Method:	See Rice *et al*. 2005 for justification. Protocols are present in Alligator MAP annual reports as well as CESI Alligator distribution project reports. Nesting protocols are present in ENP's SRF protocols. Distribution, abundance, and demographic structure are obtained through night-light survey along airboat trails and canals. Body condition is measured by morphometric measurements of captured and released animals. Alligator hole occupancy and nesting effort are estimated through aerial survey via helicopter along line transects.
Frequency:	Annual
Timing:	Night-light surveys are currently performed during mid-dry season (March-April) and mid-wet season (September-October). Body condition is measured during April and October to correspond with dry and wet seasons respectively. Nesting effort is obtained during July-September. Hole occupancy transects are performed during dry season (February-May).
Scale of Collection:	Park-wide
Scale of Operation:	Park-wide
Scale of Analysis:	Park-wide, by park region.
Basic Assumptions:	All metrics other than body condition assume that data collection provides estimation of detection probability (alligator eyeshine, alligator presence in holes, nests). This is accomplished through design of monitoring using distance sampling, transect methodology, and/or direct estimation of detection. Body condition assumes population specific models of body growth (see Zweig 2004).
Research Needs:	Work is currently underway funded by CESI and MAP to address detection under the various monitoring components.
Management Goal:	With the resumption of natural patterns of volume, timing, and distribution of flow to the Everglades, the American alligator is expected to repopulate and resume nesting in the rocky glades and the freshwater reaches of tidal rivers in the mangrove estuaries and will increase in population size and body condition throughout most of ENP. In BICY, no current targets are identified other than maintenance of current population condition.
Threshold Target:	Historical data exist to provide estimates of natural annual variation. These data have not been used to set threshold targets.
Response:	Habitat restoration as necessary.
Constraints:	Continued priority of monitoring program.
Status:	On-going. Is an indicator in the Comprehensive Everglades Restoration Plan (CERP) Monitoring and Assessment Plan (MAP) and Interim Goals.

Estimated Cost: Approximately 6 man-hours per night-light survey (4 per transect per year), 20 man-hours per body condition survey (2 per region monitored per year), 10-20 hours helicopter time and man-hours per year for hole occupancy monitoring, see NPS SRF protocols for nesting effort estimate.

References: Rice, Ken G., Mazzotti, Frank J., and Brandt, Laura A. 2005. Status and Conservation of Florida Amphibians and Reptiles. Status of the American Alligator (Alligator mississippiensis). Pages 145-153 In W.E. Meshaka and K.J. Babbitt, eds. Status and Conservation of Florida Amphibians and Reptiles. Krieger Publishers, Melbourne, Florida.

Zweig, C.L. 2003. Body condition index analysis for the American alligator. MS Thesis. University of Florida. Gainesville, FL 58pp.

HHH. *Land Birds - residential and migratory*

Which conceptual model(s) is this indicator linked to?

☑ Freshwater Wet Prairies and Marshes ☑ Forest Uplands and Wetlands

☑ Island Interior ☑ Mangroves ☑ Biscayne Bay

Parks where monitoring would be conducted

☑ BICY ☑ BISC ☑ BUIS ☑ DRTO ☑ EVER ☑ SARI ☑ VIIS

Indicator: Land Birds - residential and migratory

Monitoring Question(s): Is abundance and distribution of land birds changing?

Justification: Birds have been shown across many scales to be good indicators for ecosystem health and integrity. Birds are early responders to change across the landscape, responding quickly in foraging and nesting patterns to both habitat degradation and to habitat improvement and restoration. In addition to residential birds, both US Virgin Islands and South Florida are important migratory stop-overs for many bird species and provide over-wintering habitat to some.

Metric: Population abundance and distribution

Method: Point counts (distance sampling) by habitat
Complimented by netting if necessary

Frequency: Quarterly to annual

Timing: Population monitoring during breeding and non-breeding seasons

Scale of Collection: Multiple Parks

Scale of Operation: Regional (incl. areas outside parks)

Scale of Analysis: Multiple Parks

Basic Surveys reflect bird population abundance - requires appropriate timing and

Assumptions:	methodology
Research Needs:	How vegetation changes resulting from hydrologic restoration, exotic species invasions, and fire management alter bird abundance How sea level changes impact coastal forest land birds How natural disturbances (i.e. hurricanes, drought, flooding) impact land birds
Management Goal:	Maintain or increase non-breeding and breeding land bird population levels
Threshold Target:	Partners in flight, NABCI population and habitat objectives
Response:	Reduce impacts of principle stressors: Hydrologic alteration, improved fire management, exotic control, prohibiting/controlling pets in sensitive areas Collaborate with other agencies
Constraints:	Land bird range use is outside park system boundaries Water management control is determined by many competing concerns Fire management restrictions/constraints Precision of the sampling design to estimate populations and costs of high precision sampling design
Status:	Depends on habitat -pinelands is On-going
Estimated Cost:	Consult Gary Slater
References:	Gary Slater, M. Epstein, J. Lorenz, J. Browder, Florida Audubon, Keith Watson

III. *Land birds - Mangrove - population abundance and distribution*

Which conceptual model(s) is this indicator linked to?

☑ Mangroves ☑ Florida Bay ☑ Biscayne Bay

Parks where monitoring would be conducted

☑ BICY ☑ BISC ☑ BUIS ☑ DRTO ☑ EVER ☑ SARI ☑ VIIS

Indicator:	Land birds - Mangrove - population abundance and distribution
Monitoring Question(s):	Is abundance and distribution of land birds in mangroves changing? Do climate change (sea level -rise), invasion by exotic plants (e.g., Schinus) and animals (i.e, Rattus), and/or management activities(i.e., hydrology/fire) affect population trends? How do natural disturbances (i.e, drought, hurricanes) affect population trends?
Justification:	The national parks (coupled with state parks and 10000 Islands NWR) contain some of the largest, most intact tracts of mangrove forest left in North America. However little is known about the ecology of mangrove ecosystems and especially mangrove landbirds, of which several are thought to be at risk of becoming endangered (e.g., White-crowned pigeon and Florida Prairie Warbler). Birds in general have been shown across many scales to be good indicators for ecosystem health and integrity.
Metric:	Avian population abundance (density) and distribution. Measuring habitat variables (vegetation, hydrology) should be collected at regular intervals.

Method:	Three general types of mangrove forest are recognized in this region: riverine forest, fringing forest (including mangrove islands occurring in bays and along the Florida Keys), and basin forests (which lie inland of riverine and fringing forests) (Odum and McIvor 1990). Differences among forest types are mostly due to variation in hydrologic flushing, which leads to differences in nutrient retention and, ultimately, physiognomy. Sampling points should be randomly selected and stratified among these three types of forest to control for this variation. Because we lack a priori information on the density of birds among our strata, we will attempt to locate an equal number of survey points within each stratum. In riverine forests, survey locations will consist of a line of points running longitudinally along tidal creeks. In fringing and basin forests, points will be randomly placed within the available habitat. In all cases, points will be separated by at least 150 m. Results from several years (1999-2003) of avian monitoring at Ten Thousand Island National Wildlife Refuge (Terry Doyle, unpubl. data) provide the basis for much of the methodology. . A pilot study at Ten Thousand Island National Wildlife Refuge revealed that the best time for breeding surveys was between 1 May and 15 June, as detection rates remained uniform over this period, and that 10-minute surveys were appropriate. Each sampling point will be visited once each year and counts will be conducted between sunrise and 10:00AM, as long as weather conditions remain suitable. During the ten-minute survey, observers will note all birds detected and record distances. Each point count should be broken down into 2-minute intervals, with each detected individual occurring within only one interval. Abundance can be measured using the time-of-detection method (Farnsworth *et al*. 2002). Results of this method can then be compared with Distance Sampling, as there are some concerns about the efficacy of using distance sampling in mangrove habitats (Pacifici *et al*., unpublished report). Like distance sampling, the time-of-detection method is an empirical modeling technique that accounts for variation in the detectability of birds at survey points (index-count metrics assume that counts are a consistent proportion of total abundance), but unlike distance sampling it does not require observers to estimate the exact distance to singing birds, which can be both difficult and imprecise. Rather, the time-of-detection method treats point counts like a removal experiment, in which birds are "trapped" (counted) during discrete "trapping sessions" (intervals during the point count) and removed from the population (not counted in subsequent intervals). The decline in numbers "trapped" through time can be used to estimate detectability (via the use of mark-recapture software such as Program SURVIV (White 1983)), which in turn can be used to estimate initial population size, or abundance.
Frequency:	Annual
Timing:	Population monitoring should be conducted during breeding and non-breeding seasons. Some type of monitoring, possible mist-net station, should be considered for migration period.
Scale of Collection:	Multiple Parks
Scale of Operation:	Regional (incl. areas outside parks), Site Specific. Processes may vary among parks(i.e. salinity differences between Florida Bay and Biscayne Bay)
Scale of Analysis:	Regional (incl. areas outside parks), Multiple Parks, Park-wide, Site Specific, Other (Please specify): Assuming sample size is large enough in individual parks.
Basic Assumptions:	Surveys reflect bird abundance
Research Needs:	How bird abundance is influenced through vegetation changes, hydrologic restoration, exotic species invasions, and fire management? How sea level changes impact coastal forest land birds

	How natural disturbances (i.e. hurricanes, drought, flooding) impact land birds
Management Goal:	Maintain or increase non-breeding and breeding land bird population levels
Threshold Target:	Partners in flight, NABCI population and habitat objectives.
Response:	Hydrologic alteration, improved fire management, exotic control
Constraints:	Landbirds should serve as ideal indicator: Parks contain the largest, most intact tracts of mangrove forest left. Fate of many mangrove landbirds is in NPS hands. Birds have been shown across many scales that they are good indicators for ecosystem health and integrity
Status:	Monitoring has been proposed. Lloyd, J. L. and G. Slater. 2006. Proposal to Florida Non-game program. Abundance, population status, and breeding-season habitat requirements of mangrove landbirds in southern Florida. Slater, G. L. and J. L. Lloyd. 2005. Proposal to CESI. Mangrove Landbirds in Everglades and Biscayne National Parks: Status, Distribution, and Habitat Relationships.
Estimated Cost:	For only population surveys during breeding and non-breeding seasons [i.e., no habitat sampling (vegetation, fire history, hydrology), cost for representative surveys >100 points/park (EVER, BICY, BISC ~ $30,000 - $50,000); Costs in Caribbean Parks unknown. Consult: Gary Slater
References:	Gary Slater Department of Interior. 2004. Science plan in support of Everglades restoration, preservation, and protection in south Florida. U.S. Department of Interior, Homestead, FL. Doyle, T. and G. L. Slater. Bird Monitoring Protocol for Mangrove Forest Ecosystems. Farnsworth G.L., K.H. Pollock, J.D. Nichols, T.R. Simons, J.E. Hines, and J. R. Sauer. 2002. A removal model for estimating detection probabilities from point-count surveys. Auk 119:414-25. U.S. Fish and Wildlife Service. 1999. The south Florida multi-species recovery plan: Mangroves. Ecological Services Office, Vero Beach, FL. U.S. Fish and Wildlife Service. 2002. Birds of conservation concern 2002. Division of Migratory Bird Management, Arlington, Virginia, USA. Watson, J. K. 2003. DRAFT - Avian Conservation Implementation Plan, Everglades National Park. National Park Service, Southeast Region.

JJJ. *Landbirds - Pine Rockland - population abundance and distribution.*

Which conceptual model(s) is this indicator linked to?

☑ Forest Uplands and Wetlands

Parks where monitoring would be conducted

☑ BICY ☑ EVER

Indicator:	Landbirds - Pine Rockland - population abundance and distribution.
Monitoring Question(s):	Is abundance and distribution of land birds in pine rocklands changing? Does management activities(i.e., hydrology/fire) affect population trends? How do natural disturbances (i.e, drought, hurricanes) affect population trends?
Justification:	The remaining pine rocklands, an important upland habitat and a globally imperiled ecosystem, are almost entirely found within Everglades National Park and the southeast corner of Big Cypress (with some remnants in the Bahamas). Habitat loss, altered fire regimes and altered hydrologic regimes have contributed to the extirpation of 7 breeding bird species within pine rocklands in Everglades National Park, 5 of which are cavity-nesting species. Efforts are underway to re-establish two of these species (eastern bluebird and brown-headed nuthatch) with hopes of later re-establishing others. Fire management, water management, and invasive species management are anticipated to affect pine rockland species.
Metric:	Avian population abundance (density) and distribution. Measuring habitat variables (vegetation, fire history, hydrology) should be collected at regular intervals.
Method:	Randomly established survey points under the criteria that 1) stations are > 350 m apart, and 2) stations are surrounded by at least 100 m of contiguous pine forest. Based on data that have been collected from bird surveys in the pine rocklands in Florida, 150 survey points allow us to estimate the density of most species with a coefficient of variation (CV) no greater than 20%. Seven-minute surveys will be conducted at each survey station, during which observers will record the radial distance from the sampling station to all birds detected visually or aurally. Surveys will be conducted by trained individuals between sunrise and 10:00AM as long as weather conditions remain suitable. Each station will be visited once per season between 15 April and 1 June (breeding season) and 15 December - 15 February (non breeding season). Using data from point counts, density is estimated using distance-sampling software (Laake *et al*.1994, Buckland *et al*. 2001). Distance sampling is an empirical modeling technique that accounts for variation in the detectability of birds at survey points (index-count metrics assume that counts are a consistent proportion of total abundance). Slater, G. L. 2001. Final Report: Avian Restoration in Everglades National Park: Phase II. Pp 59. National Park Service, Homestead, FL.
Frequency:	Annual, Other (Please specify): At this time it is unclear whether surveys would have to be completed annually. With power analyses, it could easily be determined the sampling needs necessary to detect population changes (this will likely be conducted as part of existing funding)
Timing:	At a minimum, data collection should occur during the breeding and non-breeding seasons. Some consideration should be given to migration surveys. Migrating birds consistently use pine rockland/hardwood hammock ecotones. One possible alternative is to use mist net stations to sample migrating landbirds.
Scale of Collection:	Multiple Parks
Scale of Operation:	Regional (incl. areas outside parks)
Scale of Analysis:	Multiple Parks, Site Specific Inference could be made within parks if sampling intensity high enough within individual parks

Basic Assumptions:	Surveys reflect bird abundance.
Research Needs:	How vegetation changes resulting from hydrologic restoration, exotic species invasions, and fire management alter bird abundance? How natural disturbances (i.e. hurricanes, drought, flooding) impact land birds?
Management Goal:	Maintain or increase non-breeding and breeding land bird population levels?
Threshold Target:	Partners in flight, NABCI population and habitat objectives.
Response:	Improved fire management, hydrologic alteration, exotic control
Constraints:	In general, the majority of pine rocklands are protected by National Parks, thus surveys would effectively sample the south Florida population. Fire management restrictions/constraints Water management control is determined by many competing concerns
Status:	Avian community monitoring in pine rocklands is ongoing in Everglades NP and Big Cypress NP for two objectives: 1) Monitoring reintroduced cavity-nesting populations. Surveys have been conducted in Long Pine Key, EVER (reintroduced site) and Raccoon Point, BICY (high quality reference site) during period 2001 - 2003 and were re-initiated in 2005 with current funding available to continue project through 2007. From 2005-2007 surveys include non-breeding season. 2) Investigate effects of fire management treatments. Surveys began in 2006 and funding will continue through 2009 for two additional sites in Big Cypress (Addition, Stairsteps) and in areas outside NPS lands (Florida Panther Refuge, Miami Dade county). Funding not in place to continue surveys in EVER or in Raccoon Point, BICY (Objective 1) in 2009.
Estimated Cost:	For only population surveys during breeding and non-breeding seasons [i.e., no habitat sampling (vegetation, fire history, hydrology), cost for representative surveys across EVER and BICY would run ~ $30 - 50,000; Consult: Gary Slater
References:	Gary Slater Buckland, S. T., Anderson, D. R., Burnham, K. P., Laake, J. L., Borchers, D. L., and Thomas, L. (2001). Introduction to distance sampling. (Oxford University Press: New York.) Slater, G. L. 2004. Annual Report: Avian Restoration in Everglades National Park: Phase III. Pp 35. National Park Service, Homestead, FL. Slater, G. L. 2001. Final Report: Avian Restoration in Everglades National Park: Phase II. Pp 59. National Park Service, Homestead, FL.

KKK. *Landbirds-Cavity-nesting pine rockland birds - Demographics (Fecundity and Survival)*

Which conceptual model(s) is this indicator linked to?

- [x] Forest Uplands and Wetlands

Parks where monitoring would be conducted

☑ BICY ☑ EVER

Indicator:	Landbirds-Cavity-nesting pine rockland birds - Demographics (Fecundity and Survival)
Monitoring Question(s):	Are vital rates of abundance and distribution of land birds changing? Do management activities (i.e., hydrology/fire) affect vital rates? How do natural disturbances (i.e. el nino-la nina cycles, drought, hurricanes) affect vital rates?
Justification:	This indicator compliments the "Landbirds-pine rocklands-population abundance and distribution" indicator. Habitat loss, altered fire regimes and altered hydrologic regimes have contributed to the extirpation of 7 breeding bird species within pine rocklands in EVER, 5 of which are cavity-nesting bird species. Efforts are underway to re-establish two of these species (eastern bluebird and brown-headed nuthatch) with hopes of later re-establishing others. Fire management, water management, and invasive species management are anticipated to affect these species. Monitoring fecundity and nestling survival provides an early indicator of the habitat quality of a site and causes of change.
Metric:	Fecundity (clutch size, hatching rate, # of young produced, adult and juvenile survivorship). Measuring habitat variables (vegetation, fire history, hydrology) should be collected at regular intervals.
Method:	Slater, G. L. 2004. Final Report: Avian Restoration in Everglades National Park: Phase III. Pp 59. National Park Service, Homestead, FL.
Frequency:	Every 2-3 years, Other (Please specify): or after major weather events/catastrophes
Timing:	Breeding Season (March - June)
Scale of Collection:	Multiple Parks
Scale of Operation:	Regional (incl. areas outside parks), Park-wide, Site Specific (Fire management practices varied among parks (BICY vs. EVER)
Scale of Analysis:	Multiple Parks, Site Specific Inference could be made within parks if sampling intensity high enough within individual parks
Basic Assumptions:	Vital rates reflect habitat condition
Research Needs:	How vital rates (and hence population persistence) are influenced through vegetation changes, hydrologic restoration, exotic species invasions, and fire management? How natural disturbances (i.e. hurricanes, drought, flooding) affect vital rates (and hence population persistence land birds?
Management Goal:	Maintain or increase vital rates at level that insures population persistence.
Threshold Target:	Insufficient knowledge
Response:	Improved fire management, hydrologic alteration, exotic control
Constraints:	As the apparently most vulnerable group of pine rockland landbirds (5 extirpated from EVER), vital rates at levels that insure population persistence should be ideal indicator for this system. Without information on vital rates, understanding population trends is impossible. Birds have been shown across many scales that they are good indicators for ecosystem health and integrity

Status:	Monitoring ongoing for two reintroduced species (Brown-headed Nuthatch, Eastern Bluebird) in Everglades National Park 1997-2003, and 2005. Funding to continue work in place through 2007. In Big Cypress, data available from 1997-2003.
Estimated Cost:	Costs would run ~ $10-15,000 per site (e.g., Long Pine Key); Consult: Gary Slater
References:	Gary Slater Slater, G. L. 2004. Annual Report: Avian Restoration in Everglades National Park: Phase III. Pp 35. National Park Service, Homestead, FL. Slater, G. L. 2001. Final Report: Avian Restoration in Everglades National Park: Phase II. Pp 59. National Park Service, Homestead, FL. Watson, J. K. 2003. DRAFT - Avian Conservation Implementation Plan, Everglades National Park. National Park Service, Southeast Region.

LLL. *Colonial Nesting Birds (e.g., Least terns, pelicans, boobies, roseatte terns, egrets, storks, herons)*

Which conceptual model(s) is this indicator linked to?

☑ Freshwater Wet Prairies and Marshes ☑ Forest Uplands and Wetlands

☑ Island Interior ☑ Mangroves ☑ Florida Bay

Parks where monitoring would be conducted

☑ BICY ☑ BISC ☑ BUIS ☑ DRTO ☑ EVER ☑ SARI ☑ VIIS

Indicator:	Colonial Nesting Birds (e.g., Least terns, pelicans, boobies, roseatte terns, egrets, storks, herons)
Monitoring Question(s):	Are population sizes, nest success, and distribution of wading birds and sea birds changing? Effects of contaminants if appropriate to the species?
Justification:	The status of colonial nesting bird colonies, their size and nesting success, reflect the amount and quality of fish and/or invertebrates available in the surrounding landscape/seascape, plus the quality of habitat and freedom from predators in the immediate nesting areas. They also bioaccumulate certain contaminants in their feathers, blood, and eggs. Because of their sensitivity to landscape health, fishery health, and contaminants, colonial nesting birds are almost all either federal or state threatened species, endangered species or species of special concern.
Metric:	Nesting Population size, nesting success/recruitment, distribution Contaminants if a locality/species concern
Method:	Aerial/ground/boat rookery surveys-nest success, numbers of nests, number of adults Feather/blood samples if contaminants are a concern
Frequency:	Every Year - Weekly during nesting season. Monthly to determine when nesting season begins
Timing:	Monthly year-round. Then increased to weekly during nesting season.
Scale of Collection:	Regional (incl. areas outside parks), Multiple Parks, Site Specific

Scale of Operation:	Site Specific
Scale of Analysis:	Regional (incl. areas outside parks), Multiple Parks, Park-wide, Site Specific
Basic Assumptions:	Success of nesting colonies and recruitment of juveniles into the breeding colony are related to habitat quality, availability of prey base, invasive species, water management and extreme weather system impacts
Research Needs:	Movement patterns Recruitment Distribution Foraging As our fishery improves due to Marine Protected Area status, does this in turn result in improvement in population growth, # of chicks fledging As our water management in south Florida improves, does this in turn result in improvement in population growth, # of chicks fledging
Management Goal:	Maintain or increase average bird population levels, have birds reestablish rookeries in traditional areas where they are currently absent
Threshold Target:	To be determined. Since many of these are Federal T & E species, this requires consultation with US Fish and Wildlife Service
Response:	Pest control around nesting locations Habitat enhancement Water management alterations
Constraints:	Manpower limited
Status:	On-going Note: The Comprehensive Everglades Restoration Plan has "System-Wide Wading Bird Nesting Patterns" as a CERP Interim Goals Indicator and monitoring variables in the CERP Monitoring and Assessment Plan.
Estimated Cost:	Dependent on numbers of populations
References:	Judy Pierce (DPN-Div of Fish and Wildlife), Sony Bass (EVER), Gary Slater (BICY)

MMM. *Wading birds - Regional South Florida - Systematic Reconnaissance Flights*

Which conceptual model(s) is this indicator linked to?

☑ Freshwater Wet Prairies and Marshes ☑ Forest Uplands and Wetlands

☑ Island Interior ☑ Mangroves

Parks where monitoring would be conducted

☑ BICY ☑ EVER

Indicator:	Wading birds - Regional South Florida - Systematic Reconnaissance Flights
Monitoring Question(s):	Are population sizes and distribution of wading birds changing?

Justification:	This indicator compliments the "colonial nesting birds" indicator but is applicable to Everglades National Park and Big Cypress parks only. As Everglades, Big Cypress and the surrounding landscape are such large areas, the Systematic Reconnaissance Flights program provides a regional estimation of populations in south Florida that compliments rookery surveys but is more cost-effective across such wide areas. Wading bird abundance and distribution reflect the amount and quality of fish and/or invertebrates available in the surrounding landscape/seascape, the quality of habitat and freedom from predators in the immediate nesting areas, and contaminant levels. Because of their sensitivity to watershed health, and contaminants, native wading birds are almost all Florida species of special concern with wood storks listed as federally endangered.
Metric:	Abundance and distribution
Method:	Systematic Reconnaissance Flight (SRF) wading bird survey -population monitoring via 500m airplane belt transects
Frequency:	Annual, Conducted annually December-May and October
Timing:	Population monitoring during wet and dry periods
Scale of Collection:	Regional (incl. areas outside parks)
Scale of Operation:	Regional (incl. areas outside parks)
Scale of Analysis:	Regional (incl. areas outside parks), Multiple Parks, Park-wide
Basic Assumptions:	Wading bird populations and recruitment are related to hydrology
Research Needs:	Movement patterns
Management Goal:	Maintain or increase average wading bird population levels, have wading birds reestablish rookeries in traditional areas where they are currently absent
Threshold Target:	Insufficient knowledge
Response:	Hydrologic alteration toward more natural system conditions
Constraints:	Wading bird range use extends outside park system boundaries Water management control is determined by many competing concerns
Status:	On-going Note: The Comprehensive Everglades Restoration Plan has "System-Wide Wading Bird Nesting Patterns" as a CERP Interim Goals Indicator and monitoring variables in the CERP Monitoring and Assessment Plan.
Estimated Cost:	annual cost for EVER $40000
References:	Sonny Bass, Jerry Lorenz. Marilyn Spalding, Peter Frederick

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NNN. *Bats - USVI*

Which conceptual model(s) is this indicator linked to?

☑ Island Interior ☑ Mangroves

Parks where monitoring would be conducted

☑ BUIS ☑ SARI ☑ VIIS

Indicator:	Bats - USVI
Monitoring Question(s):	Are changes occurring in bat populations, foraging activity levels, and bat roosting locations with special attention to the red fruit bat, Stenoderma rufum (the rarest bat in the USVI), and the fisherman bat, Noctilio leporinus ?
Justification:	Six bat species are the only native terrestrial mammals in the U.S. Virgin Islands. Although none are locally endemic, four are listed as "Species of Greatest Concern" in the Comprehensive Wildlife Strategy for the U.S. Virgin Islands. Their role in local plant pollination and effects on local insects and fish populations are unclear but could be important.
Metric:	Roost locations and roost population counts Relative activity levels
Method:	Location of bat roosts and counts of adults leaving roosts Use of ANABAT system to establish relative activity levels in foraging areas and water areas. Mist netting used to confirm species identification.
Frequency:	Annual, Initially ever year for first 4-5 years to create baseline, then reduce frequency to once every 2-5 years as appropriate depending on data variability.
Timing:	To Be determined
Scale of Collection:	Regional (incl. areas outside parks), Multiple Parks, Park-wide, Site Specific
Scale of Operation:	Park-wide, Site Specific
Scale of Analysis:	Park-wide, Site Specific
Basic Assumptions:	Any use of ANABAT assumes that bat species and calling frequency can be related to the species and activity levels. This must either be based on previous work or by coupling mist-netting and/or roost searches with Anabat work.
Research Needs:	Research needed into roosting preferences, dietary activities, and habitat requirements of bats with special focus on Stenoderma rufum and Noctillio. Other research needed is their role in plant distribution and pollination.
Management Goal:	Maintain populations that roost within park boundaries and contribute to maintenance of bat populations that forage within the park but roost outside boundaries.
Threshold Target:	Insufficient knowledge
Response:	Protection of roosts. Other actions likely related to maintenance of plants or prey base the bats forage upon.
Constraints:	Roosts for bat populations in Buck Island Reef National Monument and Salt River Bay National Historical Park and Ecological Reserve may be outside park boundaries although this is unknown at this point.

Researchers who handle bats (i.e. during mist-netting activities) should be vaccinated against rabies.

Status: No ongoing bat monitoring is occurring. An NPS-funded inventory was conducted using ANABAT SONAR in 2001 but no roost surveys were conducted. Results are pending.

"Previous studies of bats in the USVI include anecdotal comments on their identification, distribution, and ecology (e.g., Starrett 1962, Koopman 1975), studies on the ecology, behavior, and physiology of the Cave Bat (Bond and Seaman 1958, Nellis 1971, McManus and Nellis 1972, Ehle 1977, Nellis and Ehle 1977) and Fruit Bat (Ehle 1977), and the evaluation of bat detectors and radio tracking for studying bats (Knowles 1992a, b). Recent surveys have been conducted on St. John (Gannon 2003) and St. Croix (G. Kwiecinski, pers. comm.). Efforts are underway through IRF and the University of Scranton to initiate inventory and population studies of bats on the northern USVI." (from Comprehensive Wildlife Strategy for the U.S. Virgin Islands, 2005, http://www.vifishandwildlife.com/Wildlife/05F01WildlifePlan/Part%201%20Introduction/table%20of%20contents.htm)

Estimated Cost: Approx. $40-80,000 per sampling year (???)

References: U.S. Virgin Islands Department of Planning and Natural Resources Division of Fish and
Wildlife. 2005. Comprehensive Wildlife Conservation Strategy for the U. S. Virgin Islands. June 1. 2005. 216 pages. URL: http://www.vifishandwildlife.com/Wildlife/05F01WildlifePlan/Part%201%20Introduction/table%20of%20contents.htm

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OOO. *Florida panther*

Which conceptual model(s) is this indicator linked to?

☑ Forest Uplands and Wetlands

Parks where monitoring would be conducted

☑ BICY ☑ EVER

Indicator: Florida panther

Monitoring Question(s): What is the abundance and distribution of Florida Panthers? How is it changing over time?

Justification: Florida panthers are a top predator in the south Florida region, whose primary prey are deer, but also include large fish, birds, feral hogs, etc. They are a federally endangered species that has been impacted by habitat loss and fragmentation, roadkill, contaminant bioaccumulation, and genetic bottlenecks. This sub-species is currently found only in south Florida. Big Cypress, neighboring state lands, and portions of Everglades are key areas for its conservation and recovery. Monitoring information is used to assess population status and trends and distribution information is used to inform park management about potential impacts of visitor use activities and management activities on panther distribution and relative activity

	levels.
Metric:	Population abundance and distribution
Method:	Capture, radio-telemetry, remote-camera surveys, scat survey
Frequency:	Every 2 years
Timing:	Scat surveys during dry season, radio-telemetry any time, remote-camera any time probably spring
Scale of Collection:	Regional (incl. areas outside parks)
Scale of Operation:	Regional (incl. areas outside parks)
Scale of Analysis:	Regional (incl. areas outside parks)
Basic Assumptions:	
Research Needs:	Panther kitten survival and dispersal
Management Goal:	Maintain or increase panther population levels
Threshold Target:	Consult Florida Panther Recovery plan (USFWS)
Response:	Dependent upon identified cause
Constraints:	Panther range use extends outside park system boundaries Private land development issues
Status:	Radio-telemetry On-going Some camera survey work ongoing, needs to be expanded
Estimated Cost:	
References:	Darrel Land (FFFWC), Sonny Bass, Deb Jansen

PPP. *Visitor Use (Both commercial and individual/personal use)*

Which conceptual model(s) is this indicator linked to?

☑ Freshwater Wet Prairies and Marshes ☑ Forest Uplands and Wetlands ☑ Island Interior ☑ Mangroves ☑ Florida Bay ☑ Biscayne Bay ☑ Coastal Shelf/Deep Oceanic

Parks where monitoring would be conducted

☑ BICY ☑ BISC ☑ BUIS ☑ DRTO ☑ EVER ☑ SARI ☑ VIIS

Indicator:	Visitor Use (Both commercial and individual/personal use)
Monitoring Question(s):	How do people use the park? How many? Where? When? What are the impacts of these individual activities? Are these activities impairing the integrity of the ecosystem?
Justification:	Parks must provide for both the enjoyment of the resources by the public coupled with conservation of the resources for future generations. However, visitor use, if unmanaged, can impact and alter resources in unsustainable ways. Being able to relate visitor use to impacts on resources helps management to meet both these park objectives.
Metric:	Activities Demographics Person days Spatial Distribution/ Density Numbers of people/cars/boats - both commercial and private
Method:	Surveys (sociological, aerial, etc) Questionnaire Census Counts Model development and use Commercial operator numbers
Frequency:	Continuous: for visitation, other survey may be less frequent
Timing:	Year-round, stratified weekdays, weekends, night, holidays
Scale of Collection:	Multiple Parks
Scale of Operation:	Regional (incl. areas outside parks), Multiple Parks, Park-wide, Site Specific
Scale of Analysis:	Regional (incl. areas outside parks), Multiple Parks, Park-wide, Site Specific
Basic Assumptions:	Monitoring reflects the population- appropriate timing and methodology Complex Dimensions
Research Needs:	N/A

Management Goal:	Ensure that activities aren't impairing the integrity of the ecosystem Optimize visitor experience over time
Threshold Target:	Insufficient Knowledge
Response:	Reduce impacts of principal stressors: Collaborate with other agencies Internal response- regulate human activities if impairment is identified
Constraints:	OMB
Status:	Ongoing, needs improvement
Estimated Cost:	Park specific- based on last year visitation numbers ~$0.50-$1.00/person
References:	Contact: G. Mackless (NPS), B. Leeworthy, Bhat, FIU, NOAA NOS, Alyse Getty NPS Contractor - Parsons

QQQ. *Land Development inside/outside the park (within 5 mile radius for USVI parks, radius may be expanded to 75 miles in South Florida)*

Which conceptual model(s) is this indicator linked to?

☑ Freshwater Wet Prairies and Marshes ☑ Forest Uplands and Wetlands ☑ Island Interior ☑ Mangroves ☑ Florida Bay ☑ Biscayne Bay ☑ Coastal Shelf/Deep Oceanic

Parks where monitoring would be conducted

☑ BICY ☑ BISC ☑ BUIS ☑ DRTO ☑ EVER ☑ SARI ☑ VIIS

Indicator:	Land Development inside/outside the park (within 5 mile radius for USVI parks, radius may be expanded to 75 miles in South Florida)
Monitoring Question(s):	How do activities outside the park affect the park? Development-Municipal, private, commercial Land Use Agricultural Point Source Pollution Roads/habitat fragmentation Utilities Lighting & noise
Justification:	With increasing development both within and outside of the parks there is an urgent need to identify land use changes that could impact the park, changes in the size of the non-urban buffer area around park boundaries, as well as changes in connectivity with other conserved natural areas. All of these changes have a significant impact upon park resources. Monitoring of changes over time would allow parks to understand the effects of these changes and to take appropriate actions to mitigate impacts.
Metric:	Activities Demographics Spatial Distribution/ Density Landscape Change
Method:	Cooperation with other agencies/NGO's (data-mining) Surveys (sociological, aerial, etc) Census Model development and use Aerial photography Combined with local zoning information Permit review by NPS
Frequency:	5-10 years based on management review cycle
Timing:	As data becomes available
Scale of Collection:	Regional
Scale of Operation:	Regional
Scale of Analysis:	Regional

Basic Assumptions:	Monitoring reflects the population- appropriate timing and methodology Complex Dimensions Habitat conversion/development within the parks and up to 5 miles away from parks (75 miles in S. Florida) will impact the park resources
Research Needs:	Uncertainty of known protocol
Management Goal:	Understand how outside activities are affecting the park Optimize visitor experience over time Have USVI go to one tier Coastal Zone Management system
Threshold Target:	NA
Response:	Park management is responsive and aware to outside influences
Constraints:	Dependence on outside agencies/organizations for data, management, and response
Status:	Ongoing, needs improvement
Estimated Cost:	NA
References:	Contact: Census Bureau, County Records, State, Federal, NGO's, Army Corps, DEP, FWC, USDA, Dept of Commerce

APPENDIX P

VITAL SIGNS STRATEGIES

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Vital Signs: Air Quality-Deposition, Air Quality-Mercury

[Shortened name: Air_Quality]

Parks Where Vital Sign will be Implemented & SFCN role:
EVER, VIIS – SFCN gathers data from other groups & analyzes

Justification/Issues being addressed: Good air quality is important for both human and ecosystem health. South Florida parks have serious problems with mercury toxicity which primarily comes from aerial deposition. Virgin Island parks have challenges with African dust and volcanic eruptions that decrease air quality to the extent that asthma cases rise among children during these events. Both South Florida and Virgin Islands parks are experiencing rapid urbanization with associated rises in aerial pollutants such as atmospherically deposited nitrogen. The NPS-Air Resources Division is working with the Inventory and Monitoring program to achieve reporting of air quality across NPS parks. As both EVER and VIIS receive funding for air quality monitoring from the NPS – Air Resources Division and both parks have goals regarding air quality, SFCN added air quality to the list of vital signs. This vital sign compliments the mercury monitoring in pig frogs in the Amphibians vital sign.

General Monitoring Questions:

- What are the status, trends, and episodic events in air quality in SFCN parks, as measured by wet and dry deposition?
- What are the status and trends in mercury deposition?

Measures:
Wet/dry deposition of anions, cations, mercury

Basic Approach:
If the NPS-ARD program or park staff produce reports of air quality trends by park, SFCN will merely summarize those reports and post the reports or links on the web page.

Otherwise, SFCN will gather data from the EVER and VIIS air quality monitoring stations from the National Atmospheric Deposition Program/National Trends Network (NADP/NTN) network (http://nadp.sws.uiuc.edu), the Mercury Deposition Network at EVER (MDN; http://nadp.sws.uiuc.edu/mdn/), Clean Air Status and Trends Network (CASTNet; http://www.epa.gov/castnet/) (Note: CASTNet station at VIIS discontinued in 2004), and analyze the data for trends.

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- Kevin Kotun, Physical Scientist, Everglades National Park, 305-242-7829, Kevin_Kotun@nps.gov

Development Schedule, Budget, and Expected Interim Products:
By the end of 2011, SFCN will work to place summaries on the SFCN public web page and intranet page. Estimated time required: 1-3 weeks with a combination of Quantitative Ecologist and support staff.

Expected SFCN staff time requirements once program is fully implemented in 5 years:

SFCN Staff	Full Time Equivalent (FTE)
Coordinator	
Marine Ecologist	
Fisheries Biologist	
Marine Biologist Technician (So FL)	
Marine Biologist Technician (VI)	
Community Ecologist	
Wildlife Technician (Wildlife)	
Wildlife Technician (Vegetation)	
Quantitative Ecologist	0.01
Data Manager	
GIS/Data Tech	
Interns	0.02
SFCN Total	0.03

Vital Sign: American Alligator

[Shortened name: Alligator]

Parks Where Vital Sign will be Implemented:
BICY, EVER – SFCN summarizes reports of existing program

Justification/Issues being addressed: The American Alligator ranked 22nd among the 44 SFCN vital signs. The American Alligator is considered an ecosystem engineer in the Greater Everglades due to its role in maintaining alligator holes (aquatic refugia in the dry season). Additionally, it is a top predator and can influence many other species. Alligators have been monitored as a keystone species in the Everglades over the last 20 years. Scientists have linked alligator population dynamics to resource management activities, especially to water management.

General Monitoring Questions to be Addressed by the Vital Sign:

- What are the status and trends in the relative distribution, abundance, body condition, alligator hole occupancy, nesting level, and demographic structure of alligators in various habitats in relation to water levels in EVER and BICY? How do these variables change during CERP/MOD Waters Everglade's restoration implementation?

Measures:
Animals/km, Sex ratio, Size distribution, Body condition index, Alligators per hole, Nests/km^2

Basic Approach:
At EVER and BICY alligators are being monitored as a CERP RECOVER Monitoring and Assessment Program (MAP) project. This project uses a variety of sampling methodologies including: nightlight surveys to estimate densities, capture-recapture sampling for body condition and survivorship, nest survey for fecundity, and hole occupancy. This project generates reports that will be reviewed and summarized by the SFCN Wildlife Technician.

Principal Investigators/Key Contacts and NPS Lead:

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- Kenneth G. Rice, United States Geological Survey, ken_g_rice@usgs.gov, (352) 264-3544
- Frank Mazzotti, University of Florida, fjma@ufl.edu, 954-577-6304

Development Schedule, Budget, and Expected Interim Products:
Summarizing the annual report is expected to take about 1 week of SFCN Wildlife Technician time. This indicator should begin in 2009. Table indicates proposed SFCN workload upon full monitoring implementation.

Expected SFCN staff time requirements once program is fully implemented in 5 years:

SFCN Staff	Full Time Equivalent (FTE)
Coordinator	
Marine Ecologist	
Fisheries Biologist	
Marine Biologist Technician (So FL)	
Marine Biologist Technician (VI)	
Community Ecologist	
Wildlife Technician (Wildlife)	0.01
Wildlife Technician (Vegetation)	
Quantitative Ecologist	
Data Manager	
GIS/Data Tech	
Interns	
SFCN Total	0.01

Vital Sign: American Crocodile

[Shortened name: Crocodile]

Parks Where Vital Sign will be implemented:
BISC, EVER – SFCN summarizes reports of existing program

Justification/Issues being addressed: The American Crocodile ranked 21st among the 44 SFCN vital signs. The American Crocodile is a top predator within the estuarine ecosystem. Crocodile population dynamics have been linked to resource management activities, especially water management which has resulted in increased salinities in both South Florida estuaries, Biscayne Bay and Florida Bay. Habitat alteration and conversion along western Biscayne Bay, disturbance, and road kill are also issues. Crocodiles, which are listed as a threatened species under the Federal Endangered Species Act, have core nesting areas in Biscayne Bay and Florida Bay.

General Monitoring Questions to be Addressed by the Vital Sign:

- What are the status and trends in the relative distribution, abundance, nesting effort and success, body condition, demographic structure, growth and survival of crocodiles in relation to water levels and salinities throughout mangrove estuaries of EVER and BISC? How do these change during CERP/MOD Waters Everglade's restoration implementation?

Measures
Animals/ shoreline km, nests/region, size distribution, body condition, annual survival, increase in body length

Basic Approach:
At EVER and BISC crocodiles are being monitored as a CERP RECOVER Monitoring and Assessment Program (MAP) project. This project uses a variety of sampling methodologies including, nightlight surveys to estimate densities, capture-recapture sampling for body condition and survivorship, and nest survey for fecundity. This project generates reports that will be reviewed and summarized by the SFCN Wildlife Technician.

Principal Investigators/Key Contacts and NPS Lead:

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- Kenneth G. Rice, United States Geological Survey, ken_g_rice@usgs.gov, (352)264-3544
- Frank Mazzotti, University of Florida, fjma@ufl.edu, 954-577-6304

Development Schedule, Budget, and Expected Interim Products:
Summarizing the annual report is expected to take about 1 week of SFCN staff time by the SFCN Wildlife Technician. This indicator should begin in 2009. Table indicates proposed SFCN workload upon full monitoring implementation.

Expected SFCN staff time requirements once program is fully implemented in 5 years:

SFCN Staff	Full Time Equivalent (FTE)
Coordinator	
Marine Ecologist	
Fisheries Biologist	
Marine Biologist Technician (So FL)	
Marine Biologist Technician (VI)	
Community Ecologist	
Wildlife Technician (Wildlife)	0.01
Wildlife Technician (Vegetation)	
Quantitative Ecologist	
Data Manager	
GIS/Data Tech	
Interns	
SFCN Total	0.01

Vital Sign: Amphibians

[Shortened name: Amphibians]

Parks Where Vital Sign will be Implemented:
BICY, EVER, VIIS – SFCN implements monitoring
BISC, SARI - Deferred

Justification/Issues being addressed: Amphibians ranked 25th among the 44 SFCN vital signs. Amphibians comprise a large amount of the resident vertebrate biomass and generally are a strong intermediate link in the food web. Amphibians have been used as a biological indicator for many environmental variables and are sensitive to changes in breeding habitat quality, invasive species, and contaminants. At VIIS, the native frog species are strongly tied to water resources for reproduction. The white-lipped frog (*Leptodactylus albilabris*) has a tadpole stage and the other two species, Antillean frog (*Eleutherodactylus antilliensis*) and whistling frog *(Eleutherodactylus cochranae)*, utilizing moist vegetation for egg laying with direct development to the froglet stage. Additionally, these frogs typically exploit the numerous tank bromeliads for daytime refugia. There are a number of exotic species that may be out competing and preying upon native fauna such as the Cuban treefrog (*Osteopilus septentrionalis*). In EVER and BICY, the pig frog, *Rana grylio*, is a dominant anuran within the freshwater marsh lands and makes up a large amount of the vertebrate biomass. It is both a prey source and a major predator. The pig frog life cycle (eggs-tadpoles-adults) is strongly related to marsh hydrology. Shifts in pig frog population structure have been shown to be related to water management. Additionally, pig frogs bioaccumulate mercury and currently are being monitored by the State of Florida (FWRI) for mercury levels. Previous amphibian monitoring within these parks has documented exotic species immigration and shifts in population structures of native species due to exotic species. Community composition of the amphibian species community has been related to habitat type within these park units. Presumably, amphibian community composition and proportion of area occupied (PAO) will have a quick reaction to management actions.

Note: A SFCN funded herpetofauna inventory found no amphibians at BUIS so this vital sign is assumed to not be relevant for that park unit. Monitoring at BISC and SARI is deferred due to lack of funds.

General Monitoring Questions to be Addressed by the Vital Sign:

- What are the status and trends in the distribution, abundance (or occupancy), and community composition of native and non-native amphibian species?
- What are the status and trends in pig frog demographic structure, especially in relation to water levels and CERP/MOD Waters Everglades restoration?
- What are the status and trends in mercury accumulation in pig frogs?

Measures:
Proportion of area occupied, distribution, community composition, population structure, total mercury content

Basic Approach:
SFCN will develop an "Amphibians" protocol to monitor amphibians at BICY, EVER, and VIIS. BISC and SARI are deferred. The protocol will build on the inventory work already completed. The protocol is further detailed in Appendix P. The primary parts of the protocol include:

1) At VIIS, EVER and BICY amphibians will be monitored in areas near roads and trails with Visual Encounter Surveys (VES), call surveys and tree pipes by developing a proportion of area occupied (PAO) methodology similar to the ARMI inventory protocol methods used in these parks (Rice *et al*., 2004, 2005a, 2005b) . Current funding levels are insufficient to attempt monitoring away from roads and trails, especially in areas accessible only by helicopter

2) In EVER and BICY SFCN will collect grab samples of pig frogs to determine size structure of populations, sex ratios, and juvenile to adult ratios. This sampling will build upon previously existing research.

3) SFCN will coordinate with the State of Florida mercury monitoring program. SFCN goal is to include pig frogs from EVER and BICY in the states regional assessments.

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Development Schedule, Budget, and Expected Interim Products:
The Community Ecologist and the two wildlife technicians will conduct sampling about 9 weeks of the year and 2 weeks of data entry and reporting. Additional costs are minimal: mostly for travel and some beginning equipment. However SFCN will need to evaluate the feasibility of the mercury analyses if the State of Florida does not cover the costs as these are generally expensive samples ($100.00 each). The protocol development should be completed by 2012 and begun 2013. Table indicates proposed SFCN workload upon full monitoring implementation.

Expected SFCN staff time requirements once program is fully implemented in 5 years:

SFCN Staff	Full Time Equivalent (FTE)
Coordinator	
Marine Ecologist	
Fisheries Biologist	
Marine Biologist Technician (So FL)	
Marine Biologist Technician (VI)	
Community Ecologist	0.15
Wildlife Technician (Wildlife)	0.15
Wildlife Technician (Vegetation)	0.15
Quantitative Ecologist	0.04
Data Manager	0.04
GIS/Data Tech	0.02
Interns	
SFCN Total	0.55

References:

Rice, K. G., J.H. Waddle, M.E. Crocket, B. M. Jeffrey, and H. F. Percival. 2004. Herpetofaunal Inventories of the National parks of South Florida and the Caribbean: Volume I. Everglades National Park. U.S. Geological Survey, open-File Report 2004-1065, Fort Lauderdale, Florida.

Rice, K. G., J.H. Waddle, M.E. Crocket, B. R. R. Carthy, and H. F. Percival. 2005a. Herpetofaunal Inventories of the National parks of South Florida and the Caribbean: Volume II. Virgin Islands National Park. U.S. Geological Survey, open-File Report 2005-1301, Fort Lauderdale, Florida.

Rice, K. G., J.H. Waddle, B. M. Jeffrey, A.N. Rice, and H. F. Percival. 2005b. Herpetofaunal Inventories of the National parks of South Florida and the Caribbean: Volume III. Big Cypress National Preserve. U.S. Geological Survey, open-File Report 2005-1300, Fort Lauderdale, Florida.

Vital Sign: Aquatic invertebrates in wet prairies & marshes

[shortened name: Wetland_Aquatic_Inverts]

Parks Where Vital Sign will be Implemented:
BICY - SFCN conducts monitoring (NW corner only)
BISC, EVER, VIIS – Deferred due to insufficient funds

Justification/Issues being addressed: Aquatic invertebrates in wet prairies & marshes ranked 32nd among the 44 SFCN vital signs. Aquatic invertebrate communities reflect water quality and hydrology (water depth, timing, duration, quantity) and are frequently used in indices (e.g., Macroinvertebrate Biological Integrity Index (MBI)) as early warning response indicators of change. These invertebrates are the prey base for fish, large macro-invertebrates (e.g., crayfish), herpetofauna, and wading birds in the Greater Everglades and Big Cypress ecosystems. Water diversions and altered water management practices have changed aquatic invertebrate community composition and abundance. CERP will rehabilitate system hydrology and water quality, which should affect aquatic invertebrate communities and consequently higher trophic levels.

General Monitoring Questions to be Addressed by the Vital Sign:

- What are the status and trends in aquatic invertebrate community composition and structure especially in relation to hydrological patterns and water quality in the wet prairies and marshes?

Measures:
Community composition, abundance (density and relative abundance), MBI

Basic Approach:
This indicator will only be implemented in areas where SFCN is otherwise collecting fish and periphyton data, i.e. northwestern BICY. SFCN will develop the protocol "Freshwater fish, invertebrates, and periphyton" to describe monitoring in that area. A pilot study is needed to determine the range of variability in aquatic invertebrates (as well as periphyton) in the area and estimate appropriate sample sizes. SFCN technicians will separate out the aquatic invertebrates from the periphyton, identify the species where possible, and count them.

Some existing monitoring may be occurring as part of the freshwater fish monitoring in Everglades. If so, SFCN will see if summaries of reports can be added to the SFCN web page.

Principal Investigators/Key Contacts and NPS Lead:

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- Robert Shufford, SFWMD, Everglades Division, (561) 681-2500 x4579, rshufor@sfwmd.gov
- Richard E. Jacobsen, USGS, EVER Field Station, 305-242-7313, rjacob@usgs.gov

Development schedule, budget, and expected interim products:

This vital sign will be developed and implemented in concert with the freshwater fish and large macro-invertebrates vital sign. The "Freshwater fish, invertebrates and periphyton" protocol design will occur in 2008-2010 in concert with the freshwater fish and macroinvertebrate monitoring with implementation in 2011 in Big Cypress and Biscayne National Parks only. About 75 samples per year are assumed in Big Cypress for planning purposes, although pilot studies have not been done to estimate sample sizes. Little additional field time is needed for invertebrate collection as it is done in concert with freshwater fish and periphyton monitoring. Assuming 2 hours per invertebrate sample for analysis and data entry, this indicator will take about 4 weeks of a technician's time to analyze the samples. Costs include dissecting scopes, alcohol, sampling bottles & other miscellaneous scope equip (forceps, etc).

Expected SFCN staff time requirements once program is fully implemented in 5 years:

SFCN Staff	Full Time Equivalent (FTE)
Coordinator	
Marine Ecologist	
Fisheries Biologist	
Marine Biologist Technician (So FL)	
Marine Biologist Technician (VI)	
Community Ecologist	
Wildlife Technician (Wildlife)	0.04
Wildlife Technician (Vegetation)	0.03
Quantitative Ecologist	
Data Manager	
GIS/Data Tech	
Interns	
SFCN Total	0.07

Vital Sign: Bats-USVI

[shortened name: Bats] Deferred

Parks Where Vital Sign will be Implemented:
BUIS, SARI, VIIS – Deferred due to insufficient funds

Justification/Issues being addressed: Bats-USVI ranked 39th among the 44 SFCN vital signs. Six bat species are the only native terrestrial mammals in the USVI. Although none are locally endemic, four are listed as "Species of Greatest Concern" in the Comprehensive Wildlife Strategy for the USVI. Their role in local plant pollination and effects on local insects and fish populations are unclear but could be important.

General Monitoring Questions to be addressed by the Vital Sign:

- What are the status and trends in bat species abundance and bat roosting locations including the red fruit bat, *Stenoderma rufum*, and the fisherman bat, *Noctilio leporinus?*

Measures:
Roost locations, roost population counts, relative activity levels

Basic Approach:
Deferred due to insufficient funding/staff time. If Virgin Islands National Park hires staff who can implement this monitoring, SFCN staff can assist in designing an appropriate monitoring protocol.

Principal Investigators/Key Contacts and NPS Lead:
N/A

Development schedule, budget, and expected interim products:
N/A

Vital Sign: Benthic Communities Extent & Distribution

[shortened name: Benthic_Mapping]

Parks Where Vital Sign will be Implemented:
BISC, BUIS, DRTO, EVER, SARI, VIIS

Justification/Issues being addressed: Benthic Communities Extent & Distribution ranked 23rd among the 44 SFCN vital signs. The extent, distribution, and composition of major benthic communities (e.g., hardbottom, soft-bottom, dense Thallasia sp. seagrass, sparse seagrass, etc.) across bays and marine areas influence the fish, invertebrate, and larger vertebrate communities (e.g., sea turtles, manatees) they support. Benthic communities can change with alterations in location, quantity and quality of freshwater and sediment inputs (e.g., CERP), nutrient levels, major storm events, and heavy visitor use (e.g., repeated boat groundings, scarring, and anchoring damage). Analysis of remotely-sensed data provides the spatial extent and composition of major benthic communities across relevant areas of marine parks allowing tracking of changes in large-scale patch size and shape at a broader scale than site-specific studies.

This vital sign, which is focused on mapping of communities using remote sensing, compliments the Marine Benthic Communities vital sign which involves field monitoring using divers to assess the community composition and health.

General Monitoring Questions to be Addressed by the Vital Sign:

- What is the extent and distribution of marine benthic communities and how are they changing?

Measures:
Extent, distribution, and characterization of benthic community types using remote sensing.

Basic Approach:
If funds are available, the SFCN marine ecologist will contract on a decadal frequency interval or event dependent (in response to a major natural disaster) to map SFCN marine park areas in rotation. Mapping will be accomplished using a combination of data sets, including imagery (plane or satellite based), bathymetry (derived from SONAR or LIDAR), and ground truthing via SCUBA or drop cameras/Remotely Operated Vehicles. These three data sets are to be homogenized into a single map theme which will consist of a structure/cover classification scheme based on a nested hierarchy using a proven classification system that enables the map product to mesh with other mapping activities in the area.

Ground-truthing should occur the same year the image capture occurs to ensure both

data sets represent the benthos at that time. Two anticipated problems that could be mitigated by appropriately timed ground-truthing are as follows: drift algae in seagrass beds could provide for a confusing signature if the seagrass was sparse but the algae made it look dense; and colonial zooanthids can be confused with corals from imagery as well as distant observations, and may require SCUBA reconnaissance to ensure proper classification. The ground-truthing information will assist with ensuring classification accuracy and help with training the contractor with known signatures of fixed points that would correspond to the image/data source for the spatial data layer.

Accuracy assessments will be performed by either SFCN staff, host park staff, contractors, or other cooperators.

SFCN staff will use spatial analysis techniques to look for areas of change across the benthos. Shifts in size and/or density of features will be the primary focus of analysis.

Principal Investigators/Key Contacts and NPS Lead

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- FWRI, Henry "Harry" Norris, (727) 896-8626
- NOAA, Mark Monaco, (301) 713-3028
- USGS, John Brock, (727) 803-8747 x3088

Development Schedule, Budget, and Expected Interim Products:

Mapping efforts are underway for BISC and DRTO. Florida Bay was completed in 2004. BUIS and VIIS mapping is in progress. SARI has not been mapped for benthic habitats and this is needed. West Everglades was evaluated in Spring 2007 during which it was found that seagrass was sparse along the western coast of EVER--this may have been due to Wilma sediment movement or it may have always been sparse. Due to the impacts of Hurricane Wilma in 2005, West Everglades coast will be reevaluated within the next five years. Budget is size and scale dependant, as well as technology driven. Aerial and/or Satellite imagery is generally used for the base map for shallow areas, while LIDAR or acoustic sensors may be necessary to map deeper features or in areas of high turbidity. Typical project budgets can run from <$100K to $500K depending on size of area and mapping scale. Funds may be available in the future from the National Mapping Program, but currently base funding with some other WASO funding has been leveraged with local and state agency funds, or other federal partners (USGS, NOAA)

Initially the SFCN hopes to produce accurate benthic habitat maps which will aid in

random stratified sampling design for all the marine Vital Sign indicators that are being developed. After completion of the first round of maps, it is envisioned that new map products will be generated every decade, or as otherwise warranted due to natural events or major impacts to the benthic communities. Opportunities will be leveraged to look for partners to help reduce costs.

The SFCN Marine Ecologist would be required to manage the mapping contract with assistance from the Network Coordinator, and organize the field efforts. An approximate 3-4 weeks of field time, with 3-4 weeks of office time would be required during years of mapping activity based on area mapped. Dive technicians and/or fisheries biologist would assist where necessary in both field and office activities.

Expected SFCN staff time requirements once program is fully implemented in 5 years:

SFCN Staff	Full Time Equivalent (FTE)
Coordinator	0.1
Marine Ecologist	0.1
Fisheries Biologist	
Marine Biologist Technician (So FL)	
Marine Biologist Technician (VI)	
Community Ecologist	
Wildlife Technician (Wildlife)	
Wildlife Technician (Vegetation)	
Quantitative Ecologist	
Data Manager	
GIS/Data Tech	
Interns	
SFCN Total	0.2

Vital Sign: Butterflies

[shortened name: Butterflies] deferred

Parks Where Vital Sign will be Implemented:
BICY, BISC, BUIS, DRTO, EVER, SARI, VIIS – Deferred due to insufficient funds.

Justification/Issues being addressed: Butterflies ranked 40th among the 44 SFCN vital signs.
Butterflies are a good indicator because they are important pollinators that reflect changes in plant communities, have strong species specific ties between caterpillars and host plants along with the butterfly and nectar plants. Butterflies can also indicate impacts from pesticide use. Schaus Swallowtail (*Papilio aristodemus ponceanus*) is a Federal endangered species and the Miami blue butterfly (*Hermiargus thomasi benthunebakeri*) is a candidate for Federal listing. Butterfly information could be useful in directing park based mosquito control activities in areas of rare butterflies.

General Monitoring Questions to be Addressed by the Vital Sign:

- What are the status and trends in abundance and distribution of butterflies?

Measures:
Population abundance, distribution, abundance and distribution of host plants & nectoring plants

Basic Approach:
Project is deferred due to insufficient funds.

Principal Investigators/Key Contacts and NPS lead*:*
N/A

Development Schedule, Budget, and Expected Interim Products:
N/A

Vital Sign: Coastal Geomorphology

[Shortened name: Coastal_Geomorphology]

Parks Where Vital Sign will be implemented:
BICY, BISC, BUIS, SARI, VIIS: Soil Elevation Tables (SETs)- SFCN implements monitoring
EVER: SETs – SFCN summarizes reports from existing program

EVER: Berms & Embankments – SFCN part of the Benthic communities extent and distribution indicator

Justification/Issues being addressed: Coastal Geomorphology ranked 27th among the 44 SFCN vital signs. Soil dynamics (the build up or loss of sediment) is a basic process that can have far reaching impacts on an ecosystem. This process is especially important in mangroves, mud-banks, and salt ponds. In the USVI, sediment filling of ephemeral guts and salt ponds from upland development is an important issue. In South Florida, hydrology, sea-level rise and storms have been found to affect mangrove and mud bank soil elevation. CERP/MOD Waters Everglades restoration of regional hydrology is expected to impact soil levels. At a larger scale in South Florida, berms, embankments, and mud banks in Florida Bay have substantial influence on water exchange and the general circulation patterns between the near shore estuaries and oceanic water bodies. Monitoring the position and spatial extent of these structures is critical to understand the connectivity of the water bodies for processes like: Pink Shrimp larval recruitment, export of dissolved organic matter, salinity, nutrient patterns, etc. Everglades restoration, water delivery, large storm events, and sea level rise could all affect these ecosystem structures. Long-term resource management will need to understand the change in position and spatial extent to properly understand changes within the system.

General Monitoring Questions to be addressed by the Vital Sign:

- What are the status and trends in soil dynamics (accretion, subsidence and erosion) in mangroves, mud-banks, and salt ponds, especially in relation to changes in hydrology (quality, quantity, timing and duration) sea-level, storms/hurricanes, and upland erosion?
- Where do berms, embankments and mud banks in Florida Bay change in location?

Measures:
Change in soil elevation in mangroves & salt ponds, location and spatial extent of mud banks, buttonwood embankment and berms

Basic Approach:

Soil Elevation Table (SETs) and mark horizon installation –

- SFCN will write a "Soil Elevation" protocol. In this protocol we will install soil elevation table in mangroves at a number of the parks (BICY, BISC, SARI, VIIS) and in salt ponds at BUIS and VIIS. We will coordinate with existing EVER monitoring: the southwestern mangroves being conducted by Thomas J. Smith III USGS, Taylor River mangroves sites being conducted by the Fred Sklar of South Florida Water Management District (SFWMD) in conjunction with the Florida Coastal Everglades Long term Ecological Research sites (FCE -LTER) and mud banks of Florida Bay being conducted by Robert Halley (USGS).

Mapping of mud banks in Florida Bay

- If funding is available, SFCN will work to delineate mud banks, berms, buttonwood embankment in Florida Bay every 10 years from aerial photography (potential overlap with Mangrove-marsh transition mapping). This work will be handled by the SFCN internally in conjunction with "benthic communities extent and distribution" vital sign. Select ground truthing of aerial photography will be needed.

Principal Investigators/Key Contacts and NPS Lead:

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- Fred Sklar , SFWMD, Everglades Department, South Florida Water Management District, 3301 Gun Club Road, West Palm Beach, FL 33406 , fsklar@sfwmd.gov
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- Rafe Boulon, Resource Manager, Virgin Islands National Park. 340 693-8950 x224, Rafe_Boulon@nps.gov
- GIS Technician, National Park Service, South Florida/Caribbean Inventory and Monitoring Network. 305-252-0347

Development Schedule, Budget, and Expected Interim Products:

The Soil Elevation protocol is expected to take about of 15 days of SFCN staff time to measure SETs annually (measured bi-annually – twice a year) once the sites and equipment are established. SFCN staff will be responsible for this indicator (Community Ecologist, with assistance from Technicians). One time equipment cost of $12,000.00 plus ongoing travel costs to USVI and DRTO for maintenance and monitoring at 6 month intervals. The protocol development for "Soil Elevation" should be completed by 2009 and begun 2010. Table indicates proposed SFCN workload upon full monitoring implementation.

Expected SFCN staff time requirements once program is fully implemented in 5 years:

SFCN Staff	Full Time Equivalent (FTE)
Coordinator	
Marine Ecologist	
Fisheries Biologist	
Marine Biologist Technician (So FL)	
Marine Biologist Technician (VI)	
Community Ecologist	0.02
Wildlife Technician (Wildlife)	0.08
Wildlife Technician (Vegetation)	0.08
Quantitative Ecologist	0.06
Data Manager	0.02
GIS/Data Tech	
Interns	
SFCN Total	0.26

Vital Sign: Colonial Nesting Birds

[shortened name: Colonial_Birds]

Parks Where Vital Sign will be Implemented:
BISC, – SFCN implements monitoring
BICY, DRTO - supplement current Park monitoring
BUIS, EVER, VIIS - being monitored by park
SARI - USFWS, VIDFW conducting monitoring; may need supplementation

Justification/Issues being addressed: Colonial Nesting Birds ranked 8th among the 44 SFCN vital signs. The status of colonial nesting bird colonies, their size and nesting success, indicate the surrounding ecosystems' ability to support foraging of nesting birds (i.e. amount and quality of fish and/or invertebrates available in the surrounding landscape/seascape), predictability of forage and water, freedom from colony (nest) predators, and survivable contaminant levels. Bird's bioaccumulate certain contaminants in their feathers, blood, and eggs. Because of their sensitivity to landscape health, fishery health, and contaminants, colonial nesting birds are almost all either federal or state threatened species, endangered species or species of special concern. Colonial wading birds including wood storks, roseate spoonbills, egrets and ibises have been identified as important performance measures for the CERP RECOVER program. As colonial nesting birds have a moderate foraging range and are affected by both local and larger regional scale forcing functions, the long term monitoring of colonial nesting birds will give insight to overall ecosystem health at this scale.

General Monitoring Questions to be addressed by the Vital Sign:

- What are the status and trends in colony size, distribution, and nesting status of colonial nesting birds (e.g., Great Egret, Wood Stork, White ibis, Snowy Egret, Cattle Egret, Rosette Spoonbill, Tricolor Heron, Little Blue Heron, Black-crowned Night Heron, Least terns, Brown Pelicans, Masked Boobies, Roseate terns, Sooty Terns)? Specifically in South Florida are the populations and distributions of wading birds changing?

Measures
Location and size of rookery (by species), peak nest counts, and fledging success (by species) along with summarized counts of wading birds by region.

Basic Approach:
SFCN is developing a "Colonial Nesting Birds" protocol that will summarize its approach both in terms of new monitoring in BISC and possibly BICY as well as how results will be reported from existing programs. An overview of the protocol's basic approach is below.

1) Survey known colonies with opportunistic surveys of newly reported colonies. At each colony (rookery) assess (by species) the number of nests, status of nests, and fledging with serial surveys to determine fledgling success.

Colonial nest surveys are currently occurring in EVER and sporadically at Big Cypress.
BUIS (Pelicans and Least Terns) and VIIS (Pelicans) are being monitored by park. SFCN needs to initiate monitoring in BISC and supplement current monitoring at BICY and DRTO. Sonny Bass's (EVER Wildlife Biologist) current Dry Tortugas study of Sooty Terns is very detailed but lacks whole park surveys. For BISC we will need to generate a probable nesting period and sample at monthly to biweekly intervals to determine number of nests, nest success and fledgling success. USFWS and Virgin Islands Dept. of Fish and Wildlife are conducting monitoring for least terns and brown pelicans at SARI and roseate and least terns at VIIS. SFCN will work with these agencies and park staff to see if further monitoring efforts are needed at SARI and see if these other agency efforts can be reported through the Vital Signs process. SFCN will work with park staff to formalize SOPs and help with database development and analysis and reporting processes for existing programs as needed.

2) Large scale surveys of the park lands and waters for relative abundance for wading and colonial nesting birds in South Florida.

The Systematic Reconnaissance Flights program provides a regional estimation (for Everglades National Park and Big Cypress National Preserve specifically) of wading bird populations in south Florida that compliments colony bird rookery surveys.

The Systematic Reconnaissance Flights program is a base funded monitoring program for Everglades National Park. Big Cypress National Preserve has some monitoring from Everglades National Park Systematic Reconnaissance Flights program and by sampling supported by South Florida Water Management District. The SFCN will pull together the results from these different SRF monitoring to present and general finding for both parks.

Principal Investigators/Key Contacts and NPS Lead:

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- Rafe Boulon, Resource Manager, Virgin Islands National Park. 340 693-8950 x224, Rafe_Boulon@nps.gov
- Jennifer Valiulis, U.S. Virgin Islands Department of Fish and Wildlife, j_valiulis@yahoo.com

- Claudia Lombard, U.S. Fish and Wildlife Service, St. Thomas, claudia_lombard@fws.gov

Development Schedule, Budget, and Expected Interim Products:
The "Colonial Nesting Birds" protocol is expected to take about 6 months of SFCN staff time to draft and test the protocols. Full implementation is partially dependant on continued Everglade National Park funding of SRF and colony bird rookery surveys. The Community Ecologist and the Wildlife Technicians will conduct sampling about 8 weeks of the year, including data entry and reporting. Costs include helicopter time and travel and some start-up equipment (good binoculars). However, SFCN will need to evaluate the feasibility of using the SFCN boat for rookery surveys. SFCN will create a single overarching colonial nesting birds protocol document by 2009 with different parks treated as different SOPs within the main document. Pilot work on the SOPs will begin in 2008 and be completed by the end of 2009 with full implementation beginning in 2010. Table indicates proposed SFCN workload upon full monitoring implementation.

Expected SFCN staff time requirements once program is fully implemented in 5 years:

SFCN Staff	Full Time Equivalent (FTE)
Coordinator	
Marine Ecologist	
Fisheries Biologist	
Marine Biologist Technician (So FL)	
Marine Biologist Technician (VI)	
Community Ecologist	0.1
Wildlife Technician (Wildlife)	0.17
Wildlife Technician (Vegetation)	0.07
Quantitative Ecologist	0.06
Data Manager	0.04
GIS/Data Tech	0.02
Interns	
SFCN Total	0.46

Vital Sign: Contaminants

[shortened name: Contaminants]

Parks Where Vital Sign will be Implemented:
BICY, BISC, BUIS, DRTO, EVER, SARI, VIIS – SFCN will summarize reports from existing programs

Justification/Issues being addressed: Contaminants ranked 19th among the 44 SFCN vital signs. Point-source and non-point source contaminants are a growing concern in most natural areas. Determining a proper monitoring protocol to establish a baseline and to determine trends in contaminants is critical for proper resource management, especially regarding modifications of water management from Everglades Restoration. For example, mercury (Hg) bioaccumulation in particular is a serious concern in the greater Everglades system.

General Monitoring Questions to be Addressed by the Vital Sign:

- What are the distribution, range, variability and concentrations of contaminants, including Emerging Pollutants of Concern (EPOCS), (PPCP's - Pharmaceuticals and Personal Care Products), endocrine disruptors and metals in the water column, organisms, and sediments (surface and core)?

Measures
Concentrations in water column, organisms, and sediments of : Hg (Total/Methyl), Metals, Hydrocarbons, Polcyclioaromatic hydrocarbon (PAHs), Pesticide/Herbicide/Insecticide, Polychlorinated biphenyl (PCB's), EPOC's, (Pharmaceuticals and Personal Care Products, Caffeine, Estrogen/hormone related), non-regulated contaminants (vessel anti-fouling paint).

Basic Approach: SFCN will summarize reports from existing programs and post on webpage.

Principal Investigators/Key Contacts and NPS Lead: N/A

- Andrea Atkinson, National Park Service, South Florida/Caribbean Inventory and Monitoring Network. Andrea_Atkinson@nps.gov, 305-252-0347 [SFCN lead]
- Joffre Castro, National Park Service, Everglades National Park. Joffre_Castro@nps.gov

Development Schedule, Budget, and Expected Interim Products: SFCN will work to implement as reports become available but will make a strong push to gather, summarize and fully post existing reports by 2012. Coordination of this indicator is to be accomplished by the Quantitative Ecologist and the GIS/ Data Tech. Initial webpage work will be accomplished by intern. Table indicates proposed SFCN workload upon full monitoring implementation.

Expected SFCN staff time requirements once program is fully implemented in 5 years:

SFCN Staff	Full Time Equivalent (FTE)
Coordinator	
Marine Ecologist	
Fisheries Biologist	
Marine Biologist Technician (So FL)	
Marine Biologist Technician (VI)	
Community Ecologist	
Wildlife Technician (Wildlife)	
Wildlife Technician (Vegetation)	
Quantitative Ecologist	0.02
Data Manager	
GIS/Data Tech	0.02
Interns	
SFCN Total	0.04

Vital Sign: Estuarine salinity patterns

[shortened name: Estuarine_Salinity]

Parks Where Vital Sign will be implemented:
BISC, EVER – SFCN analyzes existing data sets; summarizes existing reports
SARI - deferred

Justification/Issues being addressed: Estuarine salinity patterns ranked 9th among the 44 SFCN vital signs. Physical characteristics of marine water bodies establish environmental constraints within which other organisms must survive. Understanding the spatial and temporal distribution of the physical characteristics within marine water bodies allows more complete interpretation of other indicators. For example, historically, salinity monitoring has been correlated with benthic community monitoring, productivity analysis, fish and other organism sampling. Some parks have had continuous sampling at permanent locations for a number of years and understanding the pattern can help explain patterns observed.

General Monitoring Questions to be Addressed by the Vital Sign:

- What are the spatial and temporal changes in distributions of physical characteristics (conductivity converted to practical salinity units, pH, dissolved oxygen, temperature) in the marine water bodies of Florida Bay (coastal embankments, central bay, "open" bay), Biscayne Bay, and Salt River Bay?

Measures:
Conductivity converted to practical salinity units, pH, dissolved oxygen, and temperature in Florida Bay and Biscayne Bay.

Basic Approach:
For EVER, we can combine NPS continuous station monitoring data with Florida International University Southeastern Environmental Research Center (FIU SERC) monthly water surveys to krig salinity and temperature profiles for marine water bodies for Florida Bay and relate this to the model results for Florida Bay. For pH and dissolved oxygen we would just report from the FIU SERC monthly grab samples.

For BISC, we can combine park service continuous conductivity sampling at 30 stations (funded by CERP RECOVER Monitoring and Assessment Program) with FIU SERC 25 water quality monthly grab sample stations (funded by the South Florida Water Management District water quality program) and Miami-Dade County Department of Environmental Research (DERM) 13 water quality monthly grab sample stations to krig salinity and temperature patterns in the Biscayne Bay. For pH and dissolved oxygen we would just report from the FIU SERC and DERM monthly grab samples.

Principal Investigators/Key Contacts and NPS Lead:

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- Kevin Kotun, Everglades National Park, (305) 242-7829, Kevin_Kotun@nps.gov

Development Schedule, Budget, and Expected Interim Products:

The Standard Operating Procedures (SOPs) involved are expected to take about 6 months of SFCN staff time (by Marine Post-doc) to document the protocols from implementing agencies and to draft and test the SOPs. SFCN staff (Marine Ecologist and Fisheries Biologist) will be responsible for this indicator. SOP development will be completed by 2009 with implementation in 2011. Table indicates proposed SFCN workload upon full monitoring implementation.

Expected SFCN staff time requirements once program is fully implemented in 5 years:

SFCN Staff	Full Time Equivalent (FTE)
Coordinator	
Marine Ecologist	0.02
Fisheries Biologist	0.02
Marine Biologist Technician (So FL)	
Marine Biologist Technician (VI)	
Community Ecologist	
Wildlife Technician (Wildlife)	
Wildlife Technician (Vegetation)	
Quantitative Ecologist	0.04
Data Manager	0.02
GIS/Data Tech	0.04
Interns	
SFCN Total	0.14

Vital Sign: Fire Return Interval Departure

[shortened name: Fire_Return]

Parks Where Vital Sign will be Implemented:
EVER, BICY – SFCN will synthesize fire data

Justification/Issues being addressed: Fire Return Interval Departure ranked 29th among the 44 SFCN vital signs. Fire is a major driver in vegetation community distribution, structure, and composition across the landscape. Maintaining a fire regime that mimics the historical pattern while ensuring public safety is important for conserving such communities as the pine rocklands from being encroached by hardwood hammocks, marshes from being encroached by forests and mangroves, etc. Monitoring fire return interval departure is an important tool for assessing the health of ecosystems with respect to fire, and provides key information for fire management decisions.

General Monitoring Questions to be Addressed by the Vital Sign:

- What is the extent and distribution of areas across the landscape where a departure from native fire regimes exists?

Measures
Fire location, fire size expressed in acres, perimeter in digitized shapefile, dates of fire event, ignition source (lightning, human), time since last burn

Basic Approach:
Each fire within the parks has a folder of information that is compiled by the NPS fire ecologists.

U.S. Geological Survey researchers Tom J. Smith and Ann Foster are compiling all fire history records at Everglades National Park and Big Cypress National Preserve into a GIS database showing the fire location, fire size expressed in acres, perimeter in digitized shapefile, dates of fire event, ignition source (lightning, human) and allowing calculations across the landscape of time since last burn. This product is due to be delivered by December, 2007.

The EVER Fire Ecologist would like to have the annual fire data compiled into the above geodatabase (or a new one if necessary) and have a queryable version made available to fire management and park botanists/ecologists. SFCN will work with the EVER Fire Ecologist to develop a protocol and/or SOP for maintaining the geodatabase and analyzing the results and to make the geodatabase queryable. Currently the fire program is already GPS'ing the boundaries of fires and if the program is user-friendly, could enter the data into the geodatabase themselves.

EVER resource management staff also have requested assistance creating better links

between the fire effects monitoring, effects on rare and endangered species, and appropriate burn intervals and timing in the pinelands. SFCN is volunteering to host a workshop for EVER and BICY resource management staff, fire management staff and others involved in pineland fire research.

Principal Investigators/Key Contacts and NPS Lead:

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- Rick Anderson, Fire ecologist, National Park Service, Everglades National Park, 305-242-7853, thomas_r_anderson@nps.gov
- Jim Snyder, Fire ecologist, U.S. Geological Survey-Big Cypress National Preserve, (941) 695-2000 ext. 21, jim_snyder@usgs.gov
- Tom Smith, U.S. Geological Survey- St. Petersburg, 727-803-8747 x3130, tom_j_smith@usgs.gov
- Ann Foster, U.S. Geological Survey – Gainesville, (352) 372-2571, ann_foster@usgs.gov

Development Schedule, Budget, and Expected Interim Products:

A GIS database containing the fire history through the 2005 is due to be completed and delivered to the parks by December 2007.

The immediate next step after the database is complete will be to write a protocol for how it is updated and analyzed and make the geodatabase easily queryable which should be completed in 2008.

Expected SFCN staff time requirements once program is fully implemented in 5 years:

SFCN Staff	Full Time Equivalent (FTE)
Coordinator	
Marine Ecologist	
Fisheries Biologist	
Marine Biologist Technician (So FL)	
Marine Biologist Technician (VI)	
Community Ecologist	
Wildlife Technician (Wildlife)	
Wildlife Technician (Vegetation)	
Quantitative Ecologist	0.02
Data Manager	0.02
GIS/Data Tech	0.08
Interns	
SFCN Total	0.12

Vital Sign: Florida Box Turtle

[shortened name: Box_Turtle] Deferred

Parks Where Vital Sign will be Implemented:
BICY, EVER – Deferred due to insufficient funds

Justification/Issues being addressed:
The Florida Box Turtle ranked 38th among the 44 SFCN vital signs. *Terrapene carolina bauri* is an abundant turtle in South Florida and in some cases is called the "common" box turtle. The species is long-lived and reflects long-term habitat conditions at a site and region. Box Turtles are susceptible to habitat loss and fragmentation, roadkill (cars, farm equipment, lawn-mowers), intense fires, collection as pets, dog and cat injury and predation. They utilize a diverse selection of upland and seasonally-flooded habitats throughout the year and play a key ecological role, serving as both predators and prey, contributing to nutrient cycles and dispersing seeds for many native plants.

General Monitoring Questions to be Addressed by the Vital Sign:

- What are the status and trends in the abundance and distribution of Florida Box Turtles?

Measures:
Population size & structure, mortality, recruitment, proportion of habitat occupied.

Basic Approach:
Deferred due to insufficient funds/staff time

Principal Investigators/Key Contacts and NPS Lead:
N/A

Development schedule, budget, and expected interim products:
N/A

Vital Sign: Florida panther
[shortened name: Panther]

Parks Where Vital Sign will be Implemented:
BICY, EVER – SFCN summarizes reports from existing programs

Justification/Issues being addressed: The Florida panther (*Puma concolor coryi*) ranked 33rd among the SFCN vital signs. The Florida Panther is a top predator in South Florida, whose primary prey is deer, but also includes large fish, birds, feral hogs, etc. It is a federally endangered species that has been impacted by habitat loss and fragmentation, roadkill, contaminant bioaccumulation, and genetic bottlenecks. BICY, neighboring state lands, and portions of EVER are key areas for panther conservation and recovery. Monitoring information is used to assess panther populations, while distribution information is used to inform park managers about potential impacts of visitor use and management activities on panther distribution and relative activity levels.

General Monitoring Questions to be Addressed by the Vital Sign:
- What are the status and trends in Florida panther abundance, distribution, mortality, and recruitment?

Measures:
Population abundance, distribution, mortality, recruitment

Basic Approach:
Florida panthers are already monitored by existing parks and the Florida Fish and Wildlife Conservation Commission. The SFCN community ecologist will request and review annual reports from FFWCC, which compile panther data from the South Florida parks and adjacent areas for a regional overview. Reports back to the mid 1990's are available to download at:http://myfwc.com/panther/news/reports.html. Those links would be provided and an abridged executive summary included in an SFCN annual report that would be post on the SFCN Intranet and Internet sites.

Principal Investigators/Key Contacts and NPS Lead:
- Deborah Jansen (BICY); (239) 695-1179; Deborah_Jansen@nps.gov
- Sonny Bass (EVER); (305) 242-7833; Sonny_Bass@nps.gov
- Mark Lotz & Darrell Land (FFWCC-Naples)
- Kevin Whelan, SFCN Community Ecologist; (305) 252-0347; Kevin_R_Whelan@nps.gov [SFCN lead]

Development schedule, budget, and expected interim products:
The SFCN Community Ecologist will request reports as they are produced and request permission to share those findings with others. SFCN will begin posting reports to the SFCN website by December 2008 together with brief summaries.

Expected SFCN staff time requirements once program is fully implemented in 5 years:

SFCN Staff	Full Time Equivalent (FTE)
Coordinator	
Marine Ecologist	
Fisheries Biologist	
Marine Biologist Technician (So FL)	
Marine Biologist Technician (VI)	
Community Ecologist	
Wildlife Technician (Wildlife)	
Wildlife Technician (Vegetation)	
Quantitative Ecologist	0.01
Data Manager	0.01
GIS/Data Tech	0.01
Interns	
SFCN Total	0.03

Vital Sign: Focal fish species

[shortened name: Focal_Fish]

Parks Where Vital Sign will be Implemented:
BISC, BUIS, DRTO, EVER, SARI, VIIS – SFCN analyzes existing data and summarizes reports

Justification/Issues being addressed: Focal Fish Species ranked 30th among the SFCN vital signs. Focal fish species includes large predatory fish that are popular targets of fisherman and thus of particular concern for management. Community status, structure and trends can reflect changes in marine habitat quality, food-web structure, fishing pressure, and long-term ecosystem resilience. Balancing resource extraction with sustainability is a key management concern.

- Goliath grouper (*Epinephelus itajara*), a top marine food-web predator, has been so over-fished that it is now a rare and protected species in the state of Florida and USVI. The Goliath Grouper has all but disappeared in the USVI, as well as the Nassau Grouper (*Epinephilus striatus*) although recently a number of juveniles were seen at VIIS/VICR during a University of Virgin Islands project by Rick Nemeth (Rafe Boulon, personal communication). As such, red hind (*Epinephelus guttatus*) in the USVI is recommended instead as a top-predator to monitor, although it is also under heavy fishing pressure.
- Sharks, as top marine food-web predators, have been fished to such an extent that their numbers are reduced in South Florida and the USVI. Sharks mature late in life, have slow growth rates and produce few offspring.
- The Spotted Sea Trout (*Cynoscion nebulosus*) is a bottom-feeding intermediate trophic level species targeted as a sport fish and for human consumption within and outside SFCN parks boundaries. It is the only major sport fish in South Florida that spends its entire life cycle in bays. Spotted Sea Trout are sensitive to hypersaline conditions and thus, may respond to changes in South Florida water management restoration. Mercury bioaccumulation is also a concern in sea trout and other long lived fish in South Florida.
- The Snook (*Centropomus undecimalis*) is a euryhaline, diadromous, estuarine-dependent species targeted as a sport fish and for human consumption within and outside SFCN parks boundaries. Snook are under strong fishing pressure. Prey source varies with life stage (juveniles - small fish, plants; adults - fish, crabs).

General Monitoring Questions to be Addressed by the Vital Sign:

- What are the status, trends, and variability of focal fish species within and near parks, specifically Goliath grouper (*Epinephelus itajara*), Nassau Grouper (*Epinephilus striatus*), Red hind (*Epinephelus guttatus*), Sharks (Bonnethead (*Sphyrna tiburo*), Lemon (Negaprion brevirostris), Bull (*Carcharhinus leucas*), and Nurse (*Ginglymostoma cirratum*) sharks), Spotted sea trout (*Cynoscion nebulosus*), and Snook (*Centropomus undecimalis*)

Measures
Goliath Grouper, Nassau Grouper (Red Hind in USVI), Sharks, Spotted Sea trout, Snook – relative abundance/density, occupancy, spatial/ temporal distribution, density, size structure, catch per unit effort

Basic Approach:
Creation of a monitoring program that is species specific is cost prohibitive at this time; however there are some efforts underway to track these species by other groups which SFCN can draw upon. SFCN will gather reports and links to web pages of existing monitoring programs including but not limited to: NOAA/NOS Allyn Powell's long-term juvenile spotted sea trout monitoring trawl study in NW Florida Bay; Tonya Wiley Mote Marine/NOAA continues with deployment of long lines for 7-8 shark species, i.e. bull/nurse sharks; USVI: University of the Virgin Islands has been conducting sex ratio, size, number, and tagging on 3 species of grouper (Red Hind, Nassau and Yellow Fin) at their aggregation sites 8 miles off of St Thomas.

SFCN will gather reports and/or post links and if necessary gather data from fish community monitoring conducted by: NOAA, FWRI, territorial, and university researchers to assess distribution and occupancy of these focal species.

Creel Census data from BISC, EVER, and possibly DRTO may also be used to evaluate catch in parks.

Principal Investigators/Key Contacts and NPS Lead:
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- Tom Schmidt, Marine Biologist EVER 305-224-4269 Tom_Schmidt@nps.gov
- Mike Murphy, FWRI, 727-896-8626 mike.murphy@myFWC.com
- Jerald S. Ault, Ph.D. Professor of Marine Biology and Fisheries Rosenstiel School of Marine and Atmospheric Science University of Miami, 4600 Rickenbacker Causeway Miami, FL 33149 jault@rsmas.miami.edu (305)421-4884 ph (305) 421-4791 fax
- South Florida Natural Resource Center – National Park Service
- Richard Nementh UVI, Proff. Director, 340-693-1380 rnemeth@uvi.edu
- MOTE Marine Laboratory - Robert E. Hueter, Ph.D.

Development Schedule, Budget, and Expected Interim Products:
By the end of 2009, SFCN will coordinate with the various Principal Investigators to place summaries on the SFCN public web page and reports on the intranet page. Estimated time required: Initial set up 1 month and 1-2 weeks on going maintenance by a combination of Marine Ecologist, Quantitative Ecologist and support staff. Commercial landing and creel census information will begin being compiled by 2009.

Creel census summary information will be requested from parks and shared on the intranet site.

Expected SFCN staff time requirements once program is fully implemented in 5 years:

SFCN Staff	Full Time Equivalent (FTE)
Coordinator	
Marine Ecologist	0.02
Fisheries Biologist	
Marine Biologist Technician (So FL)	
Marine Biologist Technician (VI)	
Community Ecologist	
Wildlife Technician (Wildlife)	
Wildlife Technician (Vegetation)	
Quantitative Ecologist	
Data Manager	0.04
GIS/Data Tech	0.07
Interns	
SFCN Total	0.13

Vital Sign: Forest Ecotones and Community Structure

[shortened name: Forest_Vegetation]

Parks Where Vital Sign will be Implemented:
BICY, BISC, BUIS, DRTO, EVER, SARI, VIIS – SFCN will evaluate existing monitoring and where possible build upon it or develop new sampling plan

Justification/Issues being addressed: Forest Ecotones and Community Structure ranked 14th among the 44 SFCN vital signs. Plants are important primary producers and dominant physical structure components in terrestrial natural systems. They are the quintessential primary focus component of most natural land resource management agencies. Vegetation community composition and structure change may indicate transformation of successional state, time since disturbance, eutrophication, hydro-pattern (including groundwater), water quality, fire regime, disease or insect outbreak effects, changes in relative cover by native/non- native species, etc.

Ecotones are transition zones between habitats and are generally dynamic locations for flora and fauna. Due to the transition between habitats, tracking the position of ecotones can indicate their long-term trajectory. Understanding the physical conditions which drive ecotone location change is critical for resource management. Ecotones are expected to move, for example, in response to changes in water management, sea level rise, and fire management. Both hammocks and pinelands are important habitats for rare and endemic plant species and for wildlife. Hammocks are spatially limited vegetation communities within a matrix of pinelands. Pinelands are fire adapted whereas hammock species are less so. In the absence of fire, hammock species expand into pinelands, though fire can reduce or eliminate hammocks. Fire management is critical to maintaining a habitat balance. Invasive species could also impact relationships between these habitats.

General Monitoring Questions to be addressed by the Vital Sign:

- Are ecotones shifting due to physical conditions (e.g., hydrology, climate change, anthropogenic factors, sea level rise, fire, episodic meteorological and storm wave events, etc.)?
- What are the status and trends in plant community composition and structure?

Measures:
Community composition and physical structure (e.g., canopy height, vegetative cover of each plant species, canopy cover in each stratum (canopy, herb layer, shrub layer, etc)), shifts in community boundaries (e.g., hammock/pine), soil depth, litter depth

Basic Approach:
SFCN in cooperation with Jenny Richards of FIU have hired a post-doc to work on vegetation monitoring protocols. SFCN is developing a "Forest Ecotones and Community Structure" protocol which will detail its approach both with new

monitoring by SFCN and regarding coordinating with existing programs. Some key points include:

- SFCN will coordinate with existing programs where appropriate; such as fire monitoring plots in Long Pine Key in Everglades and long-term plots on VIIS and BISC. These existing programs will need to be evaluated for statistical rigor, compatibility of objectives and willingness to share reports and/or data.
- SFCN will evaluate ecotonal change using both aerial photography monitoring and field monitoring via belt transects or a series of plots set up along a longer transect. Table 1 shows the types of ecotones to be monitored and which methods will be used. Revisit time is likely to be once every 5 years or after a major disturbance event and administered in a rotating panel.
- SFCN will evaluate long-term change within plant communities via field plots revisited approximately once every 5-10 years (see Table 2).

Table 1. Plan for Ecotone Monitoring
A= monitored with aerial photography
F= monitored with field plots

	Pineland to Hammock	Coastal to Inland	Forest to Wet Prairie	Wet Prairie to marsh/slough
BISC		**A,F**	**A**	
BICY	**A,F**	**A,F**	**A**	
EVER	**A,F**	**A,F**	**A**	**A,F**
DRTO		**A,F**		
SARI		**A,F**		
BUIS		**A,F**		
VIIS		**A,F**		

Table 2. Plan for Long-term within-community monitoring plots

+ = SFCN monitoring
♦ = Existing monitoring program

	Pineland	Hardwood Hammock	Mangroves	Marshes	Island Moist Forest	Island Deciduous Forest	Island Scrub/ Shrub
BISC		**+,♦**	**+**				
BICY	**♦**	**+**	**+**				
EVER	**♦**	**+,♦**	**♦**	**♦**			
DRTO			**+**				
SARI			**+**				
BUIS			**+**			**+**	**+**
VIIS			**+**		**+,♦**	**+,♦**	**+**

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- Jim Burch, Big Cypress National Preserve. 239-695-111, jim_burch@nps.gov
- Jimi Sadle, Everglades National Park, Jimi_Sadle@nps.gov
- Prof. Mike Ross, Florida International University, rossm@fiu.edu, 305-348-1420 (tree island monitoring)
- Thomas J. Brandeis, Ph.D. USDA Forest Service, Southern Research Station, Forest Inventory and Analysis, 4700 Old Kingston Pike, Knoxville, TN 37919, (865) 862-2030, tjbrandeis@fs.fed.us, http://srsfia2.fs.fed.us/states/vi/USVI%20FIA.htm
- Pete Weaver, USDA/FS, Puerto Rico

Development Schedule, Budget, and Expected Interim Products:

The "Forest Ecotones and Community Structure" protocol development is expected to be completed by 2010. Implementation is expected to take 0.33 FTE/year each for the community ecologist and two wildlife technicians across all habitat types including mangroves and marshes which are covered under other vital signs. For the evaluation of change via aerial photography, this is expected to take the GIS/Data technician approximately 2 months/year. Cost is estimated to be $10,000/year to cover helicopter time plus stakes, etc. Table indicates proposed SFCN workload upon full monitoring implementation for all 3 vegetation monitoring protocols.

Expected SFCN staff time requirements once program is fully implemented in 5 years. Time estimates are for all 3 vegetation protocols.

SFCN Staff	Full Time Equivalent (FTE)
Coordinator	
Marine Ecologist	
Fisheries Biologist	
Marine Biologist Technician (So FL)	
Marine Biologist Technician (VI)	
Community Ecologist	0.3
Wildlife Technician (Wildlife)	0.4
Wildlife Technician (Vegetation)	0.4
Quantitative Ecologist	0.06
Data Manager	0.04
GIS/Data Tech	0.2
Interns	0.3
SFCN Total	1.7

Vital Sign: Freshwater fish and large macro-invertebrates

[shortened name: FW_fish_lg_inverts]

Parks Where Vital Sign will be Implemented:
BICY – SFCN expands/implements monitoring in NW BICY in cooperation with existing program in NE BICY.
EVER – SFCN summarizes reports from existing program
VIIS- deferred

Justification/Issues being addressed: Freshwater fish and large macro-invertebrates ranked 18th among the 44 SFCN vital signs. Regional populations of wet prairies and marsh fishes and other aquatic fauna reflect regional hydrology (water depth, timing, duration, quantity, quality) and are the prey base for wading birds and other higher consumers in the Greater Everglades and Big Cypress ecosystem. Water diversions and altered water management practices have resulted in declines in regional populations of fish and aquatic invertebrates with cascading impacts on higher food web levels. CERP will be rehabilitating system hydrology that is expected to affect these populations.

General Monitoring Questions to be Addressed by the Vital Sign:

- What are the status and trends of fish and large macro-invertebrate assemblages, community composition, abundance (density & relative abundance), size structure, and distribution, especially in relation to hydrological patterns and water quality in wet prairies and marshes? What is relative abundance and distribution of exotic species?

Measures:
Community composition, abundance (density and relative abundance), size structure, invasive species present

Basic Approach:
SFCN will develop the protocol "Freshwater fish, invertebrates, and periphyton" for monitoring in Northwestern BICY and will seek to report on existing monitoring efforts underway in EVER and Northeastern BICY:

1) Long-term monitoring funded by CERP RECOVER MAP is underway in Shark River Slough that is designed as a GRTS design and is re-randomized every year (58 sample sites occurred in EVER and BICY in 2005). Throw traps are used and fish are collected, counted and sized by species. (Philippi, 2003, 2005) Periphyton samples are collected simultaneously.
Long-term sentinel site monitoring is also occurring by Joel Trexler and Jeff Kline. SFCN feels this monitoring is sufficient and does not anticipate expanding this monitoring.

2) SFCN plans to work with the CERP funded effort in northeastern BICY to develop a similar sampling design and protocols for northwestern BICY. In NE BICY pilot studies are underway to study different protocols for monitoring fishes in cypress forests and in the mangrove/marsh interface paid for by CERP RECOVER MAP. It is unclear whether it will be funded long-term. Monitoring implementation in NW BICY will involve a pilot sampling period and writing of a full protocol prior to full implementation and would be conducted in cooperation with CERP funded effort in Northeastern BICY so that the two data sets could be compared and if appropriate combined. Sampling would focus in the area of northwest Big Cypress, north of Interstate 75 and west of the Florida National Scenic Trail entrance. Periphyton samples & micro-invertebrate samples would be collected simultaneously. A pilot study funded by CERP RECOVER in the northeastern portion of BICY found that throw traps similar to those used in Everglades National Park and the Water Conservation Areas appear to be the best method to use (compared with drop traps, lift traps, drift fences, gill nets) (Liston *et al.,* 2006). However additional methods may be needed to sample deeper areas in Okaloacoochee Slough and East Hinson Marsh (Joel Trexler, personal communication).

Sampling in Everglades is done at approximately 10-12 sampling units per landscape unit with about 2-5 throwtrap samples per sampling unit. Landscape units are chosen to be homogenous. If we assume that this area will include at least 1 landscape unit then about 12 sites would be visited 2 times each year with 3 throw-traps each. As with the NW BICY effort, a subset (3 sites) may be visited 5 times a year during the pilot monitoring phase (early, mid and late wet season, early & mid dry season) to determine optimal times to sample with sampling tied to number of days since drydown and water stage at nearby stations. The remainder of sites would be sampled in the late wet season (October) and possibly mid dry season (March).

In the future if additional funds become available, expansion to more of BICY and sampling in VIIS guts and Salt River should be considered. However this sampling is deferred for now due to insufficient funds.

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Development Schedule, Budget, and Expected Interim Products:
SFCN will coordinate with Jerry Lorenz and Bill Loftus who are the Principal Investigators for the NE BICY pilot program to develop monitoring for NW BICY. SFCN will seek to coordinate with CERP RECOVER MAP for reporting of monitoring results in EVER and northeast BICY in 2011. SFCN expects to conduct pilot monitoring using the protocols in development by Jerry Lorenz and Bill Loftus (Liston *et al.*, 2006) implemented in 2008-2010. The formal protocol "Freshwater fish, invertebrates, and periphyton" will be written by 2011 with full implementation in 2012. Initial design will require assistance of Quantitative Ecologist as well as subsequent analyses. If all sites are accessed by helicopter, assume about $7000/yr. Field equipment and supplies are estimated at $5000/yr. Table indicates proposed SFCN workload upon full monitoring implementation.

Expected SFCN staff time requirements once program is fully implemented in 5 years:

SFCN Staff	Full Time Equivalent (FTE)
Coordinator	
Marine Ecologist	
Fisheries Biologist	
Marine Biologist Technician (So FL)	
Marine Biologist Technician (VI)	
Community Ecologist	0.15
Wildlife Technician (Wildlife)	0.2
Wildlife Technician (Vegetation)	0.05
Quantitative Ecologist	0.04
Data Manager	0.02
GIS/Data Tech	0.02
Interns	
SFCN Total	0.48

References

Liston, Shawn E., Jerome J. Lorenz, William F. Loftus, Carole C. McIvor. 2006. Development and Testing of Protocols for Sampling Fishes in Forested Wetlands in Southern Florida: October 2005 to September 2006. Annual Report to US Army Corps of Engineers and Florida Integrated Science Center of US Geological Survey. 59 pages.

Philippi, Tom. 2003. Final Report- CERP Monitoring and Assessment Plan: Stratified Random Sampling Plan, SFWMD Agreement C-C20304A September 24, 2003

Philippi, Tom. 2005. Final Report- CERP MAP Implementation: Transect and Sentinel Site Sampling Design, SFWMD Agreement CP040131, April 28, 2005,Revised 20 May 2005 and 10 June 2005

Vital Sign: Imperiled & Rare Plants

[shortened name: Rare_Plants]

Parks Where Vital Sign will be Implemented:
BICY, BISC, BUIS, DRTO, EVER, SARI, VIIS - deferred

Justification/Issues being addressed: Imperiled & Rare Plants ranked 31st among the 44 SFCN vital signs. Critically imperiled or rare plant species are important indicators and subjects for monitoring for the following reasons: they will be the first plants to become extirpated if habitat quality declines; they are sensitive to changes in ecosystem processes, such as disruption of pollinator populations, or increases or decreases in hydrology; they are either endemic to the study region or are at the geographical limits of their ranges and extirpation would result in extinction or a contraction in the species' global range; and if endemic they may be host plants for other rare or endemic organisms, such as invertebrates.

General Monitoring Questions to be Addressed by the Vital Sign:

- What are the status and trends in the number of populations, distribution, and population sizes of rare plants?

Measures:
Targeted rare plant species distribution, annual population sizes, mortality, recruitment, extent of habitat.

Basic Approach:
Deferred due to insufficient funding/staff time. Parks have some existing monitoring programs underway.

Principal Investigators/Key Contacts and NPS Lead:
N/A

Development Schedule, Budget, and Expected Interim Products:
N/A

Vital Sign: Invasive/Exotic Animals

[shortened name: Inv_Animals]

Parks Where Vital Sign will be Implemented:
BICY, BISC, BUIS, DRTO, EVER, SARI, VIIS – SFCN conducts limited monitoring in cooperation with park staff

Justification/Issues being addressed: Invasive/Exotic Animals ranked 12th among the 44 SFCN vital signs. Invasive fauna are a serious threat to maintaining ecosystem integrity, with at least 61 exotic species found within SFCN parks and many more throughout south Florida. Some of the most problematic species include pythons, hogs, rats, mice, mongoose, Mayan cichlid, Cuban treefrogs, free-roaming and feral livestock, Mexican weevil, lac lobate scale, and fire ants (for complete list see Appendix N). These species displace and prey upon native fauna and can alter foodwebs. Tracking the distribution and level of control of known invasive species is important to assessing the health of the ecosystem for supporting native species. Detecting new species with the potential to become invasive while they are still in small controllable populations and/or outside park boundaries is important to cost-effective management. Island food-webs are particularly susceptible to invasive species, but also offer opportunities for successful control as has been demonstrated by BUIS and VIIS exotic control programs. Executive Order 13112 deals with the introduction, spread, control, and monitoring of invasive species on federal lands.

General Monitoring Questions to be Addressed by the Vital Sign:

- What exotic animal species are present in the parks and which ones are considered invasive or otherwise problematic? What is the distribution of the species? Where have new invasive/exotic species been detected in or near the parks?

Measures:
Invasive species present, distribution, vegetation types invaded, new species detected along common invasion points (e.g., canals)

Basic Approach:
SFCN will annually contact the major animal community monitoring programs and Park Resource Management personnel to develop and then update a list of exotic species within the parks and gather any new information regarding new exotic species detected and specific locations if possible (e.g., monitoring programs for fish, seagrass, amphibians, birds, coral, etc). This is intended to be a very basic list and specificity of locations may vary widely. This will be used to update the new web page being developed by the CISMA (Cooperative Invasive Species Management Area; www.evergladescisma.org) for exotic animal location reporting similar to their exotic plant page already in operation. This web page will also be queried to update the list. SFCN will immediately inform Park Resource Management and the Exotic Plant

Management Specialist about new exotic species found within their parks. SFCN will also assist in getting the word out about this new web page and will maintain a link to this web page from the SFCN web site. As CISMA becomes better known, SFCN may cease contacting major monitoring groups and instead pull new species from the CISMA.

Monitoring canals annually along the eastern border of Everglades which commonly overwash into the park plus canals nearby have been identified as a priority invasion hotspot for monitoring (L31W, L31N, C111). SFCN will work in cooperation with EVER park personnel (Jeff Kline) to use electrofishing and other sampling techniques (seine nets, dip nets, etc.) in these canals to detect new problematic fish species which can then be targeted for control by a multi-agency team that is scheduled to be developed soon. Some additional sites to monitor would be the L29 and L67 extension on the northern boundary of EVER, plus some canals in BICY (Tamiami canal, L-28, L31W, Loop road). Monitoring timing is preferably early and late dry season.

If there is sufficient SFCN and BISC staff time, the effort may be expanded to BISC canals which empty into Biscayne Bay.

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Development Schedule, Budget, and Expected Interim Products:
SFCN is developing an "Invasive/Exotic Fish in Canals" protocol that will be completed by 2009 and implemented jointly with EVER personnel in 2010. Cost of equipment for an electrofishing boat, trailer, engine, plus equipment and gear is estimated by park personnel at $83,500. Time per year would be 2.5-3 weeks in Everglades only for 1-2 SFCN personnel assuming other personnel contributed by the park. Estimates for Big Cypress would be another 2-3 weeks but may not be done every year (e.g., every 2 years). With regards to maintaining a list of species, SFCN will work to implement this by the end of 2008 and is expected to take at most 1 week/year for 1 intern once the initial list is compiled. Table indicates proposed SFCN workload upon full monitoring implementation.

Expected SFCN staff time requirements once program is fully implemented in 5 years:

SFCN Staff	Full Time Equivalent (FTE)
Coordinator	
Marine Ecologist	
Fisheries Biologist	
Marine Biologist Technician (So FL)	
Marine Biologist Technician (VI)	
Community Ecologist	0.08
Wildlife Technician (Wildlife)	0.08
Wildlife Technician (Vegetation)	
Quantitative Ecologist	
Data Manager	
GIS/Data Tech	0.06
Interns	
SFCN Total	0.22

Vital Sign: Invasive/Exotic Plants

[shortened name: Inv_Plants]

Parks Where Vital Sign will be Implemented:
BICY, BISC, BUIS, DRTO, EVER, SARI, VIIS – SFCN conducts limited monitoring and analysis in cooperation with Exotic Plant Management Team (EPMT) program

Justification/Issues being addressed: Invasive/Exotic Plants ranked 5th among the 44 SFCN vital signs. Invasive plants are one of the most serious threats to maintaining ecosystem integrity in SFCN parks. Tracking the distribution, rate of spread and control of known invasive species is important in assessing the ability of an ecosystem to supporting native species. Additionally, detecting new species with the potential to become invasive while they are still in small controllable populations is important to cost-effective resource management. Executive Order 13112 , February 3, 1999, deals with the introduction, spread, control, and monitoring of invasive species on federal lands. The National Park Service Organic Act of August 25, 1916, as amended (PL 64-235, 16 USC §1 et seq.), the National Environmental Policy Act of 1969, as amended (42 U.S.C. 4321 et seq.), Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990, as amended (16 U.S.C. 4701 et seq.), Lacey Act, as amended (18 U.S.C. 42), Federal Plant Pest Act (7 U.S.C. 150aa et seq.), Federal Noxious Weed Act of 1974, as amended (7 U.S.C. 2801 et seq.), Endangered Species Act of 1973, as amended (16 U.S.C. 1531 et seq.), and other pertinent statutes.

General Monitoring Questions to be Addressed by the Vital Sign:

- What are the status and trends in invasive exotic plants extent and distribution?
- Are new invasive exotic species becoming established in or near the park?

Measures:
Invasive species present, aerial extent and distribution of invasive species, new exotic species detected at common invasion points categorized by invasive potential, vegetation types invaded

Basic Approach:
Two methods are currently underway for assessing the extent and distribution of invasive plant species in south Florida and U.S. Virgin Island parks: 1) Digital Aerial Sketch Mapping (DASM) and 2) complete surveys. DASM was developed in the 1990's by the USDA Forest Service for the aerial detection and mapping of forest pests and pathogens. In 2005, the National Park Service (NPS) and the South Florida Water Management District (SFWMD) conducted an accurate and cost effective pilot project utilizing DASM technology for the mapping of invasive plant species in the 4 million-acre Everglades Protection Area. Using aircraft, observers sketch invasive plant distribution on touch-sensitive computer displays showing the aircraft's GPS position against a background of moving digital aerial photos and background data.

This method is currently underway for Big Cypress and Everglades National Park every 2 years. For the islands of BISC and BUIS, when an invasive species control effort is conducted, the EPMT specialist and contractors also do a complete survey of the islands involved, noting all invasive species. Digital aerial surveys for SARI and VIIS have yet to be implemented but are expected soon. This monitoring is conducted by the NPS-EPMT program but they have requested about 2 weeks of time of SFCN for a GIS knowledgeable technician or intern to work in cooperation with their own intern to process and analyze the digital aerial sketch mapping results.

SFCN will work with EPMT to develop a "Corridors of invasiveness" protocol which will involve an experienced botanist surveying corridors (public roads, fire roads, trails, beaches and canals) at low speeds for newly emerging and existing exotic plant species and recording GPS positions. Transects will be established perpendicular to corridors to detect species with lower detectability from vehicles, determine width of impact corridor, and detect presence of biological control agents. Extensive searches of known problem locations (trailheads, boat ramps, campgrounds) will be conducted. Data will be geospatially analyzed. The botanist involved should have a widespread knowledge of south Florida and/or US Virgin Islands vegetation and be able to detect exotic and unknown species as possible invasive species. This protocol will be implemented in a rotating design with only a portion of the parks surveyed each year with a revisit of approximately 5-8 years. Implementation is expected to be jointly by SFCN and NPS-EPMT personnel.

The Southeast Exotic Pest Plant Council's (SEEPPC) web-based invasive plant mapping geospatial database will be used to collect data provided by researchers currently working within the south florida parks acting as "professional exotic plant informants. SEEPPC's mapping project provides invasive plant species distribution by: compiling current data from existing sources; receiving new data from volunteers; and, providing user-friendly access to data online (www.se-eppc.org) which is useful in aiding early detection/rapid response programs, increasing accuracy of predictive modeling projects. SFCN is discussing whether a requirement to report invasive plant species could be included with permits for researchers conducting work in the parks and is working on outreach materials. Researchers are already asked to report "unusual conditions" so this would be a reasonable extension of this requirement.

SFCN is working with NPS-EPMT to develop robust exotic treatment efficacy monitoring protocols. Current pilot methods include pre- and annual post-treatment sampling of permanent plots within NPS treatment areas measuring plant species cover, richness and diversity (Daubenmire method) as well as canopy cover. Implementation is expected to be by NPS-EPMT with assistance by SFCN in developing the protocols involved.

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Development Schedule, Budget, and Expected Interim Products:
The "Corridors of Invasiveness" protocol is expected to take about 3 months of SFCN staff time and 3 months of EPMT staff time to draft and test the protocols plus staff time to develop the web page. Implementation is partially dependant on EPMT funding. The corridors of invasiveness protocol is expected to take 3 weeks of field time/year and will be rotated among the parks. The digital sketch mapping protocol should take less than a month to write as it is fairly well established. Processing and analysis of the data should take about 1.5 weeks each from an SFCN technician/intern and a EPMT intern.

The expected product is a "Corridors of Invasiveness" protocol, with assistance provided to EPMT to develop an exotic treatment efficacy protocol and formalization of the Digital Aerial Sketch Mapping protocol. Protocol completion is expected by 2009-2010 assuming hiring of technicians occurs as planned.

Expected SFCN staff time requirements once program is fully implemented in 5 years:

SFCN Staff	Full Time Equivalent (FTE)
Coordinator	
Marine Ecologist	
Fisheries Biologist	
Marine Biologist Technician (So FL)	
Marine Biologist Technician (VI)	
Community Ecologist	0.02
Wildlife Technician (Wildlife)	
Wildlife Technician (Vegetation)	0.04
Quantitative Ecologist	
Data Manager	0.04
GIS/Data Tech	0.08
Interns	
SFCN Total	0.18

Vital Sign: Island Insects

[shortened name: Island_Insects]

Parks Where Vital Sign will be Implemented:
BISC, BUIS, DRTO, EVER, SARI, VIIS - deferred

Justification/Issues being addressed: Island Insects ranked 41st among the 44 SFCN vital signs. Small islands have very simple food webs compared with mainland areas or large islands (e.g., Puerto Rico). It is assumed that insects are important in these island communities, (e.g., beetles are important to nutrient recycling and as prey base; bees are susceptible to invasive species, etc.).

General Monitoring Questions to be Addressed by the Vital Sign:

- What are the status and trends in the composition and distribution of major insect groups (e.g., beetles, pollinators)?
- What invasive species are present and how are they distributed?

Measures:
To be determined

Basic Approach:
Deferred due to insufficient funds/staff time

Principal Investigators/Key Contacts and NPS Lead:
N/A

Development schedule, budget, and expected interim products:
N/A

References

In review. Medrano-Cabral, S. and M. A. Ivie. A Catalog of the Species of *Phyllophaga* Harris (Scarabaeidae: Melolonthinae) from the Virgin Islands, West Indies, with the Description of an New Species. Zootaxia.

Vital Sign: Landbirds

[shortened name: Landbirds]

Parks Where Vital Sign will be Implemented:
BICY, BISC, BUIS, DRTO, EVER, SARI, VIIS - deferred

Justification/Issues being addressed: Landbirds ranked 24th among the 44 SFCN vital signs.
Birds are good indicators of ecosystem health and integrity and are early responders to change across the landscape, responding quickly in foraging and nesting patterns to both habitat degradation and to habitat improvement and restoration. The USVI and South Florida hold a variety of native species and are important migratory stop-overs for many non-native bird species, providing over-wintering habitats. Two habitats deserve special mention: SFCN Parks (coupled with State Parks and 10000 Islands NWR) contain some of the largest, intact tracts of mangrove forest left in North America. However, little is known about the ecology of mangrove ecosystems and especially mangrove landbirds, of which several are thought to be at risk of becoming endangered (e.g., White-crowned pigeon and Florida Prairie Warbler). Pine rocklands, an important upland habitat and a globally imperiled ecosystem, are almost entirely found within EVER and the southeast corner of BICY (with some remnants in the Bahamas). Habitat loss, and altered fire and hydrologic regimes have contributed to the extirpation of seven breeding bird species within pine rocklands in EVER, of which five are cavity-nesting species. Efforts are underway to re-establish two of these species (eastern bluebird and brown-headed nuthatch) with hopes of later re-establishing others. Monitoring fecundity and nestling survival would provide an early indicator of habitat quality and causes of change.

General Monitoring Questions to be Addressed by the Vital Sign:

- What are the status and trends in the abundance and distribution of land birds (residential and migratory) overall and in specific habitats (e.g. pine rocklands, mangroves)?
- In specific habitats (e.g. pine rocklands), what are the status and trends in fecundity and nestling survivorship?

Measures:
Abundance, distribution, community composition

Basic Approach:
SFCN will seek to get reports on the pine rocklands monitoring using point counts being conducted by Gary Slater in EVER (Long Pine Key) and BICY (Racoon Point) and the pilot mangrove bird monitoring project at BISC and post summaries as well as copies of the reports. However the long-term funding for these programs is not yet assured.

Otherwise, this indicator is deferred due to lack of funding/staff time.

While Christmas Bird Count and Breeding Bird Survey routes are being conducted within these parks, in other parts of the U.S. these data have been found to be more useful for assessing trends from a region-wide level (multi-state) than at a park-wide level. However the Quantitative Ecologist will take a look at the Christmas Bird Count, Breeding Bird Count, and another data set from a park ranger in VIIS who does weekly counts at a salt pond to see if the data can be useful for assessing trends at these sites in abundance and/or in timing of migrations.

Principal Investigators, NPS Lead and other important resources:

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- Tropical Audubon Society, www.tropicalaudubon.org
- Thomas Brandeis, USDA-FS

Development schedule, budget, and expected interim products:

SFCN will seek to get reports on the pine rocklands monitoring being conducted by Gary Slater in EVER and begin posting summaries to the SFCN web page in 2008.

Otherwise, this indicator is deferred due to lack of funding.

If SFCN were to take on this indicator, the estimated effort required is *at least* 100 point counts/habitat or park. Point Reyes Bird Observatory estimates that approximately 6-12 points can be done per day. Assuming that just 100 points/park are needed, about 6 weeks of work for two people including data entry and basic analysis would be needed (assumes protocols and sampling design are established). To cover all parks this would take about 1.5 FTE. To outsource the monitoring would take about $30-50K per 100 points (or $210-350K for all 7 parks).

Vital Sign: Land Use Change

[shortened name: Land_Use]

Parks Where Vital Sign will be Implemented:
BICY, BISC, EVER, SARI, VIIS

Justification/Issues being addressed: Land Use Change ranked 11th among the 44 SFCN vital signs. Changes in land use, sizes of the non-urban buffers around park boundaries, development of inholdings within park boundaries, and connectivity with other conserved natural areas impact park resources. Monitoring of changes over time would allow parks to understand the effects of these changes and to take appropriate actions to mitigate impacts.

General Monitoring Questions to be Addressed by the Vital Sign:

- What are the status and long-term trends in landscape change in and around SFCN parks (e.g. changes in land use (municipal, private, commercial, agriculture), land cover, road density, housing density, etc.)?
- What are the near future changes expected in and around SFCN parks based upon building permits, zoning changes, and community planning decisions?

Measures:
Land use change, permitting/zoning changes, demographics within 1 mile of USVI parks, 75 miles of S. Florida parks

Basic Approach:
SFCN GIS Technician will coordinate with FIU, County, and SFWMD efforts. GIS Layers of in-holdings will be collected.

Future land use change will require the periodic review of building permits and zoning changes. On a semi-annual basis contact will be made with each of the county level or equivalent permitting offices effecting areas around the park. The latest list of permit applicants including information on location type and size of development would be obtained from the government entity (especially Developments of Regional Impact, DRIs, for the state of Florida). The location of these permits will then be mapped to show the latest areas of planned development. SFCN would also work to get copies of state and county long-term plans so that parks can be alerted to long-term changes before it is too late to take action.

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- Trust for Public Lands
- South Florida Water Management District
- Florida International University
- County Governments
- USVI Department of Planning and Natural Resources

Development schedule, budget, and expected interim products:
SFCN will develop a "Land Use Change" protocol by 2009. The WASO office is working on a protocol for compiling general land use statistics which SFCN can pull from. Initial deliverables for network parks should include updated boundaries and layer of known inholdings. For the general land use portion of the protocol, each park would receive an update on land use every 5-10 years, but SFCN may work on these in rotation depending on whether work is done by NPS or contractor. If this work is contracted it is expected to cost approximately $100,000. Tracking of building permits would be on an annual basis but in theory this could be accomplished by an intern. The product from their internship would be a report listing and mapping all of the permits affecting a specific park. Anticipated staff time and additional costs:1 FTE every 5 years plus 1/2 intern annually; $5,000 per year for imagery (majority of imagery would be obtained from local governments.

Expected SFCN staff time requirements once program is fully implemented in 5 years:

SFCN Staff	Full Time Equivalent (FTE)
Coordinator	0.04
Marine Ecologist	
Fisheries Biologist	
Marine Biologist Technician (So FL)	
Marine Biologist Technician (VI)	
Community Ecologist	
Wildlife Technician (Wildlife)	
Wildlife Technician (Vegetation)	
Quantitative Ecologist	
Data Manager	
GIS/Data Tech	
Interns	0.5
SFCN Total	0.54

Vital Sign: Mangrove-Marsh Ecotone

[shortened name: Mangrove_Ecotone]

Parks Where Vital Sign will be Implemented:
BICY, BISC, BUIS, DRTO, EVER, SARI, VIIS– SFCN will evaluate existing monitoring and where possible build upon it or develop new sampling plan

Justification/Issues being addressed: Mangrove-Marsh Ecotone ranked 14th among the 44 SFCN vital signs. Mangroves provide important juvenile fish and invertebrate nursery areas, habitat for birds and rare plants, as well as providing important shoreline protection. Over 50% of the mangroves in the Virgin Islands have been lost since 1950. Ecotones are transition zones between habitats and are generally dynamic locations for flora and fauna. Due to the sharp transition between habitats, tracking the position of ecotones can indicate the long-term trajectory of habitats. Understanding the physical conditions which drive changes in the ecotone location is critical for proper resource management. Examples of ecotones include mangrove-tidal marsh ecotones, mangrove-marsh-cypress, and mangrove-freshwater marsh ecotones. Ecotones are expected to move, for example, in response to changes in water management, sea level rise, and fire management. Tracking the position of mangrove-marsh ecotones can indicate the long-term trajectory of a wetland ecosystem, while accounting for regional water management changes and sea-level rise. Ecotone positioning can be effectively monitored by aerial photography. At selected sentinel sites in South Florida, ecotone movement across the landscape has been an important indicator for water management (e.g., "White Zone" in southeast Everglades).

General Monitoring Questions to be Addressed by the Vital Sign:

- Are ecotones shifting or changing in aerial size (widening or narrowing) due to physical conditions (e.g., sea level rise, hydrology, climate change, anthropogenic factors, fire, episodic metrological and storm wave events, etc.)?
- What are the status and trends in plant community composition and structure?

Measures:
Community composition and physical structure (e.g., canopy height, vegetative cover of each plant species, canopy cover in each stratum (canopy, herb layer, shrub layer, etc)), shifts in community boundaries, soil depth, litter depth

Basic Approach:
SFCN will coordinate with existing programs where appropriate, such as mangrove monitoring by Tom Smith of FIU.

1) SFCN will evaluate ecotonal change using both aerial photography monitoring and field monitoring via belt transects or a series of plots set up along a longer transect.

Table 1 shows the types of ecotones to be monitored and which methods will be used. Revisit time is likely to be once every 5 years or after major disturbance event (fire, frost, hurricane) and administered in a rotating panel.

Although porewater salinity was also identified as an additional indicator to monitor in this zone, this monitoring is deferred due to insufficient funds.

2) SFCN will evaluate long-term change within plant communities via field plots revisited approximately once every 5-10 years (see Table 2). Soil Elevation Tables will be co-located with a subset of plots.

Table 1. Plan for Ecotone Monitoring
A= monitored with aerial photography
F= monitored with field plots

	Pineland to Hammock	Coastal to Inland	Forest to Wet Prairie	Wet Prairie to marsh/slough
BISC		**A,F**	**A**	
BICY	**A,F**	**A,F**	**A**	
EVER	**A,F**	**A,F**	**A**	**A,F**
DRTO		**A,F**		
SARI		**A,F**		
BUIS		**A,F**		
VIIS		**A,F**		

Table 2. Plan for Long-term within-community monitoring plots

+ = SFCN monitoring
♦ = Existing monitoring program

	Pineland	Hardwood Hammock	Mangroves	Marshes	Island Moist Forest	Island Deciduous Forest	Island Scrub/ Shrub
BISC		**+,♦**	**+**				
BICY	**♦**	**+**	**+**				
EVER	**♦**	**+,♦**	**♦**	**♦**			
DRTO			**+**				
SARI			**+**				
BUIS			**+**			**+**	**+**
VIIS			**+**		**+,♦**	**+,♦**	**+**

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- Jimi Sadle, Everglades National Park, Jimi_Sadle@nps.gov
- Craig Smith, Everglades National Park
- Prof. Mike Ross, Florida International University, rossm@fiu.edu, 305-348-1420 (tree island monitoring)
- Rafe Boulon, Resource Manager, Virgin Islands National Park. 340 693-8950 x224, Rafe_Boulon@nps.gov,

Development schedule, budget, and expected interim products:

SFCN is working in cooperation with Jenny Richards of FIU to hire a post-doc to work on vegetation monitoring protocols. The "Mangrove-Marsh Ecotone & Mangrove Community" protocol development is expected to be completed by 2010. Implementation is expected to take 0.33 FTE/year each for the community ecologist and two wildlife technicians across all habitat types including forest and marshes which are covered under other vital signs. For the evaluation of change via aerial photography, this is expected to take the GIS/Data technician approximately 2 months/year. Cost is estimated to be $10,000/year to cover helicopter time plus stakes, etc. Table indicates proposed SFCN workload upon full monitoring implementation.

Expected SFCN staff time requirements once program is fully implemented in 5 years:

SFCN Staff	Full Time Equivalent (FTE)
Coordinator	
Marine Ecologist	
Fisheries Biologist	
Marine Biologist Technician (So FL)	
Marine Biologist Technician (VI)	
Community Ecologist	0.3
Wildlife Technician (Wildlife)	0.4
Wildlife Technician (Vegetation)	0.4
Quantitative Ecologist	0.06
Data Manager	0.04
GIS/Data Tech	0.2
Interns	0.3
SFCN Total	1.7

Vital Sign: Marine Benthic Communities

[shortened name: Marine_Benthic_Communities]

Parks Where Vital Sign will be implemented:
BISC, BUIS, DRTO, EVER, SARI, VIIS – SFCN conducts monitoring for coral communities; SFCN collaborates for monitoring SAV in BISC, BUIS, DRTO, SARI, VIIS and summarizes reports in Biscayne Bay (BISC) and Florida Bay (EVER).

Justification/Issues being addressed: Marine Benthic Communities ranked 1st among the 44 SFCN vital signs. The vital sign Marine Benthic Communities is split into two communities: coral reef communities and seagrass and other submerged aquatic vegetation (SAV).

Coral reef communities within the SFCN represent the only eastern Caribbean and Western Atlantic Coral reefs within the National Park Service. The enabling legislation and/or presidential proclamations for VIIS, BUIS and DRTO specifically mention coral reefs within these park units as significant environmental communities. These communities consist of stony corals, octocorals, sponges, algae, and gorgonians, among others. These reefs support incredible diversity, including conch, lobsters, and endangered sea turtles. Reefs also play a vital role for humans by supporting fisheries, nursery areas, tourism, pharmaceutical bio-prospecting and shoreline protection to name a few. Monitoring coral reefs was identified as a national priority in President Clinton's Executive Order 13089, establishing the Coral Reef Initiative. These coral reefs are negatively impacted by unusually high water temperatures that cause "bleaching", coral disease, vessel scarring, major storms, overfishing, and in some cases by sedimentation and nutrient enrichment due to coastal development.

Communities of seagrass and other submerged aquatic vegetation (SAV) cover large portions of seven SFCN parks and consist of various seagrass and algae species. These habitats serve as nursery areas for many marine species, support a variety of vertebrate and invertebrate life, and provide connectivity pathways between nearshore and offshore habitats. Community composition is related to salinity levels, light extinction, the distribution of soft and hard-bottom sediments, nutrient enrichment, water quality (e.g., sulfides, redox), disease, level of disturbance, and succession. The 1987 seagrass die-off in Florida Bay had cascading effects on the ecosystem.

This Vital Sign which involves field monitoring of communities using SCUBA divers overlaps with the Benthic Communities Extent and Distribution Vital Sign which will be using remote sensing to monitor the extent, distribution and density of all map-able benthic communities.

General Monitoring Questions to be Addressed by the Vital Sign:

- What are the status and trends coral reef community percent cover of major taxonomic groups (e.g., coral, algae, gorgonians, sponge, substrate), coral species diversity, coral community structure, rugosity, coral recruitment, coral disease mortality, and algal community structure? What portions of this change are explainable, e.g., hurricanes, bleaching/disease outbreak events? How do coral communities compare among areas with differing management regimes (e.g., no-take zones vs. fished zones)?
- What are the status and trends in seagrass and other SAV extent, distribution, community composition and habitat quality, especially in relation to known gradients such as onshore-offshore, long-shore gradients, and depths? Is seagrass cover increasing in recently created no-anchor zones?

Vital Signs Measures:

Percent cover of major taxonomic groups (coral, algae, gorgonians, sponge), coral species diversity, coral community structure, rugosity, coral recruitment, coral disease mortality, and algal community structure, episodic assaults (bleaching); Seagrass and other SAV community composition, cover and habitat quality of seagrass and other SAV habitat

Basic Approach:

A "Marine Benthic Communities" protocol is being developed by SFCN. The portions relevant to this vital sign include:

1) Coral reef communities, depths of 2-20 m
2) Water temperature at reef depth
3) Seagrass
4) Deep stony coral communities, depths >20 m
5) Coral recruitment

<u>1) Coral reef communities, depths of 2-20 m</u>

11 intensive coral monitoring sites were established as part of the prototype program at BUIS and VIIS beginning in 1999 and then expanded to BISC and DRTO. The protocol, "Using Videography to Monitor Coral Reefs, and Using the Aqua-Map system" (for random within-site transect selection) was peer-reviewed in 1998. These index sites were selected because they were the sites of historical work, were sites of high coral cover, or were otherwise of management interest. Site size ranges from 7,125-20,200 m^2. 20 permanent 10 meter transects were randomly selected at each site. Each transect is videotaped annually and analyzed. These sites have proven invaluable in documenting the declines after the 2005 bleaching and disease outbreak event and provide a rigorous set of monitoring data within these sites and SFCN plans to continue monitoring them.

Because the index coral monitoring sites protocol is very localized in inference, SFCN is working to expand upon the existing protocol to a design that allows

inference to all stony coral communities 2-20m depth and will allow comparisons of inside vs. outside comparisons of marine protected areas (issue at DRTO and potentially BISC; BUIS is entirely protected). This sampling design is still in development with preliminary work being conducted at DRTO but will likely involve much smaller sites of 4 transects distributed throughout hard-bottom habitat in the parks sampled in a rotating design with the majority of sampling effort and revisit frequency at sites with higher coral cover (>5% stony coral cover) but a low-level focus and long revisit interval (10-20 years) for low coral cover hard-bottom. SFCN also hopes to establish such designs at BISC, BUIS, and SARI. With 5 intensive sites already established at VIIS, it is unclear whether additional effort is warranted there.

The videography protocol at both the intensive sites and park-wide assessments will be supplemented by rugosity measurements once every 10 years or subsequent to a major disturbance event such as a hurricane. A chain will be laid over each transect and the length of chain required compared with the straight chain length of 10m is a measure of the rugosity.

SFCN will also investigate whether there is a way to cost-effectively supplement the protocol to make it comparable to another protocol that is currently conducted with fish monitoring in DRTO but is re-randomized each year. Doing so might lend power to detect changes at lower coral cover sites, however it is unclear whether this other effort will have long-term funding.

2) Water temperature at reef depth

At each index site and at a subset of the park-wide sites, continuous data loggers will be used to record water temperature at reef depth to serve as a covariate when assessing sudden changes.

3) Seagrass

Existing monitoring programs for seagrass are being conducted in Florida Bay and Biscayne Bay by FHAP and DERM using a sampling unit design and sampling unit level methodology that is consistent with the program being used in the Florida Keys by Jim Fourqurean of FIU. Florida Bay is divided by basins and Biscayne Bay into three regions. Each basin or region is analyzed separately. The Florida Keys design involves dividing each area (basin or region) into sub-areas or cells. Five sampling units are selected in each sub-area and were revisited in a five year rotation. At each sampling unit 10 ($0.25m^2$) quadrats are assessed using the Braun-Blanquet method to assess seagrass density, composition, epiphytic load and biomass by species. These data are already analyzed and reported through the CERP RECOVER Program Monitoring and Assessment Plan System Status Report by first analyzing the number of sampling units with seagrass present and then the density of seagrass at units where it is present and then combining the two into a single index. SFCN hopes to coordinate with these programs to report results through the vital signs program as well. However SFCN will work with EVER resource management staff to review these programs as the resource management staff have expressed concerns that these

programs are not sufficient to meet park management information needs.

For the coastal shelf area of BISC and DRTO that is <20m deep, soft-bottom habitat will be sampled using a stratified random or a GRTS design using a protocol adapted from the Florida Keys and Florida and Biscayne Bays designs so that SFCN sampling will be comparable to these other groups. For BUIS and VIIS, although some seagrass monitoring occurs as part of the habitat monitoring portion of the fish monitoring effort being jointly conducted by the NOAA Biogeography team and NPS staff, the power and design is insufficient to adequately monitor trends in seagrass. SFCN will first examine some protocols used with historical work in the USVI and compare with the south Florida protocols to determine which to use given the tradeoffs of comparability with historical work versus having a single network-wide protocol. SARI and BUIS do not appear to need stratification although a spatially balanced approach to sampling is preferred. For VIIS, a stratification to allow increased sampling in areas of human impact such as Coral Bay and Cinnamon Bay will be considered.

It should be noted that some project specific monitoring is already being conducted by park staff. BISC staff are already monitoring seagrass restoration sites and VIIS staff are monitoring effectiveness of mooring buoy installation on seagrass recovery.

4) Deep stony coral communities, depths >20 m

SFCN will assess feasibility of the use of underwater ROV and/or drop cameras to collect imagery of these areas for a more qualitative level of monitoring. Much less is known about these deep coral reefs. These deep areas occur in BUIS, DRTO, SARI, and VIIS.

5) Coral recruitment

A pilot project will be conducted to determine the costs and feasibility of monitoring recruitment along these transects or a subset thereof. The time involved may make recruitment monitoring unfeasible.

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Development Schedule, Budget and Expected Interim Products:
Drafts of portions of the Marine Benthic Communities protocol for coral community monitoring at historic index sites (BISC, BUIS, DRTO, VIIS), for coral-water temperature monitoring, and *Diadema antillarum* monitoring have been completed and review comments from the NPS-WRD will be incorportated by December 2008. The portions of the Marine Benthic Communities protocol for monitoring coral communities 2-20m deep in the more extensive sites approach, will be completed by 2008. A feasibility assessment for monitoring deep water sites will begin in 2014. The portion of the protocol for monitoring SAV will be completed by 2009. Estimated staff time for coral monitoring per year is 2 FTE. Estimated staff time for monitoring SAV per year is 1 FTE.

Expected SFCN staff time requirements once program is fully implemented in 5 years:

SFCN Staff	Full Time Equivalent (FTE)
Coordinator	0.08
Marine Ecologist	0.6
Fisheries Biologist	0.6
Marine Biologist Technician (So FL)	0.7
Marine Biologist Technician (VI)	0.7
Community Ecologist	
Wildlife Technician (Wildlife)	
Wildlife Technician (Vegetation)	
Quantitative Ecologist	0.1
Data Manager	0.08
GIS/Data Tech	0.04
Interns	
SFCN Total	2.9

Vital Sign: Marine Exploited Invertebrates

[shortened name: Exploited_Inverts]

Parks Where Vital Sign will be Implemented:
BISC, BUIS, DRTO, EVER, SARI, VIIS – SFCN is monitoring lobster, conch; analyzes harvest data; summarizes reports from existing programs

Justification/Issues being addressed: Marine Exploited Invertebrates ranked 10th among the 44 SFCN vital signs. The exploited invertebrate assemblage (spiny lobster, pink shrimp, queen conch, crabs, sponges, oysters and whelk) includes herbivores, filter feeders, intermediate feeders, and omnivores. These species are under heavy fishing and commercial harvest pressure outside SFCN park boundaries and in some cases within park boundaries, have complicated reproductive cycles, frequently use multiple habitats inside and outside park boundaries, and can be affected by regional connectivity and stressors. Balancing resource extraction and environmental degradation with sustainability is a key management concern. The impacts of fishery management tools such as marine protected areas (BUIS, portions of DRTO) are of interest to resource managers and the public.

- The Spiny lobster (*Panulirus argus*) life cycle includes both a free-swimming larval phase and a benthic adult life stage. Adult spiny lobsters feed mainly on gastropods, chitons, bivalves, corals and scavenged food remains. Adults are heavily harvested outside parks and a managed harvest within BISC and VIIS.
- Queen conch (*Strombus gigas*) This is a heavily harvested species with strict take/no-take regulations in all of the marine parks in the SFCN.
- Pink shrimp (*Farfantepenaeus duorarum*) function as both a predatory and prey species within the marine ecosystem, providing a large amount of biomass in Florida Bay and Biscayne Bay. They are sensitive to changes in hydrological modifications, salinity patterns, and circulation effects on larval transport. Florida Bay is an important nursery ground for larval recruitment to the Dry Tortugas region commercially harvested fishery. Pink shrimp are both recreationally and commercially harvested within Biscayne Bay.
- Crabs (Stone, Blue and others) Stone crabs are a highly valuable marine resource, The Florida stone crab fishery provides 99% of all stone crab landings in the United States and the stone crab fishery is always in the top five fisheries of Florida.
- Oysters (*Crassostrea virginica)* are filter feeders and become prey to many species of fish and larger invertebrates. Oysters develop into oyster bar communities which form an extensive habitat along western edge of EVER. Oysters were once present in greater numbers within Biscayne Bay, but are now rare. Oysters have a strong association with moderate saline conditions and are being considered an indicator of proper hydrological flows for Biscayne Bay. Their shell accumulations provide information about the physical, chemical and biological conditions that allow them to flourish.

- Whelk - This mollusk is a harvested species in the Virgin Islands with size and number limits placed upon them.
- Wool Sponges - BISC Bay is a sponge harvest sanctuary. Offshore of the islands, commercial harvesting of sponges is regulated by state of Florida regulations. These were heavily harvested around the turn of the century for bathing and washing, but that harvest has decreased since the invention of synthetic sponges. They provide filtration of sediments and other marine particles to help improve water clarity, and provide shelter for juvenile fish and other invertebrates. Extraction of sponges in the other south Florida parks is regulated by the state.

General Monitoring Questions to be Addressed by the Vital Sign:

- What are the status, variability, and trends in exploited invertebrates: Lobster (relative abundance/density, distribution, size structure, sex ratio, regional harvest); Conch (density, distribution, size structure/maturity); pink shrimp (density, distribution, harvest); blue crab (harvest); stone crab (harvest); oysters (distribution); sponges (harvest); whelks (density, size structure)?

Measures: Lobster (Spatial/temporal distribution, abundance/density, size structure), Conch (spatial distribution, density, size structure, proportion immature), regional commercial harvest (Lobster, Conch, Crabs, Shrimp, Stone Crab, Blue Crab, Oysters, Sponges, Whelks)

Basic Approach:

SFCN will be monitoring spiny lobster and testing protocols for conch to see if they can be incorporated into seagrass monitoring with little additional effort. Otherwise SFCN will be working with existing programs to gather and summarize their reports and to analyze regional harvest data.

Lobster (relative abundance/density, size structure, sex ratio, regional harvest)
VIIS, VICR, BUIS, SARI, DRTO, BISC, EVER
SFCN will conduct pilot protocol testing for lobster monitoring, evaluating the use of timed searches at coral monitoring sites as well as investigating other potential fisheries independent monitoring techniques for the purpose of creating a "Spiny Lobster" protocol. Long-term monitoring conducted by FWRI is in a transitional period where past methodologies are being evaluated for power and efficacy. SFCN will stay abreast of those decisions when making our determination of what methodologies and sampling design to use and will try to coordinate with those efforts if appropriate. SFCN will also investigate coordinating with BISC lobster creel surveys and will assess commercial harvest data from the state of Florida.

Conch (density, size structure/maturity)
SFCN will conduct pilot conch counts during seagrass surveys to see if there is sufficient power to evaluate trends. Measurements of carapace length and presence

of lip indicating maturity will be taken. Conch data are already available from the NOAA Biogeography team's fish and benthic monitoring in USVI parks to assess power using their methodology in the USVI.

Pink shrimp (density, distribution, harvest) BISC,EVER
SFCN will seek to acquire and summarize the reports from the existing program being conducted by Joan Browder and Mike Roblee to estimate juvenile populations in Florida Bay.

Commercial harvest data from the state of Florida for BISC will be evaluated.

Blue crab (harvest) BISC only
Commercial harvest data from the state of Florida for BISC will be evaluated.
Other monitoring is deferred due to staff/time/funding demands.

Stone crab (harvest) BISC only
Commercial harvest data from the state of Florida for BISC will be evaluated.
SFCN will also seek to acquire and summarize the reports from an existing stone crab fishery-independent monitoring program (Anne McMillen-Jackson, FWRI). Other monitoring is deferred due to staff/time/funding demands.

Oysters (distribution) EVER only
Monitoring of oysters is deferred due to staff/time/funding demands.

Sponges (harvest)
Commercial harvest data from the state of Florida for BISC will be evaluated.
Other monitoring is deferred due to staff/time/funding demands.

Whelks (density, size structure) VIIS
SFCN will coordinate with park monitoring if this is implemented but otherwise is not establishing a monitoring program at this time.

SFCN will acquire south Florida commercial landings data from the following web site.
http://research.myfwc.com/features/view_article.asp?id=19224

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Development Schedule, Budget, and Expected Interim Products:
The Spiny Lobster protocol completion is expected by 2010. Conch surveys, if determined to be feasible when co-located with seagrass monitoring, will be described in the "Marine Benthic Communities" protocol by 2009. Commercial landing information will begin being compiled by 2009. Staff time estimated for lobster monitoring is 0.3 FTE.

Expected SFCN staff time requirements once program is fully implemented in 5 years:

SFCN Staff	Full Time Equivalent (FTE)
Coordinator	
Marine Ecologist	0.08
Fisheries Biologist	0.08
Marine Biologist Technician (So FL)	0.08
Marine Biologist Technician (VI)	0.08
Community Ecologist	
Wildlife Technician (Wildlife)	
Wildlife Technician (Vegetation)	
Quantitative Ecologist	0.04
Data Manager	0.04
GIS/Data Tech	0.06
Interns	
SFCN Total	0.46

Reference:
Cox, C. and J. H. Hunt. 2005. Change in size and abundance of Caribbean spiny lobsters Panulirus argus, in a marine reserve in the Florida Keys National Marine Sanctuary, USA. Mar. Ecol. Prog. Ser. 294:227-239.

Vital Sign: Marine Fish Communities

[shortened name: Marine_Fish]

Parks Where Vital Sign will be Implemented:
BISC, BUIS, DRTO, EVER, SARI, VIIS – SFCN augments existing monitoring; conducts additional park-specific analyses as necessary; summarizes reports

Justification/Issues being addressed: Marine Fish Communities ranked 2nd among the 44 SFCN vital signs. Fish communities in the coastal shelf and oceanic areas are an important higher trophic level of the marine system, valued by humans as fisheries. Community status, structure and trends reflect changes in marine habitat quality, connectivity, fishing pressure, and long-term ecosystem resilience. Community status also affects seabird communities and large marine vertebrates. Balancing resource extraction with sustainability is a management concern. The exploited reef fish assemblage contains intermediate and higher trophic level piscivores although herbivores are added in heavily fished USVI. These species are under heavy fishing pressure within and outside SFCN parks boundaries. The impacts of fishery management tools such as "no-take" zones are of critical interest to resource managers and the public. Several fish species within parks are at or near local or regional extirpation.

General Monitoring Questions to be Addressed by the Vital Sign:

- What are the status, trends, and variability in exploited fish assemblages (e.g., Grouper/Snapper/Parrotfish/Surgeonfish), reef fish communities, and nearshore and estuarine (bay) fish communities? Are there differences among areas with different management regimes?
- If present within parks, what are the locations and size of spawning aggregations?

Measures: Fish community taxonomic composition, species richness, targeted species (Grouper, Snapper, (parrotfish, surgeonfish in USVI), baitfish) spatial/temporal distribution, abundance/density, size structure, recruitment, biomass, fishing pressure, spawning aggregation characteristics

Basic Approach:
Considerable existing monitoring efforts are underway for South Florida and the US Virgin Islands Parks. Rather than designing new programs, SFCN will instead seek to coordinate with these existing programs and augment sampling as needed to allow for park assessment of trends as well as regional assessments. If these programs are cut, SFCN will focus on filling the need with existing staff time using the following priorities: reef fish within parks, reef fish in neighboring areas outside protected areas in parks (to allow management comparison), fish in seagrass/bays. The justification for prioritizing monitoring fish on the reef is that many juvenile fish species which inhabit seagrass and nearshore areas, migrate to adult lives on the

reefs. Monitoring fish in bays provides important information about this stage in the life cycle for management, but some of these changes will be reflected in the reef fish counts as well. Until a power analysis for BISC and DRTO reef fish monitoring is completed, SFCN won't know how much effort will be required to augment reef fish sampling in those parks and what resources are remaining to cover nearshore areas and bays. Currently SFCN staff are working about 17 weeks a year on fish monitoring activities. SFCN proposes to more than double that effort to 1 FTE equivalent a year of effort. SFCN has entered a cooperative agreement to fund a post-doctoral fellow in collaboration with Jerry Ault of the University of Miami – RSMAS to work out the details of how the groups will collaborate, conduct power analyses, work on the habitat component of the protocol and ensure that a written protocol document is completed.

Reef fish: For monitoring reef fish communities SFCN will be using visual point count or transect methods. Existing programs in south Florida parks and USVI parks are using different methodologies which are discussed below. The exploited fish species are a subset of the reef community and both objectives are met using a single protocol. However power analysis will need to focus on the exploited species to make sure there is enough power to assess trends in those species as well as aggregated community metrics.

Reef fish – South Florida
SFCN will be collaborating with the ongoing NOAA and University of Miami fish monitoring (Jim Bohnsack and Jerry Ault respectively) being conducted at BISC and DRTO. The sampling design is a two-stage stratified random design on coral reef habitats only with 8 different types of coral hard-bottom defined as different strata. Primary 200m x 200m sampling units are re-randomized each year with 2 second-stage units randomly located in each primary unit and two diver stationary visual point counts per secondary unit conducted by scuba divers (Menza *et al.*, 2006). Currently the sample size is designed to assess changes in the Florida Keys and greater Dry Tortugas region. Monitoring in the Florida Keys is currently conducted annually and in the Dry Tortugas every two years. SFCN is funding a post-doc to work with NOAA and the University of Miami to determine power and additional sampling needed to be able to report trends within the park boundaries plus assess trends inside and outside the newly established DRTO Research Natural Area (a no-fishing marine protected area). This monitoring is also critical to meet the needs of the *DRAFT Research Natural Area monitoring (RNA) and research plan: a joint Florida Fish and Wildlife Conservation Commission-National Park Service plan to assess the conservation efficacy of the RNA* (Hunt *et al.*, 2007).

The major fish monitoring efforts in the Florida Keys held a workshop in April 2007 in order to better coordinate among their protocols and sampling designs (Acosta *et al.*, 2007) so some adjustments in protocols to allow for pooling of data are under discussion.

SFCN staff has already assisted with the DRTO fish monitoring cruises in the past and expects to assist with the supplemental fish monitoring needed to report on trends within BISC and DRTO. SFCN also anticipates conducting some reef fish monitoring at DRTO during the "off" years that RSMAS is not conducting it. SFCN will also provide assistance with the park-specific supplemental analyses, if needed.

To provide a general measure of fishing pressure SFCN will assess trends in south Florida commercial harvest data and numbers of recreational saltwater fishing licenses and recreational vessel registrations. This is easily obtainable information in south Florida and provides an estimate of the fishing pressure in south Florida in and around the parks. Unfortunately it is unclear whether this information is consistently tracked in the USVI.

Marine Fish Communities - USVI

The NOAA Center for Coastal Monitoring and Assessment (CCMA) Biogeography Team Coral Reef Ecosystem Monitoring Program (CREMP) has been monitoring reef fish in and outside BUIS, VIIS, and VICR as well as La Parguera, Puerto Rico since 2001 using a multi-agency effort. Strata involve benthic habitat (hardbottom vs soft-bottom), management (inside vs. outside protected area) and geographic zone. Please note that this involves more habitats than the South Florida efforts which focus only on hardbottom and reef bottom in particular.The overall design is stratified random with the sampling unit protocol being a visual belt transect and visual point count conducted by scuba divers. Simultaneous measurements of benthic habitat (seagrass, coral), and other species of interest (lobster, conch, diadema) occur. Although the south Florida and USVI protocols are very aware of each other's efforts, it is unclear at this point whether the south Florida and the USVI protocols will be standardized or not. SFCN has already assisted with the BUIS and VIIS/VICR fish "blitzes" monitoring efforts and expects to continue doing so in the future.

The CREMP effort described above was originally funded for 3 years through a BUIS NRPP project which ended in 2007. It is unclear whether the effort will continue now that NRPP funding is no longer available. If this effort ceases to be funded, SFCN plans to continue the efforts within the parks, but may evaluate the data to determine the consequences if monitoring is restricted to hard-bottom only sites or restricting monitoring to within-park boundaries.

Bays & Mangroves – South Florida & USVI

SFCN will first seek to coordinate with existing efforts that are monitoring fish along mangrove (Joe Serafy/NOAA in BISC; and Ed Matheson, Robert McMichael/FFWCC in Florida Bay). Funding is provided by CERP and long-term funding is unclear. SFCN will look at these existing programs and see if they are sufficient or if additional effort is warranted. SFCN also has a juvenile fish monitoring program underway in

the USVI. This program is at a point where analysis of the data for trends and power would be very useful and this will be a task for the new SFCN marine post-doc.

Spawning aggregations
Regarding spawning aggregations, SFCN will investigate by contacting researchers to determine if and where spawning aggregations occur in or near the parks and what work is being done.

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Development Schedule, Budget, and Expected Interim Products:
SFCN is working in collaboration with the University of Miami-RSMAS, National Marine Fisheries Service and FWRI to ensure a written protocol is produced covering the collaborative monitoring underway between RSMAS, NOAA, FWRI and NPS. The NOAA-Biogeography team already has a different written protocol and the SFCN/post-doc will work out details of interactions between the two groups. SFCN is currently an active participant in multi-agency fish monitoring with both the South Florida and USVI groups. Implementation of a sample design for reef fish monitoring in network parks will be completed by 2009; nearshore and estuarine will be completed by 2010. Estimated staff time for fish community monitoring is 1 FTE.

Expected SFCN staff time requirements once program is fully implemented in 5 years:

SFCN Staff	Full Time Equivalent (FTE)
Coordinator	0.04
Marine Ecologist	0.2
Fisheries Biologist	0.2
Marine Biologist Technician (So FL)	0.2
Marine Biologist Technician (VI)	0.2
Community Ecologist	
Wildlife Technician (Wildlife)	
Wildlife Technician (Vegetation)	
Quantitative Ecologist	0.06
Data Manager	0.04
GIS/Data Tech	0.04
Interns	
SFCN Total	0.98

Vital Sign: Marine Infaunal Community

[shortened name: Marine_Infaunal]

Parks Where Vital Sign will be Implemented:
BICY, BISC, BUIS, DRTO, EVER, SARI, VIIS - deferred

Justification/Issues being addressed: Marine Infaunal Community ranked 36th among the 44 SFCN vital signs. Infaunal benthic communities include bivalves (clams), worms (polychaetes and oligochaetes), amphipod crustaceans, insect larvae, etc., that live within the marine substrate. They are heavily preyed upon by crabs and fish. Community composition and structure differ with habitat, salinity, and dissolved oxygen. Community composition is sensitive to changes in water quality, particularly contaminants (e.g., pesticides, heavy metals), changing salinity, and dissolved oxygen (related to nutrient and organics enrichment). Infaunal benthic communities are indicators of overall estuarine health in FL Bay and Biscayne Bay, and can be valuable indicators in ecotonal areas or areas of suspected contaminant input. They respond to the general water quality and contaminant levels at a site through time. A South Florida index for biological integrity has yet to be developed.

General Monitoring Questions to be Addressed by the Vital Sign:

- What are the status and trends in the distribution and abundance of important indicators and keystone organisms, especially with respect to salinity and nutrient gradients?

Measures:
Species composition, abundance, distribution, species richness/ diversity, in conjunction with water and sediment quality monitoring

Basic Approach:
Deferred due to insufficient funds/staff time

Principal Investigators/Key Contacts and NPS Lead:
N/A

Development schedule, budget, and expected interim products:
N/A

Vital Sign: Marine Invertebrates-Rare, Threatened, and Endangered

[shortened name: Marine_Inverts-RTE]

Parks Where Vital Sign will be implemented:
BISC, BUIS, DRTO, EVER, SARI, VIIS – SFCN will monitor Diadema; assist with Acroporiid protocol & database design if desired and summarize reports; conduct inventories of black coral.

Justification/Issues being addressed: Marine Invertebrates-Rare, Threatened and Endangered (RTE) ranked 6th among the 44 SFCN vital signs. Critically imperiled or rare invertebrate species within the marine community are important indicators and subjects for monitoring, as they are significant drivers/architects of reef community and structure. Elkhorn coral (*Acropora palmata*), once the primary reef building species, has declined >95% in some areas, dramatically effecting many marine and coastal processes. Black long-spined sea urchins (*Diadema antillarum*), once abundant herbivores, have significantly reduced populations, dramatically affecting herbivory of marine algae on coral reefs, which subsequently affects coral reef recruitment and growth processes. Black corals (*Antipathes* sp.) have been over-harvested for jewelry to the point that they are now considered rare and shallow water populations are gone.

General Monitoring Questions to be Addressed by the Vital Sign:

- What are the status and trends of these rare, threatened, and endangered species (Acropora spp., Antipathes spp., and Diadema antillarum) in relative abundance and distribution?

Measures:
Species dependent (Acropora, Diadema, Antipathes)

Basic Approach:
Acropriid species: Due to the ESA listing, we acknowledge that the parks are or will actively conduct monitoring and reporting of these species. SFCN is offering to assist development of park monitoring protocols for these species if desired by park staff with the idea of having a multi-park protocol that allows network-wide comparisons. BUIS is already well underway in developing their protocol and may be a useful prototype for the other parks to follow. Implementation of such protocols is assumed to be the parks' responsibility. SFCN hopes to synthesize multi-park data sets into cohesive reporting of this vital sign. This vital sign overlaps monitoring conducted in other marine vital signs, therefore SFCN will report findings of these species when encountered.

Black long-spined sea urchin: Monitoring of *D. antillarium* will be conducted along transects co-located along coral monitoring transects using a Standard Operating Procedure (SOP) already developed by the Prototype program.

Black coral: Given the habitat requirements of this very rare species, (e.g., deep, low light) likely monitoring locations for this species will need to be identified and surveyed. Thus SFCN proposes an initial inventory of locations of this species within the network parks. Feasibility for development of a long term trend monitoring protocol will be based upon initial inventory results.

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Development Schedule, Budget, and Expected Interim Products:

Protocols for Acropora monitoring are being conducted within the parks currently. SFCN is offering to assist development of park monitoring protocols for these species if desired by park staff with the idea of having a multi-park protocol that allows network-wide comparisons. SFCN is offering to assist with multi-park data summaries if desired by network parks.

Diadema monitoring is already incorporated into the "Marine Benthic Communities" protocol and this Standard Operating Procedure (SOP) will be completed in 2007 and included with the Coral Reef Monitoring Protocol.

If not accomplished during activities associated with other marine surveys, dedicated surveys for black coral will begin in 2011.

Expected SFCN staff time requirements once program is fully implemented in 5 years:

SFCN Staff	Full Time Equivalent (FTE)
Coordinator	
Marine Ecologist	0.02
Fisheries Biologist	
Marine Biologist Technician (So FL)	
Marine Biologist Technician (VI)	
Community Ecologist	
Wildlife Technician (Wildlife)	
Wildlife Technician (Vegetation)	
Quantitative Ecologist	
Data Manager	0.04
GIS/Data Tech	0.04
Interns	
SFCN Total	0.1

Vital Signs(2): Nutrient Dynamics *and* Water Chemistry

[shortened names: Nutrients; Water_Chem]

Parks Where Vital Sign will be implemented:
BICY, BISC, DRTO, EVER, VIIS – SFCN will analyze data collected by existing programs
BUIS, SARI - deferred

Justification/Issues being addressed: Nutrient Dynamics ranked 4th among the 44 SFCN vital signs. Nutrients and physical characteristics within freshwater and marine water bodies drive primary production and when unbalanced can have deleterious effects. Understanding their distribution allows more complete interpretation of other indicators. Nutrients can change due to numerous reasons, for example; upstream/upland development, agricultural inputs, malfunctioning septic systems, boat discharges, atmospheric deposition, as well as internal nutrient cycling. Many parks have had monthly sampling for nutrients at permanent sites for a number of years and understanding the pattern and input fluxes can help explain patterns observed. Nutrient enrichment in freshwater and brackish areas has occurred primarily due to agricultural inputs (South Florida, SARI) with some impacts due to malfunctioning septic systems (USVI). Rain events can create pulses of nutrients. CERP/MOD Waters Everglades restoration is expected to reduce nutrient inputs to the Greater Everglades system.

General Monitoring Questions to be addressed by the Vital Signs:

- What are the status and trends in the spatial and temporal distributions of nutrients at specific sites in the wet prairies and marshes, near shore areas, and marine water bodies?
- What are the status and trends in nutrient loading to the estuaries from all sources and in sediment loading to guts and standing ephemeral pools at VIIS?
- What are the status and trends in the spatial and temporal distributions of physical water chemistry (e.g. conductivity, DO, temperature, pH, etc.) in the wet prairies and marshes, near shore areas, and marine water bodies?

Measures:
Discharge of freshwater to specific estuaries need to calculate nutrient and sediment load, plus flux measurements of nutrients at specific locations, Nitrogen, Phosphorous, Dissolved oxygen, Chlorophyll a, organic carbon, and other currently collected parameters.

Basic Approach:
The basic approach for "Nutrient Dynamics" and "Water Chemistry" involves much of the same data collection at the same sites so these two vital signs are described together. Please note that the "Water Chemistry" vital sign overlaps with "Estuarine salinity patterns" which covers changes in salinity patterns and other water chemistry

parameters in bays.

1) *Freshwater marshes*
At BICY, the NPS takes six grab samples (only during the summer months) at 16 marsh stations (funded by South Florida Water Management District - SFWMD). This data is stored in SFWMD DBHydro database and is summarized into annual reports by the park staff. This report will be posted on the SFCN website.

At EVER, the NPS takes water quality grab samples 12 times a year (monthly) at 15 sites and this data is stored in SFWMD DBHydro database. These sites are located in the Shark River and Taylor River Slough and downstream of the water control structures in freshwater and marsh locations. Ground water nutrient grab samples are done quarterly at wells around the park at 12 sites. Summarizing this data and coordinating with other users of this data set will be done annually.

For EVER, summarize the Florida Coastal Everglades Long Term Ecological Research (FCE LTER) automated nutrient samples to generate annual reports at specific sites.

2) *Marine water bodies*

At BISC, DRTO, EVER, and VIIS SFCN will work with PIs to summarize existing marine nutrient grab samples (sampling varies from quarterly or biannual).

For BISC, we can combine 25 Florida International University Southeast Environmental Research Center (FIU SERC) water quality monthly grab sample stations and Miami-Dade County Department of Environmental Research (DERM) 13 water quality monthly grab sample stations to look at regional patterns.

For DRTO water quality is monitored by the Southeast Environmental Research Center (SERC) Water Quality Monitoring Network for 15 sites. This information will be summarized annually.

For EVER, summarize the FIU SERC water quality monthly grab samples and the Florida Coastal Everglades Long Term Ecological Research (FCE LTER) automated nutrient samples to generate annual reports at specific sites.

For VIIS, SFCN will assist in establishing analysis and reporting procedures for the existing 16 sites where biannual nutrient grab samples are being collected by the NPS.

3) *Nutrient and sediment loading*
Calculations of nutrient loads may be accomplished at some sites due to preexisting instrumentation and site specific knowledge (BISC, EVER). For EVER, using the FCE LTER automated nutrient samples and continuous hydrology data generate nutrient fluxes into estuary. At BISC, there are some discharge curves being

generated by FIU Joe Boyer (to be published shortly) for canal discharge into BISC. Need to see if there is consistent nutrient data to go along with this canal discharge data. Calculation of sediment loads for VIIS is only feasible when surface water runoff is known. Modeling of the sediment loading will draw upon some modeling work from NOAA (http://ccmaserver.nos.noaa.gov/ecosystems/coralreef/summit_sea2.html) Sediment loading will also be investigated by the use of Sediment Elevation Tables (SETs) see Coastal Geomorphology indicator.

This task will be split by the community ecologist for marshes (objective 1 sediment in guts part of objective 3) and the marine ecologist for marine nutrient dynamics (objective 2 and 3).

4) *Reef water temperature*
Reef water temperature is being monitored at selected reef sites using continuous water temperature data loggers. The methods will be included in the "Marine Benthic Communities" protocol.

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Development Schedule, Budget, and Expected Interim Products:
SFCN will be gathering existing protocols from the implementing agencies and developing SOPs for how SFCN will analyze and report the data. The Standard Operating Procedures (SOPs) involved are expected to take about 2 years of SFCN staff time to draft and test. The marine post-doc and a community ecologist post-doc will be developing the SOPs and gathering the existing protocols from the implementing agencies. SOP development will be completed by 2009 with implementation in 2011. Table indicates proposed SFCN workload upon full monitoring implementation.

Expected SFCN staff time requirements once program is fully implemented in 5 years:

SFCN Staff	Full Time Equivalent (FTE)
Coordinator	
Marine Ecologist	0.02
Fisheries Biologist	0.02
Marine Biologist Technician (So FL)	
Marine Biologist Technician (VI)	
Community Ecologist	
Wildlife Technician (Wildlife)	
Wildlife Technician (Vegetation)	0.02
Quantatitive Ecologist	0.06
Data Manager	0.04
GIS/Data Tech	0.04
Interns	
SFCN Total	0.2

Vital Sign: Periphyton (Freshwater)

[shortened name: Periphyton]

Parks Where Vital Sign will be Implemented:
BICY – SFCN implements monitoring in NW BICY,
EVER – SFCN summarizes reports from existing monitoring program,
BISC - deferred

Justification/Issues being addressed: Periphyton ranked 17th among the 44 SFCN vital signs. Periphyton is a critical primary producer base of the food web in South Florida non-forested wetlands and estuarine areas. Periphyton production can exceed phytoplankton; it stabilizes the sediments, controls nutrient upwelling, and changes compositionally in direct response to salinity and water management (quality, quantity, duration). Periphyton composition reflects changes over a period of time and thus may provide a better indicator of changes in hydroperiod or nutrients than monthly water quality measurements or depth measurements.

General Monitoring Questions to be Addressed by the Vital Sign:

- What are the status and trends in periphyton community composition, structure, and nutrient content, especially in response to alterations in water quality and water management (quantity, timing, duration)?

Measures:
Community composition & structure, biomass, organic/inorganic (calcite) content, nutrient content

Basic Approach:
Periphyton is easily collected as part of monitoring for other indicators but travel costs would prohibit monitoring it in isolation. Thus periphyton monitoring would be conducted in concert with monitoring for "Freshwater fish and large macro-invertebrates" vital sign and could also be collected together with coastal wetland monitoring (e.g., Vital Signs "Mangrove-Marsh Ecotone," "Coastal Geomorphology")

Use of periphyton to monitor changes in hydroperiod and nutrient status is still in its early stages. Current work appears very promising but the relationships with hydroperiod, nutrient status are still being developed and refined. Diatoms tolerant of freshwater versus saltwater are well documented. Andy Gottlieb has shown a relationship between hydroperiod and changes in the diatom community. The Department of Environmental Protection has commissioned development of relationships between algal community and nutrient levels that is expected in 2008. Pilot studies will be needed to estimate variability and sample sizes needed. SOPs for collection procedures already exist with SFWMD.

Although estimates at sample size are loose at best, for planning purposes we are assuming about 75 samples per year will be needed per area mentioned below.

Shark River Slough and Taylor Slough
SFCN is assuming that CERP MAP funded monitoring of these areas through Evelyn Gaiser of FIU and Scott Hagerthey of SFWMD is sufficient. SFCN hopes to get copies of the reports for this monitoring or provide links to CERP's web pages regarding this indicator. Approximately 125 samples are being conducted annually from Shark River Slough through the Water Conservation Areas to Lake Okeechobee with about 24 inside Everglades National Park. We are aware of no effort to date to conduct a power analysis to determine if this level of sampling is adequate.

Big Cypress
Periphyton in northwestern Big Cypress will be monitored by SFCN in concert with monitoring freshwater fish and macro-invertebrates in freshwater prairies and marshes, i.e. periphyton samples would be taken at the same time as fish sampling occurs to save on the considerable travel costs (helicopter). A single monitoring protocol "Freshwater Fish, invertebrates, and periphyton" will be developed. The sampling design should at a minimum be designed to detect changes due to alterations in hydrology and nutrients to the north and northwest of the park.

A pilot study is needed to determine the range of variability in periphyton in the area and estimate appropriate sample sizes. If monitoring can be cost-effectively expanded into other areas of Big Cypress, SFCN will explore doing so.

Other areas:
Currently there is not sufficient funding, but additional areas for expansion in the future in order of priority would include: Biscayne Coastal Wetlands, EVER's marl prairies, and Florida Bay coastal wetlands.

Principal Investigators/Key Contacts and NPS Lead:

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- Julie Espy, Department of Environmental Protection, 850-245-8185
- Evelyn Gaiser, Florida International University, SE Environmental Research Center, University Park, OE 167, Miami, FL 33199, 305-348-6145, gaisere@fiu.edu
- Scott Hagerthey, SFWMD, 3301 Gun Club Road, West Palm Beach, FL 33406, (561) 681-2563, shagerth@sfwmd.gov,
- Jennifer B. Zimmerman, South Florida Water Management District, Everglades Research Division, Westhorp & Associates, Inc., 561.686.8800 x4550, 561.681.6310 fax, jzimmerm@sfwmd.gov

Development Schedule, Budget, and Expected Interim Products:
This vital sign will be developed and implemented in concert with the freshwater fish

and large macro-invertebrates vital sign. SOPs already exist with the South Florida Water Management District for collection procedures. SFCN will develop a "Freshwater fish, invertebrates, and periphyton" protocol in 2008-2011 with implementation in 2012 in Big Cypress National Preserve only. Current estimates from possible contractors to analyze the periphyton samples for algal composition & dominance is $400/sample + $65.34/sample for FIU to analyze the sample for total phosphorous, total nitrogen and total carbon (total calcium costs were not listed). Although pilot studies have not been done to estimate sample sizes, for planning purposes, assuming 75 samples/year each in BICY, costs to analyze samples will be $34,900.50. Samples will need to be divided and mailed (.5 week/year) plus data will need to be analyzed and reported (.5 week/year). Additional time estimates involving separating and counting aquatic invertebrates is covered under a separate vital sign. Links to the CERP monitoring and reports will begin as soon as feasible but no latter than 2011.

Expected SFCN staff time requirements once program is fully implemented in 5 years:

SFCN Staff	Full Time Equivalent (FTE)
Coordinator	
Marine Ecologist	
Fisheries Biologist	
Marine Biologist Technician (So FL)	
Marine Biologist Technician (VI)	
Community Ecologist	
Wildlife Technician (Wildlife)	0.02
Wildlife Technician (Vegetation)	
Quantitative Ecologist	
Data Manager	0.02
GIS/Data Tech	
Interns	
SFCN Total	0.04

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Vital Sign: Phytoplankton (Marine)

[shortened name: Phytoplankton]

Parks Where Vital Sign will be implemented:
BISC, BUIS, DRTO, EVER, SARI, VIIS – checking MODIS imagery for presence of algal blooms

Justification/Issues being addressed: Phytoplankton (Marine) ranked 34th among the 44 SFCN vital signs. Phytoplankton are important primary producers in aquatic food webs. Although these communities help regulate the availability of dissolved oxygen (DO) in marine systems at dynamic equilibrium, the community composition and biomass respond to water quality, especially turbidity and nutrient load changes. Increased turbidity reduces the availability of light and decreases photosynthetic activity, while algal blooms may occur due to an increase in nutrient load and this in turn also increases turbidity. As the algae die, the decaying phytoplankton cause a net decrease of DO. Such events have been shown to impact fish and benthic habitat communities that depend on these resources and may cause die-offs. Some species can be especially harmful and/or toxic (e.g., red tides and "black water" events). Phytoplankton monitoring is thus an invaluable indicator of marine habitat conditions.

General Monitoring Questions to be Addressed by the Vital Sign:

- What are the status and trends in frequency, size, and distribution of algal blooms in and around SFCN park waters?
- When and where are algal blooms occurring?

Measures:
Location, size, duration, and type of algal bloom events

Basic Approach:
During our Indicator workshops many valuable indicator details were listed to monitor in regard to phytoplankton. They included Community density and composition, species abundance, Chlorophyll a, other pigments (taxonomic indicator), microscopic validation of pigment indicator, possible bioassay for red tide, location, and light extinction/turbidity. However, at this time, the SFCN will focus primarily at using remote sensing technology using Chlorophyll a as a proxy for blooms to track frequency, size, and movement around parks. Additional Chloryphyll a monitoring is occurring around South Florida and will be used to provide additional information on the bloom event. Phytoplankton monitoring is one ecosystem indicator being evaluated as part of a Comprehensive Everglades Restoration Plan report card. The SFCN will track progress with both the indicator assessment point determination as well as the other indicators that will be used for this reporting tool.

The SFCN Data Manager will periodically review the MODIS imagery site to identify bloom events. Daily MODIS Direct Broadcast products from the University of South Florida are available to show Sea Surface Temperature (SST) as well as Chl. A at http://modis.marine.usf.edu/index.html for South Florida, the USVI and other areas of interest around the hemisphere. Those blooms can be identified as Harmful by checking the Harmful Algal Bloom Forcasting System website at: http://www.csc.noaa.gov/crs/habf/ . If an event is at or near a park, the data manager will contact park resource management staff to ensure they are aware of the bloom and will continue to track its movement and fate via these web sites. The Harmful Algal Bloom forecast site will be checked to ensure the type of bloom occurring. These bloom event details will be captured and reported on in summary reports.

Principal Investigators/Key Contacts and NPS Lead:

- Ben Ruttenberg, National Park Service, South Florida/Caribbean Inventory and Monitoring Network, Ben_Ruttenberg@nps.gov, 305-252-0347
- USF – Center for Remote Sensing
- FWRI- Harmful Algal Bloom group
- DERM-Steve Blair & Susan Markley
- MOTE-Gary Kirkpatrick
- NOAA – Harmful Algal Bloom Forecast Website
- NOAA – SE Fisheries Science Center Water Quality Monitoring – Peter Ortner
- FIU – SERC –Water Quality Monitoring Program - Joe Boyer

Development Schedule, Budget and Expected Interim Products:

There is no protocol schedule to implement this protocol at this time, as higher priority vital signs are being given precedence.

SFCN Staff	Full Time Equivalent (FTE)
Coordinator	
Marine Ecologist	
Fisheries Biologist	
Marine Biologist Technician (So FL)	
Marine Biologist Technician (VI)	
Community Ecologist	
Wildlife Technician (Wildlife)	0.02
Wildlife Technician (Vegetation)	
Quantitative Ecologist	
Data Manager	0.02
GIS/Data Tech	
Interns	
SFCN Total	0.04

Vital Sign: Protected Marine Mammals

[shortened name: Marine_Mammals]

Parks Where Vital Sign will be Implemented:
BICY, BISC, EVER
BUIS, DRTO, SARI, VIIS - deferred

Justification/Issues being addressed: Protected Marine Mammals ranked 28th among the 44 SFCN vital signs. These critically imperiled or rare marine mammals are typically large species, sensitive to the effects of calving/rearing habitat loss, habitat degradation, contaminant bioaccumulation, and food-web alterations. Recovery from historic hunting/collection pressure and low reproductive fecundity are also issues. Marine mammals experience a wide range of stressors and habitat quality issues both inside and outside park boundaries. The most threatened marine mammal regularly in SFCN parks is the manatee. Because of their relatively low numbers they are affected by stochastic impacts on populations such as boat collisions, entanglement in fishing gear, and entrapment in flood control structures. Disturbance by visitors can also be an issue. Dolphins have also become a concern due to possible contaminant impacts on health. Monitoring population status, trends and distribution informs park managers about the status of these legally protected and publicly charismatic species, which enables potential impact assessments of visitor use and management activities.

General Monitoring Questions to be Addressed by the Vital Sign:

- What are the status and trends in the distribution, abundance and condition of rare, threatened, and endangered marine mammals (e.g. manatees, dolphins) regionally and within parks?

Measures:
Distribution, abundance, size, condition/disease of manatees and dolphins

Basic Approach:
SFCN will coordinate with park staff, USGS, FWRI, FKNMS, and USFWS.

FWRI is currently the key monitoring and research agency for manatees in the state of Florida
FKNMS is currently conducting research in habitat use of bottle nose dolphins in Florida Bay.

The strategy for SFCN will be to

Provide a brief annual summary of the results of monitoring dolphins and manatee on the NPS-SFCN public web page and link to FWRI and FKNMS web pages. The summary will either be put together by SFCN staff based upon reports and sent to the PI's for approval, or summaries provided by the PI's.

Provide copies or links to manatee and dolphin monitoring reports by FWRI, FKNMS and NPS on SFCN's NPS-intranet web page (NPS staff access only)

While dolphins and whales occur in BUIS, DRTO, SARI, and VIIS, monitoring is deferred due to insufficient funds.

Principal Investigators/Key Contacts and NPS Lead:

- Ben Ruttenberg, National Park Service, South Florida/Caribbean Inventory and Monitoring Network, Ben_Ruttenberg@nps.gov, 305-252-0347.
- USGS-SIRENIA(manatee), FWRI(manatee, dolphins, turtles), FWS, NMFS(dolphins and whales). FKNMS (dolphins).
- Brian Keller (Dolphin research), Science Coordinator, FKNMS 305-743-2437, Brian.Keller@noaa.gov

Development Schedule, Budget, and Expected Interim Products:
By the end of 2008, SFCN will coordinate with FWRI and FKNMS to place summaries on the SFCN public web page and reports on the intranet page. Estimated time required: 1 week with a combination of Quantitative Ecologist and support staff.

Expected SFCN staff time requirements once program is fully implemented in 5 years:

SFCN Staff	Full Time Equivalent (FTE)
Coordinator	
Marine Ecologist	
Fisheries Biologist	
Marine Biologist Technician (So FL)	
Marine Biologist Technician (VI)	
Community Ecologist	
Wildlife Technician (Wildlife)	
Wildlife Technician (Vegetation)	
Quantitative Ecologist	0.01
Data Manager	0.01
GIS/Data Tech	0.01
Interns	
SFCN Total	0.03

Vital Sign: Reptiles- United States Virgin Islands

[shortened name: Reptiles-USVI]

Parks Where Vital Sign will be Implemented:
BUIS, SARI, VIIS - deferred

Justification/Issues being addressed: Reptile-USVI ranked 37th among the 44 SFCN vital signs. Reptiles are important top predators in the USVI. Reptiles as a group are not as transient as birds, the other top island predators; therefore, understanding the status of the island reptiles should indicate if overall terrestrial island management is appropriate for the higher trophic species. Additionally, the St. Croix Ground Lizard is a federally listed endangered species due to habitat destruction and BUIS is targeted as a site for establishing a new population in 2008.

General Monitoring Questions to be Addressed by the Vital Sign:

- What are the status and trends in the distribution and abundance (or proportion of area occupied) by native and non-native reptile species at VIIS and SARI? What will be the status and trends of the St. Croix Ground Lizard, *Ameiva polops*, once the population is introduced to BUIS in 2008?

Measures:
Population size & structure, mortality, recruitment, proportion of habitat occupied.

Basic Approach:
Deferred due to insufficient funds/staff time . SFCN will provide some assistance in protocol development, data analysis and management to BUIS for relocation of St. Croix Ground Lizard, *Ameiva polops*. BUIS will be responsible for monitoring re-introduction success.

Principal Investigators/Key Contacts and NPS Lead: N/A

Development Schedule, Budget, and Expected Interim Products: N/A

Vital Sign: Sawfish

[shortened name: Sawfish]

Parks Where Vital Sign will be Implemented:
EVER – SFCN will summarize reports from existing program

Justification/Issues being addressed: Sawfish ranked 26th among the 44 SFCN vital signs.
Small-toothed sawfish (*Pristis pectinata*) is a federally listed endangered species found in EVER and BISC, typically near and in estuaries, bays, and inlets utilizing seagrass, mud/sand bottom, oyster bars, reefs, and mangroves. This long-lived and large species (record is 18 ft. long) was formerly a fishery before stocks dwindled. Its saw makes it susceptible to entanglement in nets and lines. Little is known about this species, but, like other rays and sharks, it has limited reproductive potential.

General Monitoring Questions to be Addressed by the Vital Sign:

– What are the status and trends in distribution, relative abundance, number of active nursery areas, and demographics (sex ratios, adult/juvenile ratios)

Measures:
Spatial distribution and relative abundance of adults, distribution of nurseries, recruitment, movement patterns

Basic Approach:
A sawfish monitoring program is already being conducted by MOTE Marine Laboratory and NPS that extends from Charlotte Harbor through Florida Bay. Currently the program consists of:

- Sawfish encounter reporting database with surveys and outreach at Flamingo landing to fishermen and recreational boaters.
- Spring nursery area surveys- purpose is to identify all active nursery areas and level of activity/reproduction. An intensive newborn sawfish tracking program is underway in Mud Bay using an array of receivers (two other ongoing sites in Ten Thousand Islands outside park).
- Tagging of adult sawfish and sharks. Satellite tagging in autumn of adult fish greater than 6 feet long to determine long-term movement patterns within and outside park.

As only 3 sawfish sightings have been reported in Biscayne National Park during the past 8 years, no monitoring is currently underway there.

The Recovery Plan for this endangered species is about to be finalized. The monitoring by MOTE is funded by NMFS and various grants and is expected to continue.

The strategy for SFCN will be to:

- Provide a brief annual summary of the results of monitoring of the sawfish on the NPS-SFCN public web page and link to MOTE sawfish web page (www.mote.org/sawfish). Information that could cause collectors to locate sawfish will not be included. The summary will either be put together by SFCN staff based upon MOTE and NPS reports or summaries provided by the PI's.
- Provide copies of links to sawfish monitoring reports by MOTE and NPS on SFCN's NPS-intranet web page (NPS staff access only)
- Provide letters of support for the program as needed

Principal Investigators/Key Contacts and NPS Lead:

- Tonya Wiley, Center for Shark Research, MOTE Marine Laboratory, 1600 Ken Thompson Parkway, Sarasota, FL 34236, 941-388-4441, twiley@mote.org
- Thomas Schmidt, Everglades National Park, 305 224-4269, tom_schmidt@nps.gov
- Andrea Atkinson, National Park Service, South Florida/Caribbean Inventory and Monitoring Network. Andrea_Atkinson@nps.gov, 305-252-0347 [SFCN Lead]

Development Schedule, Budget, and Expected Interim Products:

By the end of 2008, SFCN will coordinate with MOTE to place summaries on the SFCN public web page and reports on the intranet page. Estimated time required: 0.5 weeks with a combination of Quantitative Ecologist and support staff.

Expected SFCN staff time requirements once program is fully implemented in 5 years:

SFCN Staff	Full Time Equivalent (FTE)
Coordinator	
Marine Ecologist	
Fisheries Biologist	
Marine Biologist Technician (So FL)	
Marine Biologist Technician (VI)	
Community Ecologist	
Wildlife Technician (Wildlife)	
Wildlife Technician (Vegetation)	
Quantitative Ecologist	0.01
Data Manager	0.01
GIS/Data Tech	0.01
Interns	
SFCN Total	0.03

Vital Sign: Sea Turtles

[shortened name: Sea_Turtles]

Parks Where Vital Sign will be Implemented:
BISC, BUIS, DRTO, EVER, VIIS – SFCN assists with some analysis; summarizes reports

Justification/Issues being addressed: Sea Turtles ranked 20th among the 44 SFCN vital signs. Four species of sea turtles nest on beaches within SFCN parks, all of which are federally endangered or threatened. The most prevalent species are the hawksbill, green, and loggerhead sea turtles with occasional leatherbacks. Nesting activities on historic turtle nesting beaches reflect the habitat quality of the nesting beaches, species population dynamics and health of local and regional seagrass beds, coral reef areas, and oceanic areas. Sea turtles may return to their natal nesting beaches to nest every 2-3 years. Some juvenile and adult sea turtles remain in the general area and are affected by stressors and management within the park. Currently, the greatest threats to sea turtle populations include loss of nesting beaches, degradation in quality of nesting beaches, nest predation, degradation in quality of foraging habitats, collisions with boats, being trapped in fishing gear or trash, and disease. Artificial lighting may be an issue at VIIS, but is not an issue at other SFCN parks.

General Monitoring Questions to be Addressed by the Vital Sign:

- What are the status and trends by species in the number of sea turtle nests, distribution of nests, proportion of aborted nest crawls, nesting outcome, # eggs laid/nest, hatching success, and recruitment?
- What are the status and trends in the population size of nesting sea turtles (at BUIS only)?

Measures:
Nest counts by species, distribution of nests, nest crawl outcome (nest, no nest), egg counts/nest, nesting outcome, hatching success

Basic Approach:
The parks currently monitor sea turtle nesting and report their annual results to USFWS as part of the endangered species program. SFCN will not be doing any monitoring, but as desired will provide assistance to park resource managers with developing multi-year indicators to be reported in park reports as well as the SFCN web page. All parks are also requesting assistance with database development. BUIS is working with NOAA to convert their database from FoxPro to MS ACCESS. The WASO Inventory and Monitoring program has agreed to develop a generalized database with SFCN providing advice. After this is complete the SFCN quantitative ecologist will assist with developing multi-year indicators. The SFCN data manager will continue to help with data base updates and modifications.

1) BUIS
BUIS has an intensive nightly monitoring program (Buck Island Reef National Monument Sea Turtle Research Program) which identifies and tags each female that comes ashore in addition to nesting information. The BUIS protocol is available at: http://cars.er.usgs.gov/Coral_Reef_Ecology/Buck_Is_Sea_Turtle_Protocols/buck_is_sea_turtle_protocols.html.

The link to the protocol itself is: http://cars.er.usgs.gov/Seaturtles.pdf

BUIS is also conducting a juvenile sea turtle in coral reef habitat monitoring protocol initiated under the prototype Inventory and Monitoring Program in which juvenile/sub-adult sea turtles are captured by divers, tagged, and data on growth, foraging, distribution and residency collected. The program ran from 1994-2002 and will be starting again in 2008.

2) BISC, VIIS
The other parks in the network are using a reduced version of the protocol in which they are conducting daytime track and nest surveys. Thus they collect the nest information similar to BUIS, but details on individual nesting females are not collected. All have requested assistance with database development.

3) DRTO, EVER
Monitoring at DRTO and EVER has lapsed for several years but is starting again. DRTO has also started funding for a USGS sea turtle project to see relationships with local habitat use and movement

4) SARI
VIDFW has conducted daytime nest surveys. Park staff will take over with weekly surveys once they have the staff.

Principal Investigators/Key Contacts and NPS Lead:

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- Rafe Boulon, Resource Manager, Virgin Islands National Park. 340 693-8950 x224, Rafe_Boulon@nps.gov
- Amanda Bourque, Biologist, Biscayne National Park. 305-230-1144x3081, Amanda_Bourque@nps.gov
- Douglas Morrison, Ph.D., Ecologist, Everglades and Dry Tortugas National Parks 305-852-0324, ext. 0327 Douglas_Morrison@nps.gov
- Kristen Hart, Ecologist USGS 727-803-8747 ext. 3046 kristen_hart@usgs.gov
- Andrea Atkinson, South Florida/Caribbean Network, 305-252-0347, andrea_atkinson@nps.gov [SFCN lead]

Development Schedule, Budget, and Expected Interim Products:
WASO should complete a database probably by early 2008. The SFCN quantitative ecologist will assist with developing multi-year indicators to be completed no later than December 2009 with SOPs written for data analysis and reporting. The Data manager will continue to help with data base updates and modifications.

Expected SFCN staff time requirements once program is fully implemented in 5 years:

SFCN Staff	Full Time Equivalent (FTE)
Coordinator	
Marine Ecologist	
Fisheries Biologist	
Marine Biologist Technician (So FL)	
Marine Biologist Technician (VI)	
Community Ecologist	
Wildlife Technician (Wildlife)	
Wildlife Technician (Vegetation)	
Quantitative Ecologist	0.02
Data Manager	0.02
GIS/Data Tech	
Interns	
SFCN Total	0.04

Vital Sign: Surface Water Hydrology

[shortened name: Hydrology]

Parks Where Vital Sign will be implemented:
BICY, BISC, BUIS, DRTO, EVER, SARI, VIIS,

Justification/Issues being addressed: Surface Water Hydrology ranked 3rd among the 44 SFCN vital signs. Hydrology is an important driver in most ecosystems. Understanding the quantity, timing, duration, and flow of the hydrology allows a basic comprehension of how this major process affects the ecosystem and is a necessary covariate to interpret other indicators. CERP/MOD Waters Everglades restoration is fundamentally expected to affect South Florida regional hydrology. In addition, freshwater input is a major estuarine ecosystem driver. Freshwater input, coupled with hydrodynamics and evaporation, determines spatial and temporal salinity patterns. Anthropogenic alteration of freshwater input is a major estuarine ecosystem stressor, likely the most important for Biscayne Bay, Florida Bay, and the gulf coast estuarine ecosystems. Additionally, adequate archiving and reporting of rainfall is critical for the understanding of how each year's weather will affect the flora, fauna, and the ecosystem overall.

General Monitoring Questions to be addressed by the Vital Sign:

- What are the spatial and temporal patterns (quantity, timing, duration, flow) of freshwater input (surface water, and to a point groundwater) into estuaries/bays?
- What is the general hydrology (quantity, timing, duration, flow) of the freshwater marsh part of the ecosystem?
- What is the general annual weather pattern, especially in regards to rainfall?

Measures:
Water stage, flow, timing, and duration, discharge of freshwater to specific estuaries, rainfall

Basic Approach:
1) BISC, EVER, SARI, VIIS
For BISC, EVER, VIIS SFCN will generate annual reports at specific sites for freshwater discharge into the estuary, using the ForEVER (for Everglades) database maintained by Kevin Kotun at EVER and data from the Florida Coastal Everglades Long Term Ecological Research (FCE-LTER). For VIIS, the SFCN needs to gather rainfall data from the established air monitoring station at Lind Point Biosphere and private sites to compile in an annual report. For SARI, the SFCN is establishing a single crest gage station to be placed on Salt River near the park boundary at the input culvert to the park. SFCN expects park staff assistance in maintaining the station and downloading the data.

2) BICY, EVER
For BICY and EVER the SFCN will continue to maintain links to regional hydrology summaries by Bob Sobczak of BICY and EVER; additionally, SFCN will use the Everglades Depth Estimation Network (EDEN) pulling together hydropattern at key long term hydrology stations (P205 station).

3) BISC, BUIS, DRTO, SARI,
SFCN will establish new weather stations at a few select sites. At BISC the need is to generate annual rainfall at offshore islands sites and additionally record wind speed and direction for the central and the southern parts of Biscayne Bay which was cited as a critical data gap in the South Florida / Caribbean Network Weather and Climate Inventory Report (Davey *et al.*, 2007). At BUIS SFCN will generate an annual rainfall report from the soon to be newly installed weather station. At DRTO the national weather service is maintaining a station and should be approached to see if we can supplement instrumentation to the station. The station has min and max temperature, air temperature and rainfall. At SARI SFCN will establish a weather station mainly for rainfall data which will be correlated to the Crest-stage gage at the culvert under the road at headwaters of SARI. Weather stations at BUIS, DRTO, and SARI will be placed using best judgment as SFCN will be placing only one station in each park. Variability in air temperature and rainfall across these parks are assumed to be small enough that use of this data as covariates for other indicators is not jeopardized.

Principal Investigators/Key Contacts and NPS Lead:

- Ben Ruttenberg, National Park Service, South Florida/Caribbean Inventory and Monitoring Network, Ben_Ruttenberg@nps.gov, 305-252-0347.
- Kevin Whelan, National Park Service, South Florida/Caribbean Inventory and Monitoring Network. Kevin_R_Whelan@nps.gov, 305-252-0347
- Bob Sobczak, Big Cypress National Preserve, (239) 695-1151, Robert_Sobczak@nps.gov
- Kevin Kotun, Everglades National Park, (305) 242-7829, Kevin_Kotun@nps.gov
- Zandy Hillis-Starr, Resource Manager, Buck Island Reef National Monument. 340-773-1460 x235, Zandy_Hillis-Starr@nps.gov
- Rafe Boulon, Resource Manager, Virgin Islands National Park. 340 693-8950 x224, Rafe_Boulon@nps.gov

Development Schedule, Budget, and Expected Interim Products:
SFCN expects to adapt existing Standard Operating Procedures rather than submit an independent peer-reviewed protocol and is expected to take about 6 months of SFCN staff time to draft and test. SFCN staff (Marine Ecologist and Marine Technician will be responsible for this indicator, with some assistance from Community Ecologist). One time equipment cost of $10,000.00 at maximum plus travel to USVI and DRTO for maintenances at 6 month interval probably for DRTO.

SOPs completed by 2009 with implementation by 2010 for estuarine discharge and specific sites, general indication of surface water hydrology, and weather stations.

Expected SFCN staff time requirements once program is fully implemented in 5 years:

SFCN Staff	Full Time Equivalent (FTE)
Coordinator	
Marine Ecologist	0.02
Fisheries Biologist	0.02
Marine Biologist Technician (So FL)	0.02
Marine Biologist Technician (VI)	0.02
Community Ecologist	
Wildlife Technician (Wildlife)	
Wildlife Technician (Vegetation)	0.02
Quantitative Ecologist	0.02
Data Manager	0.02
GIS/Data Tech	0.04
Interns	
SFCN Total	0.18

Davey, C. A., K. T. Redmond, and D. B. Simeral. 2007. Weather and Climate Inventory, National Park Service, South Florida / Caribbean Network. Natural Resource Technical Report NPS/SFCN/NRTR—2007/037. National Park Service, Fort Collins, Colorado.

Vital Sign: Vegetation Communities Extent & Distribution

[shortened name: Veg_Mapping]

Parks Where Vital Sign will be Implemented:
1/3 BICY, BISC, BUIS, DRTO, SARI, VIIS – SFCN implements mapping
EVER, 2/3 BICY – Comprehensive Everglades Restoration Program (CERP) RECOVER funded mapping

Justification/Issues being addressed: Vegetation Communities Extent & Distribution ranked 7th among the 44 SFCN vital signs. The spatial patterns of vegetation in wet prairies and marshes, forests, tree islands, mangroves, beaches and tidal wetlands are expected to change due to management regimes (regional hydrology changes by Everglades restoration efforts; fire), natural succession processes, sea level rise, and invasive species. A baseline and sound monitoring program should be established to track impacts of these changes at a regional scale. The mosaic and diversity of vegetation communities across the landscape strongly influences animal communities, food web-structure and distribution of rare plants. Vegetation patterns are also useful in planning for management, monitoring and visitors.

General Monitoring Questions to be Addressed by the Vital Sign:

- What are the status and changes in the extent and distribution of vegetation communities, e.g., wet prairies and marshes, hammock forests, pine woodlands, scrub, and mangroves?
- What changes relate to ecotonal and community structure changes, especially those related to hydrology management, fire management, nutrient enrichment, storm damage, and sea level rise?

Measures:
Extent, distribution, shape, orientation of vegetation community types using remote sensing

Basic Approach:
Mapping of EVER and BICY is being done using a raster approach in which each 50m x 50m grid cell is classified according to the vegetation classification using 1:24000 color infrared photography and stereoplotters. CERP is funding mapping of most of EVER and 2/3 of BICY every 10? years for 30 years. The remaining portions of EVER and BICY will be funded by SFCN every 10-15 years using a consistent approach.

Mapping of BISC, VIIS, BUIS, and SARI will be mapped as vector based maps using at least 1:24000 photography and is expected to be done by outside contractors. DRTO will be mapped internally by SFCN & EVER park staff. Mapping is expected to be redone every 10-15 years.

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- Ted Schall, South Florida Water Management District, (561) 682-6766, tschall@sfwmd.gov
- Jana Newman, CERP RECOVER MAP Landscape sub-team lead, (561) 681-2563 x3726, jmnewman@sfwmd.gov
- Kevin Whelan, National Park Service, South Florida/Caribbean Inventory and Monitoring Network. Kevin_R_Whelan@nps.gov, 305-252-0347 [SFCN lead]
- USVI - USVI Department of Planning and Natural Resources

Development Schedule, Budget, and Expected Interim Products: Mapping efforts as part of the NPS I & M program vegetation map inventories are currently underway for western BICY and BISC which should be completed by the end of FY2007 or early FY2008. SFCN hopes to work with NPS staff internally to create a DRTO vegetation map by the end of FY2007. A second effort is working to further refine the Vegetation Classification for South Florida. SFCN hopes that the Inventory program will continue to fund initial inventory maps of BUIS, SARI, and VIIS. A complete map of EVER and BICY by CERP is expected in FY2011.

SFCN anticipates remapping parks every 10-15 years. Estimated costs include: NPS funded portion of BICY/EVER=$500,000; BISC=$75,000; VIIS/BUIS/SARI=$80,000; DRTO=mapped by park staff (2-3 staff weeks). This assumes that CERP continues to re-map EVER every 5 years. It's also possible we may be able to coordinate with the USVI Department of Planning and Natural Resources to map the USVI parks. GIS Technician time should be allocated towards these projects especially the change analysis and contract management of the mapping contracts. Contract management should take approximately 3 months of SFCN time. Change analysis between maps approximately 1 month of time each year. Table indicates proposed SFCN workload upon full monitoring implementation.

Expected SFCN staff time requirements once program is fully implemented in 5 years:

SFCN Staff	Full Time Equivalent (FTE)
Coordinator	0.2
Marine Ecologist	
Fisheries Biologist	
Marine Biologist Technician (So FL)	
Marine Biologist Technician (VI)	
Community Ecologist	0.04
Wildlife Technician (Wildlife)	
Wildlife Technician (Vegetation)	
Quantitative Ecologist	0.08
Data Manager	
GIS/Data Tech	0.1
Interns	
SFCN Total	0.42

Vital Sign: Visitor Use

[shortened name: Visitor_use]

Parks Where Vital Sign will be Implemented:
BICY, BISC, BUIS, DRTO, EVER, SARI, VIIS – SFCN analyzes existing data; summarizes reports

Justification/Issues being addressed: Visitor Use ranked 13th among the 44 SFCN vital signs. Without quantitative data on the types, amounts and distribution of activities occurring in the parks, managers are unable to develop reliable and sufficient park plans. Park managers must have documentation of the full range of activities occurring within their parks, how many people are doing each activity, and where these activities are occurring, as well as information on the changes in these activities over time, in order to understand the linkages between the condition of resources and specific park uses of concern. These data can also provide some indication of how changes in park management are reflected in park uses of natural areas.

General Monitoring Questions to be Addressed by the Vital Sign:

- What are the seasonal and long-term trends in the distribution and abundance of visitors and associated activity types? In areas of critical concern, how is visitor use changing over time?

Measures:
Distribution and abundance of visitors including: activities, demographics, person days, spatial distribution/ density, numbers of people/cars/boats - both commercial and private

Basic Approach:
SFCN will use the National Park Service Public Use Statistics Office reports to evaluate changes in visitation. Monthly information is available on the NPStats website: http://www2.nature.nps.gov/mpur/. Annual reports will be generated each January for the previous calendar year and posted to the intranet site with the url for those who might want to see updated information during the year.

Other measures will be deferred unless additional funding becomes available.

Principal Investigators/Key Contacts and NPS Lead:
SFCN Data Manager

Development schedule, budget, and expected interim products:
An inventory of the range of visitor use information collected by each park will be completed by 2009. A SOP will be generated by 2010 that describes the process of using the query on the site and posting the report to the intranet by the data manager.

Expected SFCN staff time requirements once program is fully implemented in 5 years:

SFCN Staff	Full Time Equivalent (FTE)
Coordinator	
Marine Ecologist	
Fisheries Biologist	
Marine Biologist Technician (So FL)	
Marine Biologist Technician (VI)	
Community Ecologist	
Wildlife Technician (Wildlife)	
Wildlife Technician (Vegetation)	
Quantitative Ecologist	
Data Manager	0.04
GIS/Data Tech	
Interns	
SFCN Total	0.04

Vital Sign: Wetland Ecotones and Community Structure

[shortened name: Wetland_Vegetation]

Parks Where Vital Sign will be Implemented:
EVER – SFCN summarizes reports from CERP RECOVER MAP monitoring,
BICY – SFCN will evaluate needs and implement monitoring if warranted
BISC – SFCN will evaluate needs and implement monitoring if warranted

Justification/Issues being addressed: Wetland Ecotones and Community Structure ranked 14th among the 44 SFCN vital signs. Healthy wet prairies and ridge and slough communities are considered critically important in supporting and restoring the Greater Everglades foodweb. Vegetation also shows visible response over relatively few years to changes in drivers and stressors. The freshwater wetlands community composition in Everglades National Park and Big Cypress National Preserve varies with flow, hydroperiod, fire history, nutrient enrichment, and invasive species. Over the past century, water has been diverted away from the Water Conservation Areas (WCAs), Everglades National Park and Big Cypress National Preserve, resulting in diminished sheetflow, reduced hydroperiods, and increased nutrients. This has been associated with a drying of Shark River Slough and marl prairies in EVER and eastern BICY, loss of tree islands especially in the WCAs, and loss of ridge and slough patterning especially in the WCAs. In addition there are concerns that development to the north of Big Cypress may also lead to diminished water entering the preserve on the northwestern portion of the park coupled with nutrient enrichment of the water that does enter. CERP is intended to rehabilitate flow and hydropatterns and reduce nutrient enrichment. This vital sign is intended to better inform decision-makers regarding the status of these wetlands and directions of change.

General Monitoring Questions to be Addressed by the Vital Sign:

- Are wetland ecotones shifting due to changes in hydrology or other physical factors (e.g., fire, nutrients, and episodic metrological events.)?
- What are the status and trends in plant community composition and structure?

Measures:
Ridge and slough patterning and depth amplitude, slough to prairie plant composition gradients, number and elevation change in tree islands, wet prairie-forest ecotones change

Basic Approach:
Two large monitoring efforts are already underway in Everglades National Park:

The Comprehensive Everglades Restoration Plan (CERP) RECOVER landscape sub-team is in the process of creating sampling designs and protocols for the first 3 objectives (Philippi 2007) and it is strongly hoped objectives 1 and 3 will be fully funded by CERP and objective 2 will be funded for the Shark River Slough to marl prairies gradient.

An existing Cape Sable Seaside Sparrow habitat monitoring program is underway in the marl prairies where they are found. The program monitors species composition in about 200 plots / year in a stratified random design throughout these areas. Although this program is limited to those areas of marl prairie where the sparrow is found, collaborating with this program could provide valuable information on the status of the marl prairies in addition to the gradients work mentioned above.

SFCN will seek to gather reports from these efforts, summarize them, and link to the MAP annual report summaries as well as provide input through the RECOVER MAP Greater Everglades Module landscape sub-team.

For areas of Big Cypress such as Lostman's slough and the concerns about changing hydrology in north-western BICY as well as BISC, SFCN will work with park resource management and area researchers to scope out these monitoring needs or determine whether vegetation mapping is sufficient. At that point given priority levels and SFCN funding, SFCN may develop protocols or Standard Operating Procedures (SOPs) as appropriate.

This vital sign also overlaps with the Vegetation Communities Extent and Distribution vital sign. The vegetation map will be used to assess objective 4, e.g., areas where trees and shrubs are encroaching on wet prairies and areas where cattails are increasing or decreasing in extent. It is unclear whether the extent of marshes versus wet prairies can also be established.

Table 1. Plan for Ecotone Monitoring
A= monitored with aerial photography; F= monitored with field plots

	Pineland to Hammock	Coastal to Inland	Forest to Wet Prairie	Wet Prairie to marsh/slough
BISC		**A,F**	**A**	
BICY	**A,F**	**A,F**	**A**	
EVER	**A,F**	**A,F**	**A**	**A,F**
DRTO		**A,F**		
SARI		**A,F**		
BUIS		**A,F**		
VIIS		**A,F**		

Table 2. Plan for Long-term within-community monitoring plots

+ = SFCN monitoring; ♦ = Existing monitoring program

	Pineland	Hardwood Hammock	Mangroves	Marshes	Island Moist Forest	Island Deciduous Forest	Island Scrub/ Shrub
BISC		+,♦	+				
BICY	♦	+	+				
EVER	♦	+,♦	♦	♦			
DRTO			+				
SARI			+	?			
BUIS			+			+	+
VIIS			+		+,♦	+,♦	+

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- Kevin Whelan, National Park Service, South Florida/Caribbean Inventory and Monitoring Network. Kevin_R_Whelan@nps.gov, 305-252-0347 [SFCN lead]
- Andrea Atkinson, National Park Service, South Florida/Caribbean Inventory and Monitoring Network. Andrea_Atkinson@nps.gov, 305-252-0347
- Tom Philippi, Assistant Professor Florida International University, 305-348-1876, philippi@fiu.edu (designed the sampling designs described above)
- Prof. Mike Ross, Florida International University, rossm@fiu.edu, 305-348-1420 (piloted the marl prairie-slough gradients protocol, involved with Cape Sable Seaside Sparrow habitat monitoring)
- Martha Nungesser, Sr. Env. Scientist, South Florida Water Management District, (561) 682-6614, mnunges@sfwmd.gov (piloted the ridge and slough protocol)

Development Schedule, Budget, and Expected Interim Products: This is a CERP indicator and is expected to be funded by CERP. A draft sampling design and protocol was reviewed at a workshop by an outside panel in Jan. 18-19, 2007. The approach and monitoring objectives above are based on the results of that workshop. A more complete draft protocol is expected to be submitted to CERP by Tom Philippi of FIU at the end of 2007. Implementation will be dependent upon CERP. SFCN hopes to report the results through the vital signs process. SFCN will scope out the monitoring needs in non-CERP wetlands by 2010 and determine a strategy forward. Table indicates proposed SFCN workload upon full monitoring implementation of all 3 vegetation vital signs

Expected SFCN staff time requirements for all three vegetation vital signs (Wetland Ecotones and Community Structure; Forest Ecotones and Community Structure; Mangrove-Marsh Ecotone)_once program is fully implemented in 5 years:

SFCN Staff	Full Time Equivalent (FTE)
Coordinator	
Marine Ecologist	
Fisheries Biologist	
Marine Biologist Technician (So FL)	
Marine Biologist Technician (VI)	
Community Ecologist	0.3
Wildlife Technician (Wildlife)	0.4
Wildlife Technician (Vegetation)	0.4
Quantitative Ecologist	0.06
Data Manager	0.04
GIS/Data Tech	0.2
Interns	0.3
SFCN Total	1.7

References:

Philippi, Tom. 2007. "Background, Design Issues, and Strawman for Everglades Landscape Monitoring Panel Workshop January 18-29, 2007." Panel of Environmental Monitoring Experts for RECOVER Landscape Monitoring Workshop. January 18-19, 2007. Florida International University. 11 pages.

Michael S. Ross, Jay P. Sah, Pablo L. Ruiz, David T. Jones, Hillary Cooley, Rafael Travieso, James R. Snyder and Sara Robinson. 2004. Effect of Hydrologic Restoration on the Habitat of The Cape Sable Seaside Sparrow: Annual Report of 2003-2004. Southeast Environmental Research Center, Florida International University, Miami, FL, Nov. 30, 2004. 36 pages.

Vital Sign: Wetland Substrate

[shortened name: Wetland_Substrate]

Parks Where Vital Sign will be Implemented:
BICY, EVER - deferred

Justification/Issues being addressed: Wetland Substrate ranked 35th among the 44 SFCN vital signs. Many biogeochemical processes critical in nutrient cycling and sediment generations in the fresh water wetlands community in Everglades National Park and Big Cypress National Preserve are dependent on substrate type (marl vs. peat). Understanding the regional pattern of peat and marl and changes between these substrates is critical to interpret other processes occurring within the fresh water marshes. The extended hydroperiods proposed through CERP restoration may promote conversion from marl to peat substrates. These conversions between substrates can affect the hydroperiod in specific community types. For example, changes in soil surface elevation in cypress strand and domes dictate the hydroperiod which drives cypress community dynamics (seedling recruitment, survival, decomposition). Long-term resource management of forest wetlands requires an understanding of how soil surface elevation changes in response to seasonal wetting, shrink-swell of soils, and fire.

General Monitoring Questions to be addressed by the Vital Sign:

- What are the status and trends in the extent and distribution of substrate types at landscape scales over time? Have abnormal changes occurred?
- What are the status and trends in soil surface elevation change in cypress strands and domes over time, especially in relation to hydrology, water quality, fire, and other processes?

Measures:
Extent and distribution of substrate type (marl vs. peat), sediment elevation changes in cypress strands/domes

Basic Approach: Deferred due to insufficient funds/staff time

Principal Investigators/Key Contacts and NPS Lead: N/A

Development Schedule, Budget, and Expected Interim Products: N/A

References
CERP RECOVER MAP funded a study on bathymetry of coastal creeks.

APPENDIX Q

PROTOCOL DEVELOPMENT SUMMARIES

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Protocol: Amphibians

[Shortened name: Amphibians]

Vital Signs to which this protocol relates: Amphibians

Parks Where Protocol will be Implemented:
BICY, EVER, VIIS – SFCN implements monitoring
BISC, SARI - Deferred

Justification/Issues being addressed: Amphibians ranked 25th among the 44 SFCN vital signs. Amphibians comprise a large amount of the resident vertebrate biomass and generally are a strong intermediate link in the food web. Amphibians have been used as a biological indicator for many environmental variables and are sensitive to changes in breeding habitat quality, invasive species, and contaminants. At VIIS, the native frog species are strongly tied to water resources for reproduction. The white-lipped frog (*Leptodactylus albilabris*) has a tadpole stage and the other two species, Antillean frog (*Eleutherodactylus antilliensis*) and whistling frog *(Eleutherodactylus cochranae)*, utilize moist vegetation for egg laying with direct development to the froglet stage. Additionally, these frogs typically exploit the numerous tank bromeliads for daytime refugia. There are a number of exotic species that may be out competing and preying upon native fauna such as the Cuban tree frog (*Osteopilus septentrionalis*). In EVER and BICY, the pig frog, *Rana grylio*, is a dominant anuran within the freshwater marsh lands and makes up a large portion of the vertebrate biomass. It is both a prey source and a major predator. The pig frog life cycle (eggs-tadpoles-adults) is strongly related to marsh hydrology. Shifts in pig frog population structure have been shown to be related to water management. Additionally, pig frogs bioaccumulate mercury and currently are being monitored by the State of Florida (FWRI) for mercury levels. Previous amphibian monitoring within these parks has documented exotic species immigration and shifts in population structures of native species due to exotic species. Community composition of the amphibian species community has been related to habitat type within these park units. Presumably, amphibian community composition and proportion of area occupied (PAO) will have a quick reaction to management actions.

Note: A SFCN funded herpetofauna inventory found no amphibians at BUIS so this vital sign is assumed to not be relevant for that park unit. Monitoring at BISC and SARI is deferred due to lack of funds.

Specific Monitoring Questions and Monitoring Objectives to be Addressed by the Protocol:
The monitoring question that is being addressed by this protocol is:

- What are the status and trends in the distribution, abundance (or occupancy), and community composition of native and non-native amphibian species?

- What are the status and trends in pig frog demographic structure in relation to water levels and Everglades restoration?
- What are the status and trends in mercury accumulation in pig frogs?

The specific monitoring objectives include:

Objective 1: Determine status and trends in distribution, abundance (e.g, relative abundance, proportion of area occupied), community composition, and population structure of amphibians in accessible areas.

Justification/Rationale for this objective: This is basic knowledge needed to identify changes of amphibian communities within the park.

Objective 2: Determine status and trends in the sex and age structure of pig frogs in EVER and BICY.

Justification/Rationale for this objective: This is needed to help management understand how water management decisions affect population structure in a mid-trophic level organism.

Objective 3: Document concentrations of mercury in pig frogs in EVER and BICY

Justification/Rationale for this objective: This knowledge allows insight into a 3 to 5 year window of general mercury bioaccumulation in the marsh habitats.

Measures:

Proportion of area occupied, distribution, community composition, population structure, total mercury content

Basic Approach:

Objective 1: At VIIS, EVER and BICY amphibians will be monitored in areas near roads and trails with Visual Encounter Surveys (VES), call surveys and tree pipes by developing a proportion of area occupied (PAO) methodology similar to the ARMI inventory protocol methods used in these parks (Rice *et al*. 2004, 2005a, 2005b) . Current funding levels are insufficient to attempt monitoring away from roads and trails, especially in areas accessible only by helicopter

Objective 2: In EVER and BICY, SFCN will collect grab samples of pig frogs to determine size structure of populations, sex ratios, and juvenile to adult ratios. This sampling will build upon previously existing research.

Objective 3: SFCN will coordinate with the State of Florida mercury monitoring program. SFCN goal is to include pig frogs from EVER and BICY in the states regional assessments.

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- Raul Urgelles, National Park Service, South Florida/Caribbean Inventory and Monitoring Network. 305-252-0347

Key Contacts

- Kenneth G. Rice, United States Geological Survey, ken_g_rice@usgs.gov, (352) 264-3544

Development Schedule, Budget, and Expected Interim Products:

The Community Ecologist and the two wildlife technicians will conduct sampling about 9 weeks of the year and 2 weeks of data entry and reporting. Additional costs are minimal: mostly for travel and some beginning equipment. However SFCN will need to evaluate the feasibility of the mercury analyses if the State of Florida does not cover the costs as these are generally expensive samples ($100.00 each). The protocol development should be completed by 2012 and begun 2013. Table indicates proposed SFCN workload upon full monitoring implementation.

Expected SFCN staff time requirements once program is fully implemented in 5 years:

SFCN Staff	Full Time Equivalent (FTE)
Coordinator	
Marine Ecologist	
Fisheries Biologist	
Marine Biologist Technician (So FL)	
Marine Biologist Technician (VI)	
Community Ecologist	0.15
Wildlife Technician (Wildlife)	0.15
Wildlife Technician (Vegetation)	0.15
Quantitative Ecologist	0.04
Data Manager	0.04
GIS/Data Tech	0.02
Interns	
SFCN Total	0.55

References:

Rice, K. G., J.H. Waddle, M.E. Crocket, B. M. Jeffrey, and H. F. Percival. 2004. Herpetofaunal Inventories of the National parks of South Florida and the

Caribbean: Volume I. Everglades National Park. U.S. Geological Survey, open-File Report 2004-1065, Fort Lauderdale, Florida.

Rice, K. G., J.H. Waddle, M.E. Crocket, B. R. R. Carthy, and H. F. Percival. 2005a. Herpetofaunal Inventories of the National parks of South Florida and the Caribbean: Volume II. Virgin Islands National Park. U.S. Geological Survey, open-File Report 2005-1301, Fort Lauderdale, Florida.

Rice, K. G., J.H. Waddle, B. M. Jeffrey, A.N. Rice, and H. F. Percival. 2005b. Herpetofaunal Inventories of the National parks of South Florida and the Caribbean: Volume III. Big Cypress National Preserve. U.S. Geological Survey, open-File Report 2005-1300, Fort Lauderdale, Florida.

Protocol: Colonial Nesting Birds

[shortened name: Colonial_Birds]

Vital Signs to which this protocol relates: Colonial Nesting Birds

Parks Where Protocol will be Implemented:
BISC, – SFCN implements monitoring
BICY, DRTO - supplement current Park monitoring
BUIS, EVER, VIIS - being monitored by park
SARI - USFWS, VIDFW conducting monitoring; may need supplementation

Justification/Issues being addressed: Colonial Nesting Birds ranked 8th among the 44 SFCN vital signs. The status of colonial nesting bird colonies, their size and nesting success, indicate the surrounding ecosystems' ability to support foraging of nesting birds (i.e. amount and quality of fish and/or invertebrates available in the surrounding landscape/seascape), predictability of forage and water, freedom from colony (nest) predators, and survivable contaminant levels. Birds bioaccumulate certain contaminants in their feathers, blood, and eggs. Because of their sensitivity to landscape health, fishery health, and contaminants, colonial nesting birds are almost all either federal or state threatened species, endangered species or species of special concern. Colonial wading birds including wood storks, roseate spoonbills, egrets and ibises have been identified as important performance measures for the CERP RECOVER program. As colonial nesting birds have a moderate foraging range and are affected by both local and larger regional scale forcing functions, the long term monitoring of colonial nesting birds will give insight to overall ecosystem health at this scale.

Specific Monitoring Questions and Monitoring Objectives to be addressed by the Protocol:
The monitoring questions that are being addressed by this protocol are:

- What are the status and trends in colony size, distribution, and nesting status of colonial nesting birds (e.g., Great Egret, Wood Stork, White ibis, Snowy Egret, Cattle Egret, Roseate Spoonbill, Tricolor Heron, Little Blue Heron, Black-crowned Night Heron, Least terns, Brown Pelicans, Masked Boobies, Roseate terns, Sooty Terns)? Specifically in South Florida are the populations and distributions of wading birds changing?

The specific monitoring objectives include:

Objective 1: Determine long term trends in annual peak nest count in colonial nesting bird colonies at BISC.

Justification/Rationale for this objective: The long term monitoring of known colony bird rookeries allows yearly estimation of nest success, fecundity, and reproductive output supported by the surrounding ecosystem at a moderate regional scale.

Objective 2: Compile and report colonial nesting bird data from EVER, BICY, BUIS, SARI, DRTO, VIIS on an approximately annual basis to better understand park and regional trends.

Justification/Rationale for this objective: The Systematic Reconnaissance Flights program provides a regional estimation (for Everglades National Park and Big Cypress National Preserve specifically) of wading bird populations in south Florida that complements colony bird rookery surveys. The Systematic Reconnaissance Flights program is a base-funded monitoring program for Everglades National Park. Big Cypress National Preserve has some monitoring from Everglades National Park Systematic Reconnaissance Flights program and by sampling supported by South Florida Water Management District.

Measures

Location and size of rookery (by species), peak nest counts, and fledging success (by species) along with summarized counts of wading birds by region.

Basic Approach:

Objective 1: Survey known colonies with opportunistic surveys of newly reported colonies. At each colony (rookery) assess (by species) the number of nests, status of nest, and fledging with serial surveys to determine fledgling success.

Colonial nest surveys are currently occurring in EVER and sporadically at Big Cypress.

BUIS (Pelicans and Least Terns) and VIIS (Pelicans) are being monitored by park. SFCN needs to initiate monitoring in BISC and supplement current monitoring at BICY and DRTO. Sonny Bass's (EVER Wildlife Biologist) current Dry Tortugas study of Sooty Terns is very detailed but lacks whole park surveys. For BISC we will need to generate a probable nesting period and sample at monthly to biweekly intervals to determine number of nests, nest success and fledgling success. USFWS and Virgin Islands Dept. of Fish and Wildlife are conducting monitoring for least terns and brown pelicans at SARI and roseate and least terns at VIIS. SFCN will work with these agencies and park staff to see if further monitoring efforts are needed at SARI and see if these other agency efforts can be reported through the Vital Signs process. SFCN will work with park staff to formalize SOPs and help with database development, and analysis and reporting processes for existing programs as needed.

Objective 2: Large scale surveys of the park lands and waters for relative abundance for wading and colonial nesting birds in South Florida.

The Systematic Reconnaissance Flights program provides a regional estimation (for Everglades National Park and Big Cypress National Preserve specifically) of wading bird populations in south Florida that complements colony bird rookery surveys.

The Systematic Reconnaissance Flights program is a base funded monitoring program for Everglades National Park. Big Cypress National Preserve has some monitoring from Everglades National Park Systematic Reconnaissance Flights program and by sampling supported by South Florida Water Management District. The SFCN will pull together the results from these different SRF monitoring to present and general finding for both parks.

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- Elsa Alvear, Biscayne National Park

Development Schedule, Budget, and Expected Interim Products:

The "Colonial Nesting Birds" protocol is expected to take about 6 months of SFCN staff time to draft and test the protocols. Full implementation is partially dependant on continued Everglades National Park funding of SRF and colony bird rookery surveys. The Community Ecologist and the Wildlife Technicians will conduct sampling about 8 weeks of the year including data entry and reporting. Costs include helicopter time and travel and some start-up equipment (good binoculars). However, SFCN will need to evaluate the feasibility of using the SFCN boat for rookery surveys. SFCN will create a single overarching colonial nesting bird protocol document by 2009 with different parks treated as different SOPs within the main document. Pilot work on the SOPs will begin in 2008 and be completed by the end of 2009 with full implementation beginning in 2010. Table below indicates proposed SFCN workload upon full monitoring implementation.

Expected SFCN staff time requirements once program is fully implemented in 5 years:

SFCN Staff	Full Time Equivalent (FTE)
Coordinator	
Marine Ecologist	
Fisheries Biologist	
Marine Biologist Technician (So FL)	
Marine Biologist Technician (VI)	
Community Ecologist	0.1
Wildlife Technician (Wildlife)	0.17
Wildlife Technician (Vegetation)	0.07
Quantitative Ecologist	0.06
Data Manager	0.04
GIS/Data Tech	0.02
Interns	
SFCN Total	0.46

Protocol: Forest Ecotones and Community Structure

[shortened name: Forest_Vegetation]

Vital Signs to which this protocol relates: Forest Ecotones and Community Structure

Parks Where Protocol will be Implemented:
BICY, BISC, BUIS, DRTO, EVER, SARI, VIIS – SFCN will evaluate existing monitoring and where possible builds upon it or develops new sampling plan

Justification/Issues being addressed: Forest Ecotones and Community Structure ranked 14th among the 44 SFCN vital signs. Plants are important primary producers and dominant physical structure components in terrestrial natural systems. They are the quintessential primary focus component of most natural land resource management agencies. Vegetation community composition and structure change may indicate transformation of successional state, time since disturbance, eutrophication, hydro-pattern (including groundwater), water quality, fire regime, disease or insect outbreak effects, changes in relative cover by native/non- native species, etc.

Ecotones are transition zones between habitats and are generally dynamic locations for flora and fauna. Due to the transition between habitats, tracking the position of ecotones can indicate their long-term trajectory. Understanding the physical conditions which drive ecotone location change is critical for resource management. Ecotones are expected to move, for example, in response to changes in water management, sea level rise, and fire management. Both hammocks and pinelands are important habitats for rare and endemic plant species and for wildlife. Hammocks are spatially limited vegetation communities within a matrix of pinelands. Pinelands are fire adapted whereas hammock species are less so. In the absence of fire, hammock species expand into pinelands, though fire can reduce or eliminate hammocks. Fire management is critical to maintaining a habitat balance. Invasive species could also impact relationships between these habitats.

Specific Monitoring Questions and Monitoring Objectives to be addressed by the Protocol:

The monitoring questions that are being addressed by this protocol are:

- Are ecotones shifting due to physical conditions (e.g., hydrology, climate change, anthropogenic factors, sea level rise, fire, episodic meteorological and storm wave events, etc.)?
- What are the status and trends in plant community composition and structure?

The specific monitoring objectives include:

Objective 1: At approximately 5 to 10 year intervals, document changes in the location of the pineland-hammock ecotones.

Justification/Rationale for this objective:
Ecotones can shift in part due to hydrology and fire management which are partially under park management control as well as due to natural factors such as natural succession, disease, insect outbreaks, hurricanes, extreme droughts, and frost events. Park management especially tries to maintain rarer communities which support endemic or endangered species such as hardwood hammocks and pine rocklands.

Objective 2: At approximately 5 to 10 year intervals, document changes in the location of the forest- marsh ecotones.

Justification/Rationale for this objective:
Ecotones can shift in part due to hydrology and fire management which are partially under park management control as well as due to natural factors such as natural succession, disease, insect outbreaks, hurricanes, extreme droughts, and frost events.

Objective 3: Determine long term trends in forest community structure and composition.

Justification/Rationale for this objective:
Forest structure and composition changes due to natural succession, establishment of new species including invasive species as well as stochastic events. Much of the forest systems in the Virgin Islands as well as BICY and BISC have been historically logged and are still in intermediate states of succession back to climax forest communities.

Measures:
Community composition and physical structure (e.g., canopy height, vegetative cover of each plant species, canopy cover in each stratum (canopy, herb layer, shrub layer, etc)), shifts in community boundaries (e.g., hammock/pine), soil depth, litter depth

Basic Approach:
SFCN in cooperation with Jenny Richards of FIU have hired a post-doc to work on vegetation monitoring protocols. SFCN will coordinate with existing programs where appropriate; such as fire monitoring plots in Long Pine Key in Everglades and long-term plots on VIIS and BISC. These existing programs will need to be evaluated for statistical rigor, compatibility of objectives and willingness to share reports and/or data.

SFCN will evaluate ecotonal change using both aerial photography monitoring and field monitoring via belt transects or a series of plots set up along a longer transect.

Table 1 shows the types of ecotones to be monitored and which methods will be used. Revisit time is likely to be once every 5 years or after major disturbance event and administered in a rotating panel.

SFCN will evaluate long-term change within plant communities via field plots revisited approximately once every 5-10 years (see Table 2).

Table 1. Plan for Ecotone Monitoring
A= monitored with aerial photography
F= monitored with field plots

	Pineland to Hammock	Coastal to Inland	Forest to Wet Prairie	Wet Prairie to marsh/slough
BISC		**A,F**	**A**	
BICY	**A,F**	**A,F**	**A**	
EVER	**A,F**	**A,F**	**A**	**A,F**
DRTO		**A,F**		
SARI		**A,F**		
BUIS		**A,F**		
VIIS		**A,F**		

Table 2. Plan for Long-term within-community monitoring plots

+ = SFCN monitoring
♦ = Existing monitoring program

	Pineland	Hardwood Hammock	Mangroves	Marshes	Island Moist Forest	Island Deciduous Forest	Island Scrub/ Shrub
BISC		**+,♦**	**+**				
BICY	**♦**	**+**	**+**				
EVER	**♦**	**+,♦**	**♦**	**♦**			
DRTO			**+**				
SARI			**+**				
BUIS			**+**			**+**	**+**
VIIS			**+**		**+,♦**	**+,♦**	**+**

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Development Schedule, Budget, and Expected Interim Products:

The "Forest Ecotones and Community Structure" protocol development is expected to be completed by 2010. Implementation is expected to take 0.33 FTE/year each for the community ecologist and two wildlife technicians across all habitat types including mangroves and marshes which are covered under other vital signs. For the evaluation of change via aerial photography, this is expected to take the GIS/Data technician approximately 2 months/year. Cost is estimated to be $10,000/year to cover helicopter time plus stakes, etc. Table indicates proposed SFCN workload upon full monitoring implementation for all 3 vegetation monitoring protocols.

Expected SFCN staff time requirements once program is fully implemented in 5 years.
Time estimates are for all 3 vegetation protocols.

SFCN Staff	Full Time Equivalent (FTE)
Coordinator	
Marine Ecologist	
Fisheries Biologist	
Marine Biologist Technician (So FL)	
Marine Biologist Technician (VI)	
Community Ecologist	0.3
Wildlife Technician (Wildlife)	0.4
Wildlife Technician (Vegetation)	0.4
Quantitative Ecologist	0.06
Data Manager	0.04
GIS/Data Tech	0.2
Interns	0.3
SFCN Total	1.7

Protocol: Freshwater fish, invertebrates and periphyton

[shortened name: FW_fish_inverts_periphyton]

Vital Signs to which this protocol relates: Freshwater fish and large macro-invertebrates; Periphyton; and Aquatic invertebrates in freshwater prairies and marshes.

Parks Where Protocol will be Implemented:
BICY – SFCN expands/implements monitoring in NW BICY in cooperation with the existing program in NE BICY.
EVER – SFCN summarizes reports from existing programs.
VIIS- deferred

Justification/Issues being addressed: Freshwater fish and large macro-invertebrates ranked 18th, aquatic invertebrates in wet prairies & marshes ranked 32nd and periphyton ranked 17th among the 44 SFCN vital signs. Regional populations of wet prairies and marsh fishes, macroinvertebrates, aquatic invertebrates and periphyton are early responders to changes in regional hydrology (water depth, timing, duration, quantity, quality) and are the prey base for wading birds and other higher consumers in the Greater Everglades and Big Cypress ecosystem.

Specific Monitoring Questions and Monitoring Objectives to be Addressed by the Protocol:
The monitoring questions that are being addressed by this protocol are:

- What are the status and trends of fish, large macro-invertebrate assemblages, aquatic invertebrates, and periphyton community composition, abundance (density & relative abundance), size structure, distribution, and nutrient content (periphyton) especially in relation to hydrological patterns and water quality in wet prairies and marshes? What is relative abundance and distribution of exotic species?

The specific monitoring objectives include:

Objective 1: Determine status and trends in community composition, abundance (density & relative abundance), size structure, and distribution of fish, large macro-invertebrates, aquatic invertebrates, and periphyton in Northwestern Big Cypress.

Justification/Rationale for this objective: Development is occurring to the north and northwest of Big Cypress National Preserve that is expected to impact both the hydrology (quantity, duration of flooding, distribution and drydown) and quality (total phosphorous and total nitrogen) of waters entering the park. Periphyton is expected to be an early indicator of changes in hydroperiod and phosphorous-loading due to CERP large-scale hydrological changes and water quality

improvements

Measures:
Freshwater fish, invertebrate and periphyton community composition, abundance (density and relative abundance); freshwater fish size structure and invasive species present; aquatic invertebrate MBI; and periphyton biomass, organic/inorganic (calcite) content, nutrient content, species composition.

Basic Approach:
A single sampling design will be used to monitor freshwater fish, large macro-invertebrates, aquatic invertebrates, and periphyton as co-location will save considerably on sample costs.

Freshwater fish and large macroinvertebrates: SFCN plans to work with the CERP funded effort in northeastern BICY to develop a similar sampling design and protocols for northwestern BICY. In NE BICY pilot studies are underway to study different protocols for monitoring fishes in cypress forests and in the mangrove/marsh interface paid for by CERP RECOVER MAP. It is unclear whether it will be funded long-term. Monitoring implementation in NW BICY will involve a pilot sampling period and writing of a full protocol prior to full implementation and would be conducted in cooperation with CERP funded effort in Northeastern BICY so that the two data sets could be compared and if appropriate combined. Sampling would focus in the area of northwest Big Cypress, north of Interstate 75 and west of the Florida National Scenic Trail entrance. Periphyton samples & micro-invertebrate samples would be collected simultaneously. A pilot study funded by CERP RECOVER in the northeastern portion of BICY found that throw traps similar to those used in Everglades National Park and the Water Conservation Areas appear to be the best method to use (compared with drop traps, lift traps, drift fences, gill nets) (Liston *et al.*, 2006). However additional methods may be needed to sample deeper areas in Okaloacoochee Slough and East Hinson Marsh (Joel Trexler, personal communication).

Sampling in Everglades is done at approximately 10-12 sampling units per landscape unit with about 2-5 throwtrap samples per sampling unit. Landscape units are chosen to be homogenous. If we assume that this area will include at least 1 landscape unit then about 12 sites would be visited 2 times each year with 3 throw-traps each. As with the NW BICY effort, a subset of sites may be visited 5 times a year during the pilot monitoring phase (early, mid and late wet season, early & mid dry season) to determine optimal times to sample with sampling tied to number of days since drydown and water stage at nearby stations. The remainder of sites would be sampled in the late wet season (October) and possibly mid dry season (March).

Aquatic invertebrates: SFCN will need to conduct a pilot study to determine the range of variability in aquatic invertebrates in the area and estimate appropriate sample

sizes. SFCN technicians will separate out the aquatic invertebrates from the periphyton samples, identify the species where possible, and count them.

Periphyton: Periphyton is easily collected as part of monitoring for other indicators but travel costs would prohibit monitoring it in isolation. Use of periphyton to monitor changes in hydroperiod and nutrient status is still in its early stages. Current work appears very promising but the relationships with hydroperiod, nutrient status are still being developed and refined. Diatoms tolerant of freshwater versus saltwater are well documented. Andy Gottlieb has shown a relationship between hydroperiod and changes in the diatom community. The Department of Environmental Protection has commissioned development of relationships between algal community and nutrient levels that is expected in 2008. SFCN will need to conduct a pilot study to determine the range of variability in periphyton in the area and estimate appropriate sample sizes. SOPs for collection procedures already exist with SFWMD. Although estimates at sample size are loose at best, for planning purposes we are assuming about 75 samples per year will be needed per area mentioned below.

Other areas:

Currently there is insufficient funding, but additional areas for possible expansion in the future include: other areas of BICY, Biscayne Coastal Wetlands, EVER's marl prairies, Florida Bay coastal wetlands, VIIS guts and SARI.

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Development Schedule, Budget, and Expected Interim Products:
The "Freshwater Fish, Invertebrates and Periphyton" protocol will be written by 2011 with full implementation in 2012. Initial design and subsequent analyses will require assistance of the Quantitative Ecologist.

For the freshwater fish and macro-invertebrate portion of the protocol, SFCN will coordinate with Jerry Lorenz and Bill Loftus who are the Principle Investigators for the NE BICY pilot program to develop monitoring for NW BICY. SFCN expects to pilot monitoring using the protocols in development by Jerry Lorenz and Bill Loftus (Liston *et al.*, 2006) implemented in 2008-2010. If all sites are accessed by helicopter, SFCN assumes annual helicopter costs of $7000/yr. Field equipment and supplies are estimated at $5000/yr.

Processing of aquatic invertebrates is assumed to take 2 hours per sample for analysis and data entry, thus this indicator will take about 4 weeks of a technician's time to analyze the samples. Costs include dissecting scopes, alcohol, sampling bottles & other miscellaneous scope equip (forceps, etc).

Current estimates from possible contractors to analyze the periphyton samples for algal composition & dominance is $400/sample + $65.34/sample for FIU to analyze the sample for total phosphorous, total nitrogen and total carbon (total calcium costs were not listed). Although pilot studies have not been done to estimate sample sizes, for planning purposes, assuming 75 samples/year each in BICY, costs to analyze samples will be $34,900.50. Periphyton samples will need to be divided and mailed (.5 week/year) plus data will need to be analyzed and reported (.5 week/year)

Table indicates proposed SFCN workload upon full monitoring implementation.

Expected SFCN staff time requirements once program is fully implemented in 5 years:

SFCN Staff	Full Time Equivalent (FTE)
Coordinator	
Marine Ecologist	
Fisheries Biologist	
Marine Biologist Technician (So FL)	
Marine Biologist Technician (VI)	
Community Ecologist	0.15
Wildlife Technician (Wildlife)	0.1
Wildlife Technician (Vegetation)	0.24
Quantitative Ecologist	0.04
Data Manager	0.04
GIS/Data Tech	0.02
Interns	
SFCN Total	0.59

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Protocol: Invasive/Exotic Fish in Canals

[shortened name: Inv_Fish_Canals]

Vital Signs to which this protocol relates: Invasive/Exotic Animals

Parks Where Protocol will be Implemented:
BICY, EVER – SFCN conducts limited monitoring in cooperation with park staff

Justification/Issues being addressed: Invasive/exotic animals ranked 12th among the 44 SFCN vital signs. Invasive fauna are a serious threat to maintaining ecosystem integrity, with at least 61 exotic species found within SFCN parks and many more throughout south Florida. Invasive/exotic fish are among the most problematic species. Canals bordering EVER and BICY are thought to be important vectors for invasion by new fish species into the parks. Early detection of new potentially invasive species in these canals would allow the greatest opportunity for successful control efforts and possible prevention of establishment of breeding populations within the parks.

Specific Monitoring Questions and Monitoring Objectives to be Addressed by the Protocol:
The monitoring questions that are being addressed by this protocol are:

- Where have new and existing invasive/exotic species been detected in canals in or near the parks?

The specific monitoring objectives include:

Objective 1: Routinely search canals bordering EVER (and BICY pending an analysis of effort) to detect new exotic fish species.

Justification/Rationale for this objective:
This is the most basic information needed for management.

Measures:
Exotic species present, distribution, new species detected along common invasion points (e.g., canals, degraded levees)

Basic Approach:
Canals along the eastern border of Everglades which commonly overwash into the park plus canals nearby has been identified for annual monitoring as these priority invasion hotspots (L31W, L31N, C111). SFCN will work in cooperation with EVER park personnel (Jeff Kline) to use electrofishing and other sampling techniques (seine nets, dip nets, etc.) in these canals to detect new exotic fish species which can then be targeted for control by a multi-agency team that is scheduled to be developed soon.

Some additional sites to monitor would be the L29 and L67 extension on the northern boundary of EVER, plus some canals in BICY (Tamiami canal, L-28, Loop road). Monitoring will preferably take place in early and late dry season.

If there is sufficient SFCN and BISC staff time, the effort may be expanded to BISC canals which empty into Biscayne Bay.

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Development Schedule, Budget, and Expected Interim Products:

Objective 1 will be implemented by the end of 2008 and is expected to take at most 1 week/year for 1 intern once the initial list is compiled and protocol developed (2 weeks). Cost of equipment for an electrofishing boat, trailer, engine, plus equipment and gear is estimated at $83,500. Time per year would be 2.5-3 weeks in Everglades only for 1-2 SFCN personnel assuming other personnel contributed by the park. Estimates for Big Cypress would be another 2-3 weeks but may not be done every year (e.g., every 2 years).

Table indicates proposed SFCN workload upon full monitoring implementation.

Expected SFCN staff time requirements once program is fully implemented in 5 years:

SFCN Staff	Full Time Equivalent (FTE)
Coordinator	
Marine Ecologist	
Fisheries Biologist	
Marine Biologist Technician (So FL)	
Marine Biologist Technician (VI)	
Community Ecologist	0.08
Wildlife Technician (Wildlife)	0.08
Wildlife Technician (Vegetation)	
Quantitative Ecologist	
Data Manager	
GIS/Data Tech	0.06
Interns	
SFCN Total	0.22

Protocol: Invasive/Exotic Plants – Corridors of Invasiveness

[shortened name: Inv_Plants]

Vital Signs to which this protocol relates: Invasive/Exotic Plants

Parks Where Protocol will be Implemented:
BISC, BICY, BUIS, DRTO, EVER – SFCN implements in cooperation with EPMT program
SARI, VIIS - deferred

Justification/Issues being addressed: Invasive/Exotic Plants ranked 5th among the 44 SFCN vital signs. Invasive plants are one of the most serious threats to maintaining ecosystem integrity in SFCN parks. Tracking the distribution, rate of spread and control of known invasive species is important in assessing the ability of an ecosystem to supporting native species. Additionally, detecting new species with the potential to become invasive while they are still in small controllable populations is important to cost-effective resource management. Executive Order 13112 , February 3, 1999, deals with the introduction, spread, control, and monitoring of invasive species on federal lands. The National Park Service Organic Act of August 25, 1916, as amended (PL 64-235, 16 USC §1 et seq.), the National Environmental Policy Act of 1969, as amended (42 U.S.C. 4321 et seq.), Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990, as amended (16 U.S.C. 4701 et seq.), Lacey Act, as amended (18 U.S.C. 42), Federal Plant Pest Act (7 U.S.C. 150aa et seq.), Federal Noxious Weed Act of 1974, as amended (7 U.S.C. 2801 et seq.), Endangered Species Act of 1973, as amended (16 U.S.C. 1531 et seq.), and other pertinent statutes.

Detecting new problem species early before they have a chance to spread by monitoring in the areas of most likely early establishment is a very cost-effective way of managing invasive species.

Specific Monitoring Questions and Monitoring Objectives to be Addressed by the Protocol:
The monitoring questions that are being addressed by this protocol are:

- Are invasive exotic plants increasing in extent?
- Are new invasive exotic species becoming established in or near the park?

The specific monitoring objectives include:

Objective 1: Routinely search roads, trails, canals, campgrounds, and other "Corridors of Invasiveness" to detect newly emerging and existing invasive plant species.

Justification/Rationale for this objective: This is fundamental knowledge required for an effective exotic plant management program to direct control efforts as well as report to GPRA goals. Detecting new problem species early before they have a chance to spread by monitoring in the areas of most likely early establishment is a very cost-effective way of managing invasive species.

Measures:

Invasive species present, aerial extent and distribution of invasive species, new exotic species detected at common invasion points categorized by invasive potential, vegetation types invaded.

Basic Approach:

The protocol for "Corridors of invasiveness" will involve an experienced botanist surveying corridors (public roads, fire roads, trails, beaches and canals) at low speeds for newly emerging and existing exotic plant species and recording GPS positions. Transects will be established perpendicular to corridors to detect species with lower detectability from vehicles, determine width of impact corridor, and detect presence of biological control agents. Extensive searches of known problem locations (trailheads, boat ramps, campgrounds) will be conducted. Data will be geospatially analyzed. The botanist involved should have a widespread knowledge of south Florida and/or US Virgin Islands vegetation and be able to detect exotic and unknown species as possible invasive species. This protocol will be implemented in a rotating design with only a portion of the parks surveyed each year with a revisit of approximately 5-8 years. Implementation is expected to be jointly by SFCN and NPS-EPMT personnel.

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Development Schedule, Budget, and Expected Interim Products:
The Corridors of Invasiveness protocol is expected to take about 3 months of SFCN staff time and 3 months of EPMT staff time to draft and test the protocols plus staff time to develop the web page. Implementation is partially dependant on EPMT funding. The corridors of invasiveness protocol is expected to take 3 weeks of field time/year and will be rotated among the parks.

Expected products include a "Corridors of Invasiveness" protocol by 2009-2010 assuming hiring of technicians occurs as planned.

Expected SFCN staff time requirements once program is fully implemented in 5 years:

SFCN Staff	Full Time Equivalent (FTE)
Coordinator	
Marine Ecologist	
Fisheries Biologist	
Marine Biologist Technician (So FL)	
Marine Biologist Technician (VI)	
Community Ecologist	0.02
Wildlife Technician (Wildlife)	
Wildlife Technician (Vegetation)	0.04
Quantitative Ecologist	
Data Manager	0.04
GIS/Data Tech	0.08
Interns	
SFCN Total	0.18

Protocol: Land-use Change

[shortened name: Land_Use]

Parks Where Protocol will be Implemented:
BICY, BISC, EVER, SARI, VIIS

Vital Signs to which this protocol relates: Land-use Change

Justification/Issues being addressed: Land-use Change ranked 11th among the 44 SFCN vital signs. Changes in land-use, sizes of the non-urban buffers around park boundaries, development of inholdings within park boundaries, and connectivity with other conserved natural areas impact park resources. Monitoring of changes over time would allow parks to understand the effects of these changes and to take appropriate actions to mitigate impacts.

Specific Monitoring Questions and Monitoring Objectives to be Addressed by the Protocol:
The monitoring questions that are being addressed by this protocol are:

- What are the status and long-term trends in landscape change in and around SFCN parks (e.g. changes in land use (municipal, private, commercial, agriculture), land cover, road density, housing density, etc.)?
- What are the near future changes expected in and around SFCN parks based upon building permits, zoning changes, and community planning decisions?

The specific monitoring objectives include:

Objective 1: At approximately 5-10 year intervals, determine long-term trends in spatial and temporal landscape change in and around SFCN parks based on changes in land-use and land cover, road density, housing density, and other available data.

Justification/Rationale for this objective: This is basic knowledge required for tracking land-use changes over time allowing for the identification of development which may affect park resources. Location and extent of proposed development would identify areas of change and would give parks the ability to mitigate undesirable effects brought about by land-use change.

Objective 2: Compile and summarize current approved building permits for selected areas to provide advisories to the park.

Justification/Rationale for this objective:
This information would allow parks to know what building is occurring adjacent to the park before it actually occurs.

Objective 3: Compile and summarize current applications for changes in land zoning, and approved zoning-changes for selected areas.

Justification/Rationale for this objective:
This information would allow parks to know what zoning changes are being debated while there is still time for the park to offer an opinion.

Objective 4: Compile and summarize proposals for larger-scale land-conversions, such as from agricultural to manufacturing or to sub-divisible status, creation of new sub-divisions, planned communities, and retail and industrial zones.

Justification/Rationale for this objective:
This information would allow parks to know large-scale proposals are being debated while there is still time for the park to offer an opinion.

Measures:
Land-use change, permitting/zoning changes, demographics within 1 mile of USVI parks, 75 miles of S. Florida parks

Basic Approach:
SFCN GIS Technician will coordinate with FIU, County, and SFWMD efforts. GIS Layers of in-holdings will be collected.

Future land-use change will require the periodic review of building permits and zoning changes. On a semi-annual basis contact will be made with each of the county level or equivalent permitting offices effecting areas around the park. The latest list of permit applicants including information on location type and size of development would be obtained from the government entity (especially Developments of Regional Impact, DRIs, for the state of Florida). The location of these permits will then be mapped to show the latest areas of planned development. SFCN would also work to get copies of state and county long-term plans so that parks can be alerted to long-term changes before it is too late to take action.

Principal Investigators and NPS Lead:
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- Trust for Public Lands
- South Florida Water Management District
- Florida International University
- County Governments

- USVI Department of Planning and Natural Resources

Development schedule, budget, and expected interim products:
SFCN will develop a "Land Use Change" protocol by 2009. The WASO office is working on a protocol for compiling general land use statistics which SFCN can pull from. Initial deliverables for network parks should include updated boundaries and layer of known inholdings. For the general land use portion of the protocol, each park would receive an update on land use every 5-10 years, but SFCN may work on these in rotation depending on whether work is done by NPS or contractor. If this work is contracted it is expected to cost approximately $100,000. Tracking of building permits would be on an annual basis but in theory this could be accomplished by an intern. The product from their internship would be a report listing and mapping all of the permits affecting a specific park. Anticipated staff time and additional costs: 1 FTE every 5 years plus 1/2 intern annually; $5,000 per year for imagery (majority of imagery would be obtained from local governments.

Expected SFCN staff time requirements once program is fully implemented in 5 years:

SFCN Staff	Full Time Equivalent (FTE)
Coordinator	0.04
Marine Ecologist	
Fisheries Biologist	
Marine Biologist Technician (So FL)	
Marine Biologist Technician (VI)	
Community Ecologist	
Wildlife Technician (Wildlife)	
Wildlife Technician (Vegetation)	
Quantitative Ecologist	
Data Manager	
GIS/Data Tech	
Interns	0.5
SFCN Total	0.54

Protocol: Mangrove-Marsh Ecotone & Mangrove Community

[shortened name: Mangrove_Ecotone]

Vital Signs to which this protocol relates: Mangrove-Marsh Ecotone

Parks Where Protocol will be Implemented:
BICY, BISC, BUIS, DRTO, EVER, SARI, VIIS– SFCN will evaluate existing monitoring and, where possible, build upon it or develop new sampling plan

Justification/Issues being addressed: Mangrove-Marsh Ecotone ranked 14th among the 44 SFCN vital signs. Mangroves provide important juvenile fish and invertebrate nursery areas, habitat for birds and rare pl ants, as well as providing important shoreline protection. Over 50% of the mangroves in the Virgin Islands have been lost since 1950. Ecotones are transition zones between habitats and are generally dynamic locations for flora and fauna. Due to the sharp transition between habitats, tracking the position of ecotones can indicate the long-term trajectory of habitats. Understanding the physical conditions which drive changes in the ecotone location is critical for proper resource management. Examples of ecotones include mangrove-tidal marsh, mangrove-marsh-cypress, and mangrove-freshwater marsh. Ecotones are expected to move, for example, in response to changes in water management, sea level rise, and fire management. Tracking the movement of mangrove-marsh ecotones can indicate the long-term trajectory of a wetland ecosystem, while accounting for regional water management changes and sea-level rise. Ecotone positioning can be effectively monitored by aerial photography. At selected sentinel sites in South Florida, ecotone movement across the landscape has been an important indicator for water management (e.g., "White Zone" in southeast Everglades).

Specific Monitoring Questions and Monitoring Objectives to be Addressed by the Protocol:

The monitoring questions that are being addressed by this protocol are:

- Are ecotones shifting or changing in aerial size (widening or narrowing) due to physical conditions (e.g., sea level rise, hydrology, climate change, anthropogenic factors, fire, episodic meteorological and storm wave events, etc.)?
- What are the status and trends in plant community composition and structure?

The specific monitoring objectives include:

Objective 1: At approximately 5 to 10 year intervals, document changes in the location of the mangrove-marsh ecotone (e.g. shifting inland due to sea level rise or storm events).

Justification/Rationale for this objective:

Ecotones can shift due to altered hydrology and fire management which are partially under park management control as well as due to sea level rise, natural succession, hurricanes, extreme droughts, and frost events.

Objective 2: Determine status and trends of mangrove community structure and composition.

Justification/Rationale for this objective:
Mangrove community structure and composition changes due to changes in elevation relative to sea level and drainage, natural succession, establishment of new species including invasive species, disease, as well as stochastic events such as frost and lightning strikes.

Measures:
Community composition and physical structure (e.g., canopy height, vegetative cover of each plant species, canopy cover in each stratum (canopy, herb layer, shrub layer, etc)), shifts in community boundaries, soil depth, litter depth.

Basic Approach:
SFCN is working in cooperation with Jenny Richards of FIU to hire a post-doc to work on vegetation monitoring protocols. SFCN will coordinate with existing programs where appropriate, such as mangrove monitoring by Tom Smith of FIU.

Objective 1: SFCN will evaluate ecotonal change using both aerial photography monitoring and field monitoring via belt transects or a series of plots set up along a longer transect. Table 1 shows the types of ecotones to be monitored and which methods will be used. Revisit time is likely to be once every 5-10 years or after major disturbance event (fire, frost, hurricane) and administered in a rotating panel.

Although porewater salinity was also identified as an additional indicator to monitor in this zone, this monitoring is deferred due to insufficient funds.

Objective 2: SFCN will evaluate long-term change within plant communities via field plots revisited approximately once every 5-10 years (see Table 2). Sediment Elevation Tables will be co-located with a subset of plots.

Table 1. Plan for Ecotone Monitoring
A= monitored with aerial photography
F= monitored with field plots

	Pineland to Hammock	Coastal to Inland	Forest to Wet Prairie	Wet Prairie to marsh/slough
BISC		**A,F**	**A**	
BICY	**A,F**	**A,F**	**A**	
EVER	**A,F**	**A,F**	**A**	**A,F**
DRTO		**A,F**		
SARI		**A,F**		
BUIS		**A,F**		
VIIS		**A,F**		

Table 2. Plan for Long-term within-community monitoring plots

+ = SFCN monitoring

♦ = Existing monitoring program

	Pineland	Hardwood Hammock	Mangroves	Marshes	Island Moist Forest	Island Deciduous Forest	Island Scrub/ Shrub
BISC		**+,♦**	**+**				
BICY	**♦**	**+**	**+**				
EVER	**♦**	**+,♦**	**♦**	**♦**			
DRTO			**+**				
SARI			**+**				
BUIS			**+**			**+**	**+**
VIIS			**+**		**+,♦**	**+,♦**	**+**

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Development schedule, budget, and expected interim products:

The "Mangrove-marsh Ecotone and Mangrove Community" protocol development is expected to be completed by 2010. Implementation is expected to take 0.33 FTE/year each for the community ecologist and two wildlife technicians across all habitat types including forest and marshes which are covered under other vital signs. For the evaluation of change via aerial photography, this is expected to take the GIS/Data technician approximately 2 months/year. Cost is estimated to be $10,000/year to cover helicopter time plus stakes, etc. Table indicates proposed SFCN workload upon full monitoring implementation for all 3 vegetation monitoring protocols.

Expected SFCN staff time requirements once program is fully implemented in 5 years.
Time estimates are for all 3 vegetation protocols.

SFCN Staff	Full Time Equivalent (FTE)
Coordinator	
Marine Ecologist	
Fisheries Biologist	
Marine Biologist Technician (So FL)	
Marine Biologist Technician (VI)	
Community Ecologist	0.3
Wildlife Technician (Wildlife)	0.4
Wildlife Technician (Vegetation)	0.4
Quantitative Ecologist	0.06
Data Manager	0.04
GIS/Data Tech	0.2
Interns	0.3
SFCN Total	1.7

Protocol: Marine Benthic Communities

[shortened name: Marine_Benthic_Communities]

Vital Signs to which this protocol relates: Marine Benthic Communities; Marine Invertebrates: Rare, Threatened, Endangered; Marine Exploited Invertebrates

Parks where protocol will be implemented:
BISC, BUIS, DRTO, EVER, SARI, VIIS – SFCN conducts monitoring for coral communities; SFCN collaborates for monitoring SAV in BISC, BUIS, DRTO, SARI, VIIS and summarizes reports in Biscayne Bay (BISC) and Florida Bay (EVER).

Justification/Issues being addressed: Marine Benthic Communities ranked 1st among the 44 SFCN vital signs, Marine Exploited Invertebrates ranked 10th, and Marine Invertebrates-Rare, Threatened and Endangered (RTE) ranked 6th. The vital sign Marine Benthic Communities is split into two communities: 1) coral reef communities and 2) seagrass and other submerged aquatic vegetation (SAV).

Coral reef communities within the SFCN represent the only eastern Caribbean and Western Atlantic Coral reefs within the National Park Service. The enabling legislation and/or presidential proclamations for VIIS, BUIS and DRTO specifically mention coral reefs within these park units as significant environmental communities. These communities consist of stony corals, octocorals, sponges, algae, and gorgonians, among others. These reefs support incredible diversity, including conch, lobsters, and sea turtles. Reefs also play a vital role for humans by supporting fisheries, nursery areas, tourism, pharmaceutical bio-prospecting and shoreline protection to name a few. Monitoring coral reefs was identified as a national priority in President Clinton's Executive Order 13089, establishing the Coral Reef Initiative. These coral reefs are negatively impacted by events, such as unusually high water temperatures that cause "bleaching", coral disease, vessel scarring, major storms, overfishing, and in some cases by sedimentation and nutrient enrichment due to coastal development.

Communities of seagrass and other submerged aquatic vegetation (SAV) cover large portions of seven SFCN parks and consist of various seagrass and algae species. These habitats serve as nursery areas for many marine species, support a variety of vertebrate and invertebrate life, and provide connectivity pathways between nearshore and offshore habitats. Community composition is related to salinity levels, light extinction, the distribution of soft and hard-bottom sediments, nutrient enrichment, water quality (e.g. sulfides, redox), disease, level of disturbance, and succession. The 1987 seagrass die-off in Florida Bay had cascading effects on the ecosystem.

Queen conch (*Strombus gigas*) is a heavily harvested species with strict take/no-take regulations in all of the marine parks in the SFCN.

Critically imperiled or rare invertebrate species within the marine community are important indicators and subjects for monitoring, as they are significant drivers/architects of reef community and structure. Elkhorn coral (*Acropora palmata*), once the primary reef building species, has declined >95% in some areas, dramatically effecting many marine and coastal processes. Black long-spined sea urchins (*Diadema antillarum*), once abundant herbivores, have significantly reduced populations, dramatically affecting herbivory of marine algae on coral reefs, which subsequently affects coral reef recruitment and growth processes. Black corals (*Antipathes* sp.) have been over-harvested for jewelry to the point that they are now considered rare, and shallow water populations are gone.

Specific Monitoring Questions and Monitoring Objectives to be Addressed by the Protocol:

The monitoring questions that are being addressed by this protocol are:

- What are the status and trends in coral reef community percent cover of major taxonomic groups (e.g., coral, algae, gorgonians, sponge, substrate), coral species diversity, coral community structure, rugosity, coral recruitment, coral disease mortality, and algal community structure? What portions of this change are explainable, e.g., hurricanes, bleaching/disease outbreak events? How do coral communities compare among areas with differing management regimes (e.g., no-take zones vs. fished zones)?
- What are the status and trends in seagrass and other SAV extent, distribution, community composition and habitat quality, especially in relation to known gradients such as onshore-offshore, long-shore gradients, and depths? Is seagrass cover increasing in recently created no-anchor zones?
- What are the status and trends of these rare, threatened, and endangered species (Acropora spp., Antipathes spp., and Diadema antillarum) in relative abundance and distribution?
- What are the status, variability, and trends in conch density, distribution, and size structure/maturity? What are the status and trends in regional harvest?

The specific monitoring objectives include:

Objective 1: At depths of 2-20 m with initial stony coral cover >5%, determine the status and trends in the percent cover of major taxonomic groups (stony coral, algae, octocoral, sponge), coral species richness, coral community structure, coral condition (proportion bleached; number, size and type of coral disease lesions), algal community structure (crustose coralline algae, macroalgae, turf algae), rugosity, and density of the herbivorous long-spined sea urchin (*Diadema antillarum)*.

Justification/Rationale for this objective: Although areas of low coral cover (less than 5%) exist throughout the park, the primary interest is in the high stony coral cover sites which are valued for their beauty and as habitat for important habitat diverse fish and marine invertebrate communities. Episodic bleaching events, disease mortality, ocean acidification, algal overgrowth, and tourism impacts are negatively impacting reefs, causing losses of live coral cover and altering species composition. Detecting trends and possible causes for further investigation will help park managers as well as provide important information for interpreting changes in fish and exploited invertebrate communities. Several parameters can be used to describe reef structure, including coral cover, density of colonies, condition of colonies, and size frequency distributions. We decided to emphasize monitoring of coral cover (as well as algal cover) for several reasons. Most of the stresses that affect corals in VIIS and BUIS cause loss of coral tissue. If the corals fail to recover, the affected areas will be rapidly colonized by algae. Major stresses therefore will result in a decrease in the amount of "live coral cover" and, usually, an increase in the amount of algae.

Objective 2: At reef depth (2-20 m), document with a temperature logger when ocean temperatures exceed thresholds known to cause bleaching or other stress to corals and how long the event occurred.

Justification/Rationale for this objective: Although areas of low coral cover (less than 5%) exist throughout the parks, the primary interest is in the high stony coral cover sites which are valued for their beauty and as habitat for important habitat diverse fish and marine invertebrate communities. Episodic bleaching events, disease mortality, ocean acidification, algal overgrowth, and tourism impacts are negatively impacting reefs, causing losses of live coral cover and altering species composition. Detecting trends and possible causes for further investigation will help park managers as well as provide important information for interpreting changes in fish and exploited invertebrate communities. Several parameters can be used to describe reef structure, including coral cover, density of colonies, condition of colonies, and size frequency distributions. We decided to emphasize monitoring of coral cover (as well as algal cover) for several reasons. Most of the stresses that affect corals in VIIS and BUIS cause loss of coral tissue. If the corals fail to recover, the affected areas will be rapidly colonized by algae. Major stresses therefore will result in a decrease in the amount of "live coral cover" and, usually, an increase in the amount of algae.

Objective 3: Determine status and trends in seagrass occurrence, percent cover, community composition, and epiphytic load in areas <20 m depth and with sufficient water clarity for visual assessments. Results will be described in relation to proximity to shore, long-shore gradients, depths, and water quality changes (i.e. salinity, nutrients, and turbidity).

Justification/Rationale for this objective: Seagrass and other SAV cover, biomass, community composition, distribution, and diversity are affected by changes in light penetration, salinity, nutrient availability, light penetration, epiphyte load,

hypoxia/anoxia, sulfide toxicity, disease, boat groundings and anchor damage, hurricane "blowouts," grazing, and plant succession. Seagrass communities are expected to show much faster positive responses to improvements in water quality and reductions in visitor damage than coral communities. Declines in seagrass communities can in turn increase sediment resuspension and turbidity causing further problems to both seagrass and coral communities.

Objective 4: Determine status and trends in adult and juvenile conch density and size structure within seagrass communities <20m deep.

Justification/Rationale for this objective: Conch are heavily harvested in the islands although no longer permitted in south Florida. Assessing density and size structure are important for showing how closures affect populations and for management in case fishing is re-opened in south Florida.

Objective 5: For coral reefs at depths >20 m, determine status and trends in percent cover of major taxonomic groups (stony coral, algae, octocoral, sponge), coral species diversity and coral community structure, pending a pilot study to establish feasilibility, safety and cost-effectiveness.

Justification/Rationale for this objective:
Regularly diving below 20m is difficult and dangerous for divers. Thus an alternate protocol is needed for these deeper depths.

Objective 6: Determine status and trends in stony coral recruitment, pending a pilot study to establish feasilibility, safety and cost-effectiveness.

Justification/Rationale for this objective:
Coral recruitment is an important life stage to be monitoring to determine long-term health of the reef. This stage is very sensitive to stressors and having sufficient substrate on which to grow. However monitoring recruitment may be difficult to do from video and may not be feasible to accomplish given time, safety constraints *in situ*.

Vital Signs Measures:
Percent cover of major taxonomic groups (coral, algae, gorgonians, sponge), coral species diversity, coral community structure, rugosity, coral recruitment, coral disease mortality, and algal community structure, episodic assaults (bleaching); Seagrass and other SAV community composition, cover and habitat quality of seagrass and other SAV habitat. Conch (spatial distribution, density, size structure, proportion immatureMeasures for rare, threatened and endangered invertebrates are species dependent (*Acropora*, *Diadema*, *Antipathes*).

Basic Approach:

Objective 1: Coral reef communities, depths of 2-20 m

Eleven intensive coral monitoring sites were established as part of the prototype program at BUIS and VIIS beginning in 1999 and then expanded to BISC and DRTO. The protocol, "Using Videography to Monitor Coral Reefs, and Using the Aqua-Map system" (for random within-site transect selection) was peer-reviewed in 1998. These index sites were selected because they were the sites of historical work, were sites of high coral cover, or were otherwise of management interest. Site size ranges from 7,125-20,200 m^2. 20 permanent 10 meter transects were randomly selected at each site. Each transect is videotaped annually and analyzed. These sites have proven invaluable in documenting the declines after the 2005 bleaching and disease outbreak event and provide a rigorous set of monitoring data within these sites and SFCN plans to continue monitoring them and an updated version of the protocols "Using videography to monitor coral reefs" and "Using the Aqua-Map system" will be incorporated into the "Marine Benthic Communities" protocol.

Because the index coral monitoring sites protocol is very localized in inference, SFCN is working to expand upon the existing protocol to a design that allows inference to all stony coral communities 2-20m depth and will allow comparisons of inside vs. outside comparisons of marine protected areas (issue at DRTO and potentially BISC; BUIS is entirely protected). This sampling design is still in development with preliminary work being conducted at DRTO but will likely involve much smaller sites of 4 transects distributed throughout hard-bottom habitat in the parks sampled in a rotating design with the majority of sampling effort and revisit frequency at sites with higher coral cover (>5% stony coral cover) but a low-level focus and long revisit interval (10-20 years) for low coral cover hard-bottom. SFCN also hopes to establish such designs at BISC, BUIS, and SARI. With 5 intensive sites already established at VIIS, it is unclear whether additional effort is warranted there.

The videography protocol at both the intensive sites and park-wide assessments will be supplemented by rugosity measurements once every 10 years or subsequent to a major disturbance event such as a hurricane. A chain will be laid over each transect and the length of chain required compared with the straight chain length of 10m is a measure of the rugosity.

SFCN will also investigate whether there is a way to cost-effectively supplement the protocol to make it comparable to another protocol that is currently conducted with fish monitoring in DRTO but is re-randomized each year. Doing so might lend power to detect changes at lower coral cover sites, however it is unclear whether this other effort will have long-term funding.

Objective 2: Water temperature at reef depth

At each index site and at a subset of the park-wide sites, continuous data loggers will

be used to record water temperature at reef depth to serve as a covariate when assessing sudden changes.

Objective 3: Seagrass

Existing monitoring programs for seagrass are being conducted in Florida Bay and Biscayne Bay by FHAP and DERM using a sampling unit design and sampling unit level methodology that is consistent with the program being used in the Florida Keys by Jim Fourqurean of FIU. Florida Bay is divided by basins and Biscayne Bay into three regions. Each basin or region is analyzed separately. The Florida Keys design involves dividing each area (basin or region) into sub-areas or cells. Five sampling units are selected in each sub-area and were revisited in a five year rotation. At each sampling unit 10 ($0.25m^2$) quadrats are assessed using the Braun-Blanquet method to assess seagrass density, composition, epiphytic load and biomass by species. These data are already analyzed and reported through the CERP RECOVER Program Monitoring and Assessment Plan System Status Report by first analyzing the number of sampling units with seagrass present and then the density of seagrass at units where it is present and then combining the two into a single index. SFCN hopes to coordinate with these programs to report results through the vital signs program as well. However SFCN will work with EVER resource management staff to review these programs as the resource management staff have expressed concerns that these programs are not sufficient to meet park management information needs.

For the coastal shelf area of BISC and DRTO that is <20m deep, soft-bottom habitat will be sampled using a stratified random or a GRTS design using a protocol adapted from the Florida Keys and Florida and Biscayne Bays designs so that SFCN sampling will be comparable to these other groups. For BUIS and VIIS, although some seagrass monitoring occurs as part of the habitat monitoring portion of the fish monitoring effort being jointly conducted by the NOAA Biogeography team and NPS staff, the power and design is insufficient to adequately monitor trends in seagrass. SFCN will first examine some protocols used with historical work in the USVI and compare with the south Florida protocols to determine which to use given the tradeoffs of comparability with historical work versus having a single network-wide protocol. SARI and BUIS do not appear to need stratification although a spatially balanced approach to sampling is preferred. For VIIS, a stratification to allow increased sampling in areas of human impact such as Coral Bay and Cinnamon Bay will be considered.

It should be noted that some project specific monitoring is already being conducted by park staff. BISC staff are already monitoring seagrass restoration sites and VIIS staff are monitoring effectiveness of mooring buoy installation on seagrass recovery.

Objective 4: Conch

SFCN will conduct pilot conch counts during seagrass surveys to see if there is sufficient power to evaluate trends. Measurements of carapace length and presence

of lip indicating maturity will be taken. Conch data are already available from the NOAA Biogeography team's fish and benthic monitoring in USVI parks to assess power using their methodology in the USVI.

Objective 5: Deep stony coral communities, depths >20 m

SFCN will assess feasibility of the use of underwater ROV and/or drop cameras to collect imagery of these areas for a more qualitative level of monitoring. Much less is known about these deep coral reefs. These deep areas occur in BUIS, DRTO, SARI, and VIIS.

Objective 6: Coral recruitment

A pilot project will be conducted to determine the costs and feasibility of monitoring recruitment along these transects or a subset thereof. The time involved may make recruitment monitoring unfeasible.

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Development Schedule, Budget and Expected Interim Products:

Drafts of portions of the Marine Benthic Communities protocol for coral community monitoring at historic index sites (BISC, BUIS, DRTO, VIIS), for coral-water temperature monitoring, and *Diadema antillarum* monitoring have been completed and review comments from the NPS-WRD will be incorportated by December 2008. The portions of the Marine Benthic Communities protocol for monitoring coral communities 2-20m deep in the more extensive sites approach, will be completed by 2008. A feasibility assessment for monitoring deep water sites will begin in 2014. The portions of the protocol for monitoring SAV and for Conch will be completed by 2009. Estimated staff time for coral monitoring per year is 2 FTE. Estimated staff time for monitoring SAV per year is 1 FTE.

Expected SFCN staff time requirements once program is fully implemented in 5 years:

SFCN Staff	Full Time Equivalent (FTE)
Coordinator	0.08
Marine Ecologist	0.6
Fisheries Biologist	0.6
Marine Biologist Technician (So FL)	0.7
Marine Biologist Technician (VI)	0.7
Community Ecologist	
Wildlife Technician (Wildlife)	
Wildlife Technician (Vegetation)	
Quantitative Ecologist	0.1
Data Manager	0.08
GIS/Data Tech	0.04
Interns	
SFCN Total	2.9

Protocol: Marine Fish Communities

[shortened name: Marine_Fish]

Vital Signs to which this protocol relates: Marine Fish Communities

Parks Where Protocol will be Implemented:
BISC, BUIS, DRTO, EVER, SARI, VIIS – SFCN augments existing monitoring; conducts additional park-specific analyses as necessary; summarizes reports

Justification/Issues being addressed: Marine Fish Communities ranked 2nd among the 44 SFCN vital signs. Fish communities in the coastal shelf and oceanic areas are an important higher trophic level of the marine system, valued by humans as fisheries. Community status, structure and trends reflect changes in marine habitat quality, connectivity, fishing pressure, and long-term ecosystem resilience. Community status also affects seabird communities and large marine vertebrates. Balancing resource extraction with sustainability is a management concern. The exploited reef fish assemblage contains intermediate and higher trophic level piscivores although herbivores are added in heavily fished USVI. These species are under heavy fishing pressure within and outside SFCN parks boundaries. The impacts of fishery management tools such as "no-take" zones are of critical interest to resource managers and the public. Several fish species within parks are at or near local or regional extirpation.

Specific Monitoring Questions and Monitoring Objectives to be Addressed by the Protocol:
The monitoring questions that are being addressed by this protocol are:

- What are the status, trends, and variability in exploited fish assemblages (e.g., Grouper/Snapper/Parrotfish/Surgeonfish), reef fish communities, and nearshore and estuarine (bay) fish communities? Are there differences among areas with different management regimes?
- If present within parks, what are the locations and size of spawning aggregations?

The specific monitoring objectives include:

Objective 1 Determine status, trends, and variability in exploited reef fish species (Grouper/Snapper species plus parrotfish, surgeonfish, and baitfish in USVI parks) relative abundance (density), distribution and size structure.

Justification/Rationale for this objective:
Knowing trends in exploited species is critical for effective park management of these resources and to answer questions regarding the effects of marine protected areas.

Objective 2: Compile data on status, trends, and variability in exploited reef fish species from other sources to allow comparison inside vs. outside marine protected areas.

Justification/Rationale for this objective:
Determining effectiveness of marine protected areas is an important management issue. Data from multiple sources may need to be compiled to best answer this question.

Objective 3: Determine status, trends and variability in reef fish community relative abundance (density), distribution, biomass, size distribution, fish community taxonomic composition, species richness, and recruitment.

Justification/Rationale for this objective: Knowledge of the overall fish community health is necessary to assess park health in addition to the exploited species. Species of interest change over time and maintaining measures of all species helps buffer against future changes, both natural and anthropogenic.

Objective 4: Compile data on status, trends, and variability in reef fish species from other sources to allow comparison inside vs. outside marine protected areas.

Justification/Rationale for this objective: Knowledge of the overall fish community health is necessary to assess park health in addition to the exploited species. Species of interest change over time and maintaining measures of all species helps buffer against future changes, both natural and anthropogenic.

Objective 5: Determine recruitment, relative abundance (density), and distribution of nearshore and estuarine (bay) fish communities.

Justificiation/Rationale for this objective:
Nearshore areas in bays and estuaries especially near mangroves and marshes are important juvenile fish nursery areas and monitoring may help show if there are problems during this life stage. This objective is very important but of less priority than the Objectives 1 and 2 as juvenile fish should eventually recruit to the reef.

Objective 6: Document locations and approximate sizes of spawning aggregations in network parks when encountered.

Justification/Rationale for this objective:
Spawning aggregations are critically important for maintaining some species such as goliath grouper or red hind but it is unclear where aggregations occur within park boundaries. One aggregation has been discovered in the northwest corner of BUIS by The Nature Conservancy.

Measures: Fish community taxonomic composition, species richness, targeted species (Grouper, Snapper, (parrotfish, surgeonfish in USVI), baitfish) spatial/temporal distribution, abundance/density, size structure, recruitment, biomass, fishing pressure, spawning aggregation characteristics

Basic Approach:

Considerable existing monitoring efforts are underway for South Florida and the US Virgin Islands Parks. Rather than designing new programs, SFCN will instead seek to coordinate with these existing programs and augment sampling as needed to allow for park assessment of trends as well as regional assessments. If these programs are cut, SFCN will focus on filling the need with existing staff time using the following priorities: reef fish within parks, reef fish in neighboring areas outside protected areas in parks (to allow management comparison), fish in seagrass/bays. The justification for prioritizing monitoring fish on the reef is that many juvenile fish species which inhabit seagrass and nearshore areas migrate to adult lives on the reefs. Monitoring fish in bays provides important information about this stage in the life cycle for management, but some of these changes will be reflected in the reef fish counts as well. Until a power analysis for BISC and DRTO reef fish monitoring is completed, SFCN won't know how much effort will be required to augment reef fish sampling in those parks and what resources are remaining to cover nearshore areas and bays. Currently SFCN staff are working about 17 weeks a year on fish monitoring activities. SFCN proposes to more than double that effort to 1 FTE equivalent a year of effort. SFCN has funded a post-doctoral fellow in collaboration with Jerry Ault of the University of Miami – RSMAS to work out the details of how the groups will collaborate, conduct power analyses, work on the habitat component of the protocol and ensure that a written protocol document is completed.

<u>Objectives 1 and 2:</u>
For monitoring reef fish communities SFCN will be using visual point count or transect methods. Existing programs in south Florida parks and USVI parks are using different methodologies which are discussed below. The exploited fish species are a subset of the reef community and both objectives are met using a single protocol. However power analysis will need to focus on the exploited species to make sure there is enough power to assess trends in those species as well as aggregated community metrics.

Reef fish – South Florida
SFCN will be collaborating with the ongoing NOAA and University of Miami fish monitoring (Jim Bohnsack and Jerry Ault respectively) being conducted at BISC and DRTO. The sampling design is a two-stage stratified random design on coral reef habitats only with 8 different types of coral hard-bottom defined as different strata. Primary 200m x 200m sampling units are re-randomized each year with 2 second-stage units randomly located in each primary unit and two diver stationary visual

point counts per secondary unit conducted by scuba divers (Menza *et al.*, 2006). Currently the sample size is designed to assess changes in the Florida Keys and greater Dry Tortugas region. Monitoring in the Florida Keys is currently conducted annually and in the Dry Tortugas every two years. SFCN has funded a post-doc to work with NOAA and the University of Miami to determine power and additional sampling needed to be able to report trends within the park boundaries plus assess trends inside and outside the newly established DRTO Research Natural Area (a no-fishing marine protected area). This monitoring is also critical to meet the needs of the *DRAFT Research Natural Area monitoring (RNA) and research plan: a joint Florida Fish and Wildlife Conservation Commission-National Park Service plan to assess the conservation efficacy of the RNA* (Hunt *et al.*, 2007).

The major fish monitoring efforts in the Florida Keys held a workshop in April 2007 in order to better coordinate among their protocols and sampling designs (Acosta *et al.*, 2007) so some adjustments in protocols to allow for pooling of data are under discussion.

SFCN staff has already assisted with the DRTO fish monitoring cruises in the past and expects to assist with the supplemental fish monitoring needed to report on trends within BISC and DRTO. SFCN also anticipates conducting some reef fish monitoring at DRTO during the "off" years that RSMAS is not conducting it. SFCN will also provide assistance with the park-specific supplemental analyses, if needed.

To provide a general measure of fishing pressure SFCN will assess trends in south Florida commercial harvest data and numbers of recreational saltwater fishing licenses and recreational vessel registrations. This is easily obtainable information in south Florida and provides an estimate of the fishing pressure in south Florida in and around the parks. Unfortunately it is unclear whether this information is consistently tracked in the USVI.

Marine Fish Communities - USVI

The NOAA Center for Coastal Monitoring and Assessment (CCMA) Biogeography Team Coral Reef Ecosystem Monitoring Program (CREMP) has been monitoring reef fish in and outside BUIS, VIIS, and VICR as well as La Parguera, Puerto Rico since 2001 using a multi-agency effort. Strata involve benthic habitat (hardbottom vs soft-bottom), management (inside vs. outside protected area) and geographic zone. Please note that this involves more habitats than the South Florida efforts which focus only on hardbottom and reef bottom in particular.The overall design is stratified random with the sampling unit protocol being a visual belt transect and visual point count conducted by scuba divers. Simultaneous measurements of benthic habitat (seagrass, coral), and other species of interest (lobster, conch, diadema) occur. Although the south Florida and USVI protocols are very aware of each other's efforts, it is unclear at this point whether the south Florida and the USVI protocols will be standardized or not. SFCN has already assisted with the BUIS and

VIIS/VICR fish "blitzes" monitoring efforts and expects to continue doing so in the future.

The CREMP effort described above was originally funded for 3 years through a BUIS NRPP project which ended in 2007. It is unclear whether the effort will continue now that NRPP funding is no longer available. If this effort ceases to be funded, SFCN plans to continue the efforts within the parks, but may evaluate the data to determine the consequences if monitoring is restricted to hard-bottom only sites or restricting monitoring to within-park boundaries.

Objective 3: *Bays & Mangroves – South Florida & USVI*
SFCN will first seek to coordinate with existing efforts that are monitoring fish along mangrove (Joe Serafy/NOAA in BISC; and Ed Matheson, Robert McMichael/FFWCC in Florida Bay). Funding is provided by CERP and long-term funding is unclear. SFCN will look at these existing programs and see if they are sufficient or if additional effort is warranted. SFCN also has a juvenile fish monitoring program underway in the USVI. This program is at a point where analysis of the data for trends and power would be very useful and this will be a task for the new SFCN marine post-doc.

Objective 4: *Spawning aggregations*
Regarding spawning aggregations, SFCN will investigate by contacting researchers to determine if and where spawning aggregations occur in or near the parks and what work is being done.

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Development Schedule, Budget, and Expected Interim Products:

SFCN is working in collaboration with the University of Miami-RSMAS, National Marine Fisheries Service and FWRI to ensure a written protocol is produced covering the collaborative monitoring underway between RSMAS, NOAA, FWRI and NPS. The NOAA-Biogeography team already has a different written protocol and the SFCN/post-doc will work out details of interactions between the two groups. SFCN is currently an active participant in multi-agency fish monitoring with both the South Florida and USVI groups. Implementation of a sample design for reef fish monitoring in network parks will be completed by 2009; nearshore and estuarine will be completed by 2010. Estimated staff time for fish community monitoring is 1 FTE.

Expected SFCN staff time requirements once program is fully implemented in 5 years:

SFCN Staff	Full Time Equivalent (FTE)
Coordinator	0.04
Marine Ecologist	0.2
Fisheries Biologist	0.2
Marine Biologist Technician (So FL)	0.2
Marine Biologist Technician (VI)	0.2
Community Ecologist	
Wildlife Technician (Wildlife)	
Wildlife Technician (Vegetation)	
Quantitative Ecologist	0.06
Data Manager	0.04
GIS/Data Tech	0.04
Interns	
SFCN Total	0.98

Protocol: Soil Elevation

[Shortened name: Soil_Elevation]

Vital Signs to which this protocol relates: Coastal Geomorphology

Parks Where Protocol will be implemented:
BICY, BISC, BUIS, SARI, VIIS: Soil Elevation Tables (SETs)- SFCN implements monitoring
EVER: SETs – SFCN summarizes reports from existing program

Justification/Issues being addressed: Soil dynamics (the build up or loss of sediment) is a basic process that can have far reaching impacts on an ecosystem. This process is especially important in mangroves, mudbanks, and salt ponds. CERP/MOD Waters Everglades restoration of regional hydrology, water deliveries, large storm events, and sea level rise could all affect these soil dynamics and have implications for long-term changes in coastal wetlands. In the USVI, sediment filling of ephemeral guts and salt ponds from upland development is also an important issue.

Specific Monitoring Questions and Monitoring Objectives to be addressed by the Protocol:
The monitoring questions that are being addressed by this protocol are:

- What are the status and trends in soil dynamics (accretion, subsidence and erosion) in mangroves, mudbanks, and salt ponds, especially in relation to changes in hydrology (quality, quantity, timing and duration) sea-level, storms/hurricanes, and upland erosion?

The specific monitoring objectives include:

Objective 1: Determine changes in soil elevation (accretion, subsidence, and erosion) in mangroves, mudbanks and salt ponds.

Justification/Rationale for this objective: This is fundamental knowledge required to understand if mangrove environments will be able to keep up with sea level rise, determine restoration impacts, determine storm impacts, and to determine if salt ponds are being filled by sediment runoff.

Measures:
Change in soil elevation in mangroves & salt ponds

Basic Approach:

Soil Elevation Table (SETs) and mark horizon installation – We will install SETs in mangroves at a number of the parks (BICY, BISC, SARI, VIIS) and in salt ponds at BUIS and VIIS. We will coordinate with existing EVER monitoring: the southwestern mangroves being conducted by Thomas J. Smith III USGS, Taylor River mangrove sites being conducted by Fred Sklar of the South Florida Water Management District (SFWMD) in conjunction with the Florida Coastal Everglades Long term Ecological Research (FCE -LTER) sites and mudbanks of Florida Bay being conducted by Robert Halley (USGS).

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Development Schedule, Budget, and Expected Interim Products:

The protocols involved are expected to take about of 15 days of SFCN staff time to measure SETs annually (measured bi-annually – twice a year). SFCN staff will be responsible for this indicator (Community Ecologist, with assistance from Technicians). One time equipment cost of $12,000.00 plus ongoing travel costs to USVI and DRTO for maintenance and monitoring at 6 month intervals. The protocol development for SET should be completed by 2009 and begun 2010. Table indicates proposed SFCN workload upon full monitoring implementation.

Expected SFCN staff time requirements once program is fully implemented in 5 years:

SFCN Staff	Full Time Equivalent (FTE)
Coordinator	
Marine Ecologist	
Fisheries Biologist	
Marine Biologist Technician (So FL)	
Marine Biologist Technician (VI)	
Community Ecologist	0.02
Wildlife Technician (Wildlife)	0.08
Wildlife Technician (Vegetation)	0.08
Quantitative Ecologist	0.06
Data Manager	0.02
GIS/Data Tech	
Interns	
SFCN Total	0.26

Protocol: Spiny Lobster

[shortened name: Spiny_Lobster]

Vital Signs to which this protocol relates: Marine Exploited Invertebrates

Parks Where Protocol will be Implemented:
BISC, DRTO, EVER, SARI, VIIS – SFCN is monitoring lobster; analyzes harvest data; summarizes reports from existing programs
BUIS – SFCN summarizes reports from park monitoring

Justification/Issues being addressed: Marine Exploited Invertebrates ranked 10th among the 44 SFCN vital signs. Spiny lobster (*Panulirus argus*) adults are under heavy fishing and commercial harvest pressure outside SFCN park boundaries and a managed harvest occurs within park boundaries (BISC, VIIS). The Spiny lobster (*Panulirus argus*) life cycle includes both a free-swimming larval phase and a benthic adult life stage, frequently use multiple habitats inside and outside park boundaries, and can be affected by regional connectivity and stressors. Adult spiny lobsters feed mainly on gastropods, chitons, bivalves, corals and scavenged food remains. Balancing resource extraction and environmental degradation with sustainability is a key management concern. The impacts of fishery management tools such as marine protected areas (BUIS, DRTO) are of interest to resource managers and the public.

Specific Monitoring Questions and Monitoring Objectives to be Addressed by the Protocol:
The monitoring questions that are being addressed by this protocol are:

- What are status, variability, and trends in spiny lobster relative abundance/density, distribution, size structure, sex ratio, and harvest?

The specific monitoring objectives include:

Objective 1: Determine trends in the relative abundance/density, size structure and sex ratio of spiny lobster.

Justification/Rationale for this objective:
Spiny lobster abundance and size structure are important for managing harvest of these species and showing how closures affect the populations

Measures:
Relative abundance/density, size structure, sex ratio, regional harvest

Basic Approach:
SFCN will conduct pilot protocol testing for lobster monitoring, evaluating the use of timed searches at coral monitoring sites as well as investigating other potential fisheries independent monitoring techniques. Long-term monitoring conducted by FWRI is in a transitional period where past methodologies are being evaluated for power and efficacy. SFCN will stay abreast of those decisions when making our determination of what methodologies and sampling design to use and will try to coordinate with those efforts if appropriate. SFCN will also investigate coordinating with BISC lobster creel surveys and will assess commercial harvest data from the state of Florida.

SFCN will acquire south Florida commercial landings data from the following web site. http://research.myfwc.com/features/view_article.asp?id=19224

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Development Schedule, Budget, and Expected Interim Products:
The Spiny Lobster protocol completion is expected by 2010. Commercial landing information will begin being compiled by 2009. Staff time estimated for lobster monitoring is 0.3 FTE.

Expected SFCN staff time requirements once program is fully implemented in 5 years:

SFCN Staff	Full Time Equivalent (FTE)
Coordinator	
Marine Ecologist	0.08
Fisheries Biologist	0.08
Marine Biologist Technician (So FL)	0.08
Marine Biologist Technician (VI)	0.08
Community Ecologist	
Wildlife Technician (Wildlife)	
Wildlife Technician (Vegetation)	
Quantitative Ecologist	0.04
Data Manager	0.04
GIS/Data Tech	0.06
Interns	
SFCN Total	0.46

Reference:

Cox, C. and J. H. Hunt. 2005. Change in size and abundance of Caribbean spiny lobsters Panulirus argus, in a marine reserve in the Florida Keys National Marine Sanctuary, USA. Mar. Ecol. Prog. Ser. 294:227-239.

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Atlanta, Georgia

South Florida/Caribbean Network
Data Management Plan

Natural Resource Report NPS/SER/SFCN/NRR—2008/064



ON THE COVER
Coral Monitoring transect pin. NPS Photo.

South Florida/Caribbean Network
Data Management Plan

Natural Resource Report NPS/SER/SFCN/NRR—2008/064

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Change History

Titles of updated or revised sections of the plan will be followed by brackets containing the date of the latest version of that section and a brief update history. For example, the title of Section 2.2 may be followed by "[07/05/2007; Update History: 1/15/2005, 10/23/2004]." This indicates the current wording of that section was last updated on July 5, 2007 and it was previously revised on October 23, 2004 and January 15, 2005.

The following revisions have occurred:

Original Version #	Date of Revision	Revised By	Changes	Justification	New Version #
1.0	**10/15/2007**	**Brian Witcher**	**Draft version**		**1.0**

Executive Summary

The central mission of the NPS Inventory and Monitoring Program is to provide timely and usable scientific information about the status and trends of park natural resources to park managers. To meet this challenge, we need an information management system that can effectively produce, maintain and distribute the products of scientific investigation conducted in our parks.

Good data management is the means by which a thorough understanding of the value of scientific information about our natural resources can become a part of our National Park Service heritage. Data management refers to the framework by which data are acquired, maintained, and made available. Data management is not an end unto itself, but a means of maximizing the quality and utility of our natural resource information. A robust data management system is particularly important for long-term programs where the lifespan of a dataset will span the careers of several scientists. Viewed in this way, it becomes obvious that data management is vital to the success of any long-term research program.

The purpose of the South Florida/Caribbean Data Management Plan is to provide I&M and other park staff with a conceptual framework for a system of data management that will ensure the production and dissemination of timely and usable scientific information about the status and trends of park natural resources to park managers. Our strategy for achieving this goal can be summarized as follows: Ensure the quality, interpretability, security, longevity and availability of our natural resource data. Our objectives include:

- Confidence in the security and availability of natural resource data and related information
- Easy access to most information, and appropriate safeguards for sensitive information
- Awareness of the intended use and limitations of each dataset
- Infrastructure and documentation that encourages data exploration
- Compatibility of datasets for exploration and analysis at larger scales and across disciplines
- Implementation of standards and procedures that facilitate information management, and that reinforce good habits among staff at all levels of project implementation – project leaders, technicians, and volunteer data collectors
- A proper balance between the standards needed to ensure quality and usability, and the flexibility to meet specific needs and encourage innovation
- A team of natural resource professionals who view data not as a commodity but as the lifeblood of our work

This plan describes how our Network will:

- Support Inventory and Monitoring Program objectives
- Acquire and process data
- Assure data quality
- Document, analyze, summarize and disseminate data and information
- Maintain nationally developed data management systems
- Maintain, store and archive natural resources data and information

Chapter 1. Introduction

The National Park Service (NPS) Inventory and Monitoring (I&M) Program was the catalyst for developing the South Florida/Caribbean Network (SFCN) Data Management Plan (DMP). The I&M Program represents a long-term commitment by the NPS to assess and document the status and trends of park natural resources (DMP Appendix C – National Park Omnibus Act 1998). To effectively assess and document park natural resource status and trends, the Network must develop and implement a plan that outlines a sound long-term roadmap to guide the development, management, and dissemination of data and information.

1.1. The South Florida/Caribbean Network

The South Florida/Caribbean Network includes seven National Park units located in the Southern Florida Coastal Plain and the U.S. Virgin Islands, including:

- Big Cypress National Preserve
- Biscayne National Park
- Buck Island Reef National Monument
- Dry Tortugas National Park
- Everglades National Park
- Salt River Bay National Historical Park and Ecological Preserve
- Virgin Islands National Park

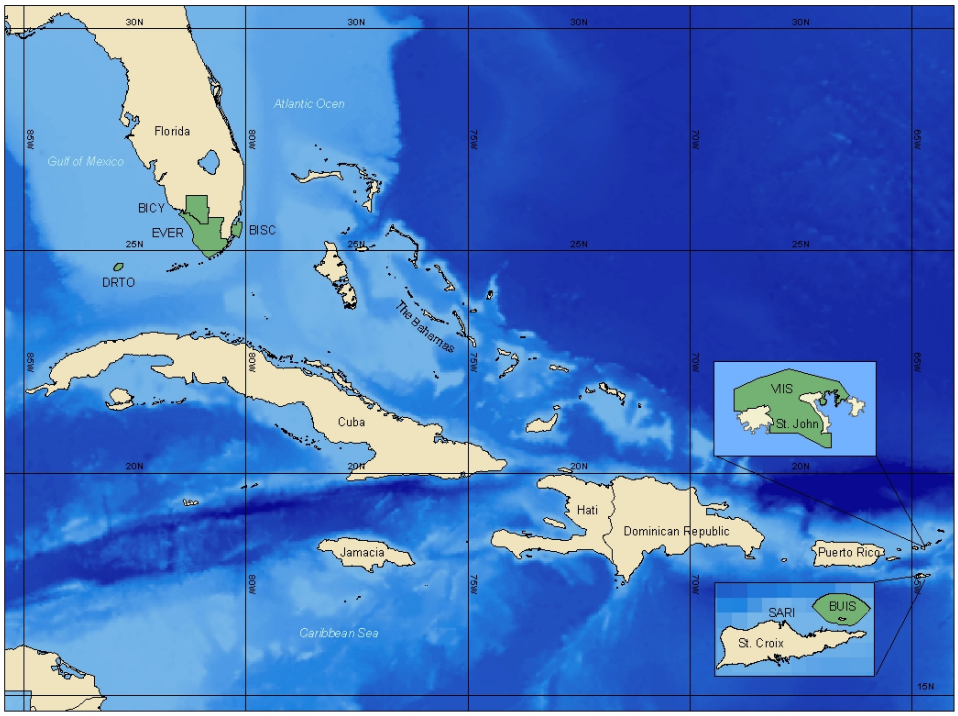
1.2. Purpose and Scope

The primary audience of this plan is the I&M program itself. The practices and procedures outlined will also apply to cooperators who have fiscal or formal agreements with Network programs.

This plan offers a guide for Network programs and outlines how we intend to implement and maintain data management systems and best practices that optimize the data and information needs of selected programs. It reflects a commitment to ensure the quality, interpretability, security, longevity, and long-term availability of high-quality natural resource data and information. This is accomplished through standards and guidelines outlined for:

- Proper work flow and management of data through a project's life cycle
- The data management responsibilities of each person involved with a project
- Quality assurance and quality control measures that should become standard practice
- Documentation of projects (project development summaries and SOPs) and datasets (formal metadata)
- Handling and protection of sensitive data and information
- Dissemination to the public of non-sensitive data and information
- Proper management, archival, and storage of all records and objects associated with projects
- Project organization and tracking

Figure 1.1 South Florida/Caribbean Network Parks and Ecoregion.



1.3. Goals and Priorities

The data management goals of the South Florida/Caribbean Network have developed and evolved over several years and are intended to apply broadly to all Network programs. Adoption of the standards and guidelines contained in this plan can be used as general indicators of program success. I&M staff will be responsible for application to I&M projects. Priority must be given to new projects as these will most easily be able to incorporate the practices we describe. Priority for legacy data should be given to:

1. Datasets needed for current project development
2. Datasets used frequently by park staff or cooperators
3. Historic datasets archived for possible future use

1.4. Organization

In a move to create a more efficient, workable document the SFCN has created a data management plan that focuses on the specifics and how the network performs data management. The more general statements discussing relevant laws and polices have been referenced back to the national data management plan. The main body of this document addresses principal subject areas, but incorporates greater detail, into chapter appendices. It has been designed with a consistent modular format to maximize ease of locating specific information on each general topic. Future implementation will include an Intranet site, organized similarly to this document

that will ease the location of guidance documents and standard operating procedures to all Network staff and interested users.

Most chapters include the following sections:

Objectives – Specific statements describing the results to be achieved by the programs subscribing to this plan. These will be referenced via hyperlink to the national data management plan.

Laws and Policies – Requirements and sideboards established through laws, policies, and mandates at different levels of governance, ranging from broad federal law to NPS and I&M policies. These will be referenced via hyperlink to the national data management plan. Policies developed specifically for the South Florida/Caribbean Network will be included.

General Standards and Guidelines – Relevant Network standards and guidelines applicable to specific chapter topic(s). These reference more detailed information in chapter appendices.

At the end of each chapter is a list of references to literature cited, a list of appendices, and chapter credits.

1.5. Key Terms and Definitions

Since the principal purpose of this plan is to provide standards and guidelines for the development, management, and dissemination of *data*, we strive to apply consistent terminology when discussing key concepts and terms.

Data are distinct pieces of information, usually formatted in a special way: they include symbols or representations of facts or ideas that can be communicated, interpreted, or processed by manual or automated means.

Digital natural resources data generally occur either in tabular form or as files specially formatted for use in Geographic Information Systems (GIS). GIS-formatted data include, but are not limited to, shapefiles, coverages, layers, personal geodatabases or georeferenced Tagged Image File Formats (TIFFS).

GIS data contain information about the location and shape of, and relationships among features on the surface of the earth and are usually stored as geographic coordinates and topology. Topology is used to compare the geographic locations of features relative to one another (e.g., roads connected to a highway, two vegetation polygons adjacent to one another).

Tabular data are usually organized into logical tables of records and fields, arranged in a matrix of rows and columns. Tabular data can be displayed, manipulated, and stored as simple text files or in software applications (e.g., spreadsheets, relational databases). Tabular data can contain reference to a geographic coordinate system and when they do, can also be displayed with GIS software.

Spatial data are any data that reference geographic coordinates. GIS data always contain these references. Tabular data that contain spatial references are also considered spatial. For example,

a table of wildlife observations might include the x and y coordinates of the location of observation, along with other information, such as species identified, observer name, and date of observation. These data can be imported and displayed graphically with other spatial data layers, such as roads and highways, or vegetation types. For this reason, the terms *GIS data* and *spatial data* are often used interchangeably. We use *spatial data* to refer to any dataset containing reference to a geographic coordinate system.

Tabular data (spatial or not) can be organized within a *Relational Database Management System* (*RDBMS*). RDBMS allow data to be structurally organized for maximum efficiency of storage and retrieval. If properly designed, they enable data to be recombined in any way desired, and therefore provide powerful vehicles for synthesis, analysis, and reporting.

Raw data are data in their original form, i.e., data that have not been altered, summarized, or grouped into broader categories. Raw data can exist in many forms: as hand-written information on field data forms and in notebooks, as unaltered photographs, sound and video recordings, remote sensing imagery, and Global Positioning System (GPS) files. They may be typed or uploaded directly into a computer upon acquisition, or transcribed later from data sheets.

Derived data are raw data that have been processed, or converted to another form using some automated or manual process. Raw natural resources data are often processed and packaged for summation, statistical analysis, and graphical display, or the production of maps and other information products.

Legacy data are data existing prior to the adoption of this data management plan, and at risk of becoming obsolete due to software or metadata limitations.

Programmatic data are data developed specifically for a project with well-defined objectives and specific requirements describing data use and application. As an example, satellite imagery may be acquired for a geographic area to provide an analytical data framework for monitoring landscape change over a period of time.

Non-programmatic data are data developed for other programs, but are of value to meeting current objectives. For example, the same data acquired for monitoring landscape change might be reclassified and used to evaluate the severity of historical wildfires.

Sensitive data are data that through loss, unauthorized access, or modification, could be used in such as way as to adversely affect valuable resources, the national interest, the conduct of federal programs, or individual privacy. Examples of sensitive natural resources data might include the locations of rare flora or fauna species, caves, or cultural sites.

Metadata is information about data. A complete set of metadata describes all aspects of the data in question, including the ‘who, what, where, when, how, and why’ the data were collected, along with any processing that has occurred. Metadata are considered an essential component of any good dataset.

1.6. Making it Work

Successful implementation will depend on the active participation of everyone who collects and manages data, and so we provide guidelines for data management responsibilities associated with the roles of individuals within park natural resources programs.

1.7. References

Boetsch, J. R., B. Christoe. and R. E. Holmes. 2005. Data management plan for the North Coast and Cascades Network Inventory and Monitoring Program. U.S. Department of the Interior, National Park Service. Port Angeles, WA.

Cook, R. R. and P. Lineback. 2006. Sierra Nevada Network data management plan. Natural Resource Report NPS/PWR/SFCN/NRR—2006/000. Department of the Interior, National Park Service, Three Rivers, CA.

Michener W. and J. Brunt. 2000. Ecological data: Design, management and processing. Blackwell Science, Oxford.

Mortenson, D. 2005. Data management plan for the Inventory and Monitoring Program, Southwest Alaska Network. U.S. Department of the Interior, National Park Service. Anchorage.

1.8. Credits

This chapter was taken largely from Cook and Lineback (2006). Portions were adapted from Boetsch *et al*. (2005) and Mortenson (2005).

Chapter 2. Infrastructure and Systems Architecture

Modern information management infrastructure and system architecture represent the foundation of network information management systems. *Infrastructure* refers to the system of computers and servers that are functionally or directly linked through computer networking services. *System architecture* refers to the applications, database systems, repositories, and software tools that make up the framework of our information management enterprise.

Network programs rely on a mix of contractor, park, regional and national information technology (IT) personnel and resources to maintain its computer infrastructure and systems architecture. Local park program IT specialists are primarily responsible for development and management of local architecture with oversight and support from regional and national IT programs. Development and management of network architecture is more broadly distributed between local, regional and national IT staffs and direct participation by other local and national programs including GIS and I&M staffs.

Ongoing maintenance of computer resources includes, but is not limited to, hardware replacement, software installation and support, security updates, virus-protection, telecommunications networking, and backup/archiving processes. As technology relating to computer hardware resources advances, and the Network's computer infrastructure evolves, modifications will be made to meet information management objectives.

2.1. Objectives

- Ensure that staff have appropriate access to electronic files that are secure and protected from accidental and malicious loss
- Simplify GIS software installation and management, and expedite access and retrieval of GIS data using automation tools
- Identify and implement appropriate collaborative technologies and tools that enhance networking and communications at both an intra and interagency level
- Develop a collective long-term strategy for SFCN parks towards identifying and developing a content management system and intranet portal for storing, managing, searching, and disseminating electronic files

2.2. Laws and Policies

For specific laws and policies please see WASO DMP Chapter 2.

Specific infrastructure and systems related Network policies are listed below.

- The network directory structure will have a decentralized security system allowing appropriate individuals the ability to manage and maintain file security permissions
- Generally, computer users should not encrypt files and folders because of the potential for lost encryption keys and unrecoverable data

- SFCN Parks should implement modern data structures and data models that optimize flexibility and scalability and integrate with other national applications
- SFCN Parks should employ software tool(s) that simplify and streamline staff access to spatial data and metadata

2.3. General Standards and Guidelines

These standards and guidelines expand and clarify local and national policies and offer accountability and metrics for measuring staff and program performance.

2.3.1. Network Computer Resources

An important element of an information management program is a reliable and secure network of computers and servers. SFCN makes use of a main server located in the South Florida office and an auxiliary server located in the VIIS office. Both servers use a similar directory structure and data backup routine.

There are multiple components associated with the NPS infrastructure including park level, regional, and national systems. Each hosts different parts of information systems that are maintained and secured by various park, Network, regional, and national IT and resource specialists and staff. IT duties for Network programs based in the South Florida are handled by the network data manager. IT assistance for the VIIS office is provided in part by VIIS IT staff. This includes hosting and managing electronic files being created, managed, and disseminated by Network staff and cooperators.

2.3.2. Network Security

Local and wide area networks currently conform to Department of Interior security guidelines (see WASO DMP). All sensitive electronic files should be placed in protected folders with limited read and write access. Electronic file and directory permissions administration will be partially decentralized with file and folder administrative rights controlled by limited Network staff including IT and a few trained program staff. A database of file permissions will be developed and maintained. Deployment of a Microsoft utility will enable the management and restoration of New Technology File System (NTFS) file and folder permissions on network servers.

2.3.3. National Applications and Tools

Various national offices, including the NPS Natural Resource Program Center (NRPC) and the national I&M program actively develop and implement national-level, program-wide information management systems. Other programs such as cultural resources and maintenance have their own distributed applications that often intersect and also have broader program application and use. Principal applications and data repositories developed for the I&M and Service-wide programs, and referenced throughout this document, are summarized below.

Integrated Resource Management Application (IRMA) – a functional portal for searching and retrieving records from multiple data sources (NatureBib, NPSpecies, and NPS Data Store) from a single access point.

The NPS Data Store – an Internet-based graphical search interface that links data and metadata to a searchable server on which data are organized by NPS units, offices and programs. Access permission is required.

NPS Focus Digital Library and Research Station – a decentralized digital imagery and data management system, implemented through a central public Internet portal sponsored by the NPS Office of the Chief Information Officer. Includes access to the NPS Data Clearinghouse.

NPS Data Clearinghouse – the central repository for NPS GIS data available to the public. Implemented through the NPS Focus gateway.

NPS Automated National Catalog System (ANCS+) – the official curatorial cataloging system of the NPS.

NatureBib – the master database for natural resources bibliographic references for the NPS. Implemented on a dual system of public and secure servers to protect sensitive information.

NPSpecies – the master species database for the NPS. Includes park-specific lists of the plant and animal species that occur in or near the parks along with records (vouchers, observations, and literature citations) of physical or written evidence of their occurrence and status. Implemented on a dual system of public and secure servers to protect sensitive information.

NPSTORET (also known as NPS Water Quality Database Templates) – a NPS database designed to facilitate park-level standardized reporting for STORET, an Internet-based interagency water quality database developed and supported by the Environmental Protection Agency (EPA) to house local, state, and federal water quality data collected in support of managing the nation's water resources under the Clean Water Act.

2.3.4. SFCN I&M Web Site

The SFCN I&M web site (http://science.nature.nps.gov/im/units/sfcn/) provides general information to the public about the Network and its parks, and the I&M Program, including information on inventories, monitoring, data management, and reports & publications as directed by WASO's general webpage templates. The website will also be used to serve products such as results of I&M vital signs monitoring (e.g., executive briefs, progress reports, trend reports, etc.) and the SFCN Data Management Plan. Future plans include the inclusion of a linked blog site, for updating park staff, partners, and interested parties on recent program highlights and newsworthy happenings. A separate Intranet portal provides a venue, where park and Network staff can share information and data that are not ready for public posting.

Structure and content of the SFCN I&M web site comply with National Park Service standards (see WASO DMP).

2.3.5. Collaboration Technologies

The following are communication options that have been approved by DOI and NPS IT staff

2.3.5.1. Web Meetings

There are many web and video conferencing applications available commercially, however, all but *Lotus Sametime Meeting* are hosted on external servers and, therefore, prohibited by current NPS IT policy. Network staffs are currently using Sametime to provide web meeting capability between the South Florida and VIIS office.

2.3.5.2. Personal Communications

The use of email and telephones to conduct personal communication between individuals at separate locations is ubiquitous. Instant messaging complements these and adds additional functionality. Email is comparatively slow and a telephone call limits access to an individual's desk or cell phone availability. Instant messaging is near real-time and offers additional flexibility for communicating with one or more employees. *Lotus Notes Sametime Instant Messaging* is currently available to all NPS employees with a NPS computer network login profile.

2.3.6. Geographic Information Systems

ESRI GIS applications and products are regularly used by Network staff. This includes use of map products or analyses generated from GIS software. Skill levels range from infrequent users with beginning skills to advanced users who can complete complex analyses.

ArcGIS license manager software runs on two servers (both the South Florida and the VIIS office have their own license allocations) and distributes client software licenses to local area network staff.

To run ArcGIS *off* network, individual hardware dongle keys must be installed and configured on each computer.

2.3.6.1. Recommendations

- Automate GIS Software Installations and Updates – Because of the increasing numbers of GIS software users, it is most efficient to implement ESRI software installation protocols that streamline installation and updates including silent updates for existing ArcGIS software users. Initial software installations should be completed through a flexible intranet portal, but future updates conducted through silent and bulk updates.
- NPS Theme Manager - There are hundreds of spatial data layers available to staff. They are hosted in multiple locations and require intimate familiarity with spatial data to find,

understand, and use these data. It is inefficient, particularly for infrequent users to find and use the data they need. In an effort to consolidate data and ensure that only the most current and accurate information is used, SFCN has implemented NPS ThemeManager at both of its offices. The theme list is updated on a regular basis. Where possible SFCN has worked with park GIS specialist to implement NPS ThemeManager at the park level.

2.3.7. Database Applications Development

Desktop versions of SFCN databases will be in the latest Microsoft Access format unless otherwise specified in the project study plan. Desktop databases produced under contract will also use Microsoft Access unless otherwise specified in advance.

SFCN projects will invest in modular, standalone project databases that share design standards and links to centralized lookup tables, and can be developed, maintained, and archived separately. There are numerous advantages to this strategy:

- Datasets are modular, allowing greater flexibility in accommodating the needs of each project area
- Individual project databases and protocols can be developed at different rates without a significant cost to data integration
- Any project database can be modified without affecting the functionality of other project databases
- We avoid a large initial investment in a centralized database and the concomitant difficulties of integrating among project areas with very different – and often unforeseen – structural requirements
- Potentially greater efficiency for interdisciplinary use

The SFCN will develop a set of master look-up tables or an Integrated Data Dictionary (also referred to as a Buffet of Fields and Tables [BOFAT] by WASO), that will allow databases across projects and across disciplines to remain as consistent as possible. Likely, lists of standard attributes and values to be developed include park codes, place names, watershed codes, species identifiers, and vegetation or land type classifications (See Chapter 5 – Database Design for more details). To the furthest extent possible, SFCN will work with WASO and other Networks to develop and utilize shared look-up tables for data consistency and inter-operability at higher level programs.

2.3.8. Word Processing

All reports and other textual documents will be finalized in editable electronic format in the latest available version of Microsoft Word or Adobe Acrobat, unless otherwise specified in the project study plan. Distribution copies will be converted to the latest version of Adobe Acrobat.

2.3.9. Digital Data Formats

For the purposes of discussion, data formats are broken into tabular data and spatial data.

2.3.9.1. Tabular Databases

Well thought-out database design standards are necessary to promote compatibility among datasets that will be aggregated and summarized, encourage sound database design and facilitate interpretability of datasets. As much as possible, SFCN standards for database design will mirror those conveyed through the Natural Resource Database Template (NRDT). The NRDT is a flexible, relational database template, designed for storing inventory, monitoring, and research data (including raw data collected during field studies). The template was designed to be used in the development of standalone databases and databases that interact with GIS software (e.g., ArcView or ArcGIS). A description of the NRDT and a working database is presented in Chapter 5 – Database Design. Additional information can be found at (http://science.nature.nps.gov/im/apps/template/index.cfm).

2.3.9.2. Spatial data

The coordinate system standard for SFCN parks is *Universal Transverse Mercator with North American Datum 1983*. Generally, existing spatial data should be migrated to this data projection and it should be used for any new spatial data development.

Currently, Network and park staff use many different raster and vector data formats for storing and managing spatial data. Vector data formats commonly include Arc/Info coverages, shapefiles, and personal geodatabases. Raster data formats commonly include MRSID, TIFF, GEOTIFF, and Grid structures. ESRI software products have historically demonstrated excellent backward compatibility with older data structures and there is no SFCN requirement that data formats be migrated to the more modern data structures.

The national NPS GIS office (WASO-GIS) is facilitating the development of standardized data models for spatial data. These data models are designed to be flexible, scalable, and integrate with other national applications. GIS tools are being developed to simplify development and management of this data. Current WASO-GIS spatial standardization efforts include buildings, trails, and vegetation. As these new data models are released, Network parks should implement these new data models and convert legacy data into these new data models.

2.4. References

Boetsch, J. R., B. Christoe, and R. E. Holmes. 2005. Data management plan for the North Coast and Cascades Network Inventory and Monitoring Program. U.S. Department of the Interior, National Park Service. Port Angeles, WA.

Cook, R. R. and P. Lineback. 2006. Sierra Nevada Network data management plan. Natural Resource Report NPS/PWR/SFCN/NRR—2006/000. Department of the Interior, National Park Service, Three Rivers, CA.

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Svancara, L. K. 2006. Upper Columbia Basin Network, information management plan. Natural Resource Report NPS/PWR/UCBN/NRR—2006/000. U.S. Department of the Interior, National Park Service, Moscow, ID.

2.5. Credits

This chapter was taken largely from Cook and Lineback (2006), and information provided by Boetsch *et al*. (2005), Daley (2005), Mortenson (2005), Svancara, (2006).

Chapter 3. Project Development and Data Management Workflow

To better understand the information management needs of the SFCN, it is useful to understand the general work flow of project development and the information management tasks associated with each stage. There are two main types of projects handled by Network natural resources staff and the Inventory and Monitoring Program:

1. Short-term, which may include individual park research projects, inventories, or pilot work done in preparation for long-term monitoring or research.

2. Long-term, including Network vital-signs monitoring projects central to the I&M program and multi-year research projects and monitoring performed by other park programs, agencies and cooperators. Long-term projects will often require a higher level of documentation, peer review, and program support.

For information management, the primary difference between short- and long-term projects is an increased need to adhere to and maintain standards for long-term projects. Maintaining standardization from year-to-year will be necessary when comparing data over an extended period of time (decades for long-term monitoring).

3.1. Five Stages of Project Development

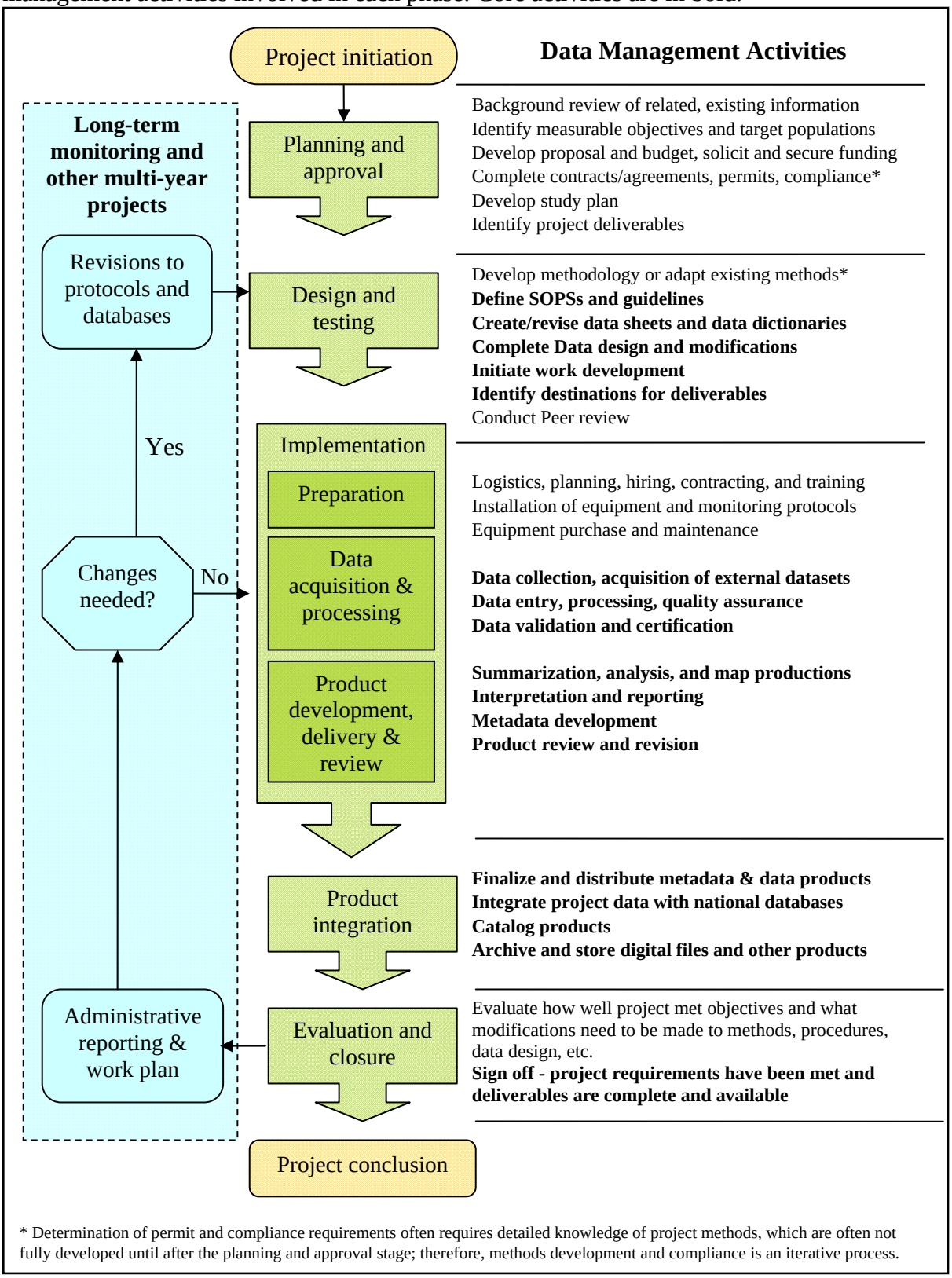
To ensure the development of high quality scientific information, data management must be a component of all aspects of project development. Projects can be divided into five primary stages:

- planning and approval
- design and testing
- implementation
- product integration
- evaluation and closure

Each stage is characterized by a set of activities carried out by staff involved in the project (Figure 3.1). Primary responsibility for these activities rests with different individuals according to the different phases of a project. Additional discussion of the different roles and responsibilities of park and Network staff can be found in Chapter 4 of this plan. Specific project tracking methods and documentation are presented in Chapter 12.

1. *Planning and Approval* – This is the stage at which many of the preliminary decisions are made regarding project scope and objectives. Funding sources, permits and compliance are also addressed at this time. Primary responsibility rests with project leaders and program administrators. Although this phase lacks specific data management activities, it is important that data managers remain informed. This is especially true as timelines for deliverables are finalized. All contracts, agreements, and permits should include standard language that describes the formats, specifications, and timelines for project deliverables.

Figure 3.1. Data management steps during the five stages of project development with data management activities involved in each phase. Core activities are in bold.



* Determination of permit and compliance requirements often requires detailed knowledge of project methods, which are often not fully developed until after the planning and approval stage; therefore, methods development and compliance is an iterative process.

2. *Design and Testing* – All details regarding how data will be acquired, processed, documented, analyzed, reported and made available to others are worked out. The project leader is responsible for developing and testing project methodology, or for modifying existing methods to meet project objectives. It is critical that project leaders and data managers work together during this phase. The dialog between these individuals will help to build and reinforce good data management throughout the project. By beginning collaborative development as soon as possible after project approval, data integrity and quality can most easily be assured.

   An important part of this collaboration is the development and detailed documentation (Chapter 5) of project databases, including relational diagrams, data dictionaries, business rules, and front-end programming, along with the formal metadata. Devoting adequate attention to this aspect of a project is the single most important part of assuring the quality, integrity and usability of the resulting data. Although it is possible that post-hoc changes will occasionally be required, it is important to minimize these through careful initial design work.

3. *Implementation* – Data are acquired, processed, error-checked (Chapter 6) and further documented (Chapter 8), and products such as reports, maps, GIS themes, and other products are developed. The project leader oversees all aspects of implementation – from logistics planning, contracting, training, and equipment procurement to data acquisition, documentation, report preparation and final delivery. Data management staff function primarily as facilitators – providing training and support for database applications, GIS, GPS and other data processing applications; facilitation of data summarization, validation and analysis; and assistance with the technical aspects of documentation and product development. The specific roles of data management staff will depend primarily on the technical capabilities of the project staff. As much as is possible, these roles should be worked out in advance of implementation. Toward the end of this phase, project staff members work to develop and finalize the deliverables that were identified in the project planning documents (i.e., protocol, study plan, contracts, agreements or permits).

4. *Product Integration and Distribution* – Data are merged from the working database to a master database maintained on the Network server, certified datasets and their metadata are finalized and posted in national repositories, and products are distributed or otherwise made available to their intended audience (Chapter 10). Data are merged to the master only after the annual working dataset has been certified for quality by the project leader. Product integration may include creating records for reports and other project documents in NatureBib, posting imaged documents to NPFocus, and updating NPSpecies and ANCS+ to reflect any new species occurrence information or specimen vouchers derived from the project. These updates allow the information from the project to be searchable and available to others via service-wide search engines. Certain projects may also have additional integration needs, such as when working jointly with other agencies.

   In general, all raw and derived data products, metadata, reports and other documentation should be delivered to the data steward assigned to the project. Administrative records should be delivered to appropriate park and Network staff as specified. All project

deliverables should be distributed according to specifications, which should be stipulated in all protocols, contracts, agreements, and permits. Products that do not meet program requirements should be returned for revision.

5. *Evaluation and Closure* – Records are updated to reflect the status of the project and its associated deliverables in a Network project tracking application (Chapter 12). For long-term monitoring and other cyclic projects, this phase occurs at the end of each field season, and leads to an annual review of the project. For non-cyclic projects, this phase represents the completion of the project. After products are catalogued and made available, program administrators, project leaders, and data managers should work together to assess how well the project met its objectives, and to determine what might be done to improve various aspects of the methodology, implementation, and formats of the resulting information. For monitoring protocols, careful documentation of all changes is required. Changes to methods, Standard Operating Procedures (SOPs), and other procedures are maintained in a tracking table associated with each document. Major revisions may require additional peer review.

3.2. The Data Life Cycle

Data take on different forms during various phases of a project, and are maintained in different places as they are acquired, processed, documented, analyzed, reported, and distributed. What we refer to as the "data life cycle" is characterized by a series of events that we can model to facilitate communication (Figure 3.2) as follows:

1. *Acquire data* – Data are acquired in digital or analog form. Digital data can be recorded on handheld computers and PDAs, tablets, data loggers, or laptop computers. Analog data are entered on field data sheets.

2. *Archive raw data* – Copies of all raw data files are archived intact. Digital files are copied to the digital library (the set of LAN folders created for the project); hard copy forms are either scanned and placed in the digital library or are copied and placed in the archives. Archiving or scanning of hard copy data forms may occur at the end of a season as a means of retaining all marks and edits made during the verification and validation steps.

3. *Enter/import data* – Analog data are entered manually and digital data files are uploaded to the working database.

4. *Verify, process, and validate* – Accurate transcription of the raw data is verified; data are processed to remove missing values and other flaws; and data are validated through visual inspection and queries to capture missing data, out-of-range values, and logical errors.

5. *Documentation and certification* – Develop or update project metadata and certify the dataset. Certification is a confirmation by the project leader that the data have passed all quality assurance requirements and are complete and documented. It also means that data and metadata are ready to be posted and delivered.

6. *Upload data* – Certified data are uploaded from the working database to the master project database. This step might be skipped for short-term projects where there is no need to distinguish working data for the current season from the full set of certified project data.

7. *Archive versioned dataset* – The SFCN Project Data Certification Form is completed (DMP Appendix D). Copies of the certified data and metadata are placed in the digital library. This can be accomplished by storing a compressed copy of the working database or by exporting data to a more software-independent format (e.g., ASCII text).

8. *Disseminate data and update national databases*– Certified data and metadata, and digital image products are posted to national repositories (the NPS Data Store, Biodiversity Data Store, NPS Focus) to make them more broadly available to others. National databases, including NPSpecies, NPSTORET, and ANCS+ are updated with data obtained from certified datasets.

9. *Reporting and analysis* – Certified data are used to generate data products, analyses, and reports, including semi-automated annual summary reports for monitoring projects. Depending on project needs, data might be exported for analysis or summarized within the database.

10. *Distribute information products* – Information products such as reports, maps, and checklists are disseminated to the public through the SFCN website and NPS Focus, and catalogued in NatureBib.

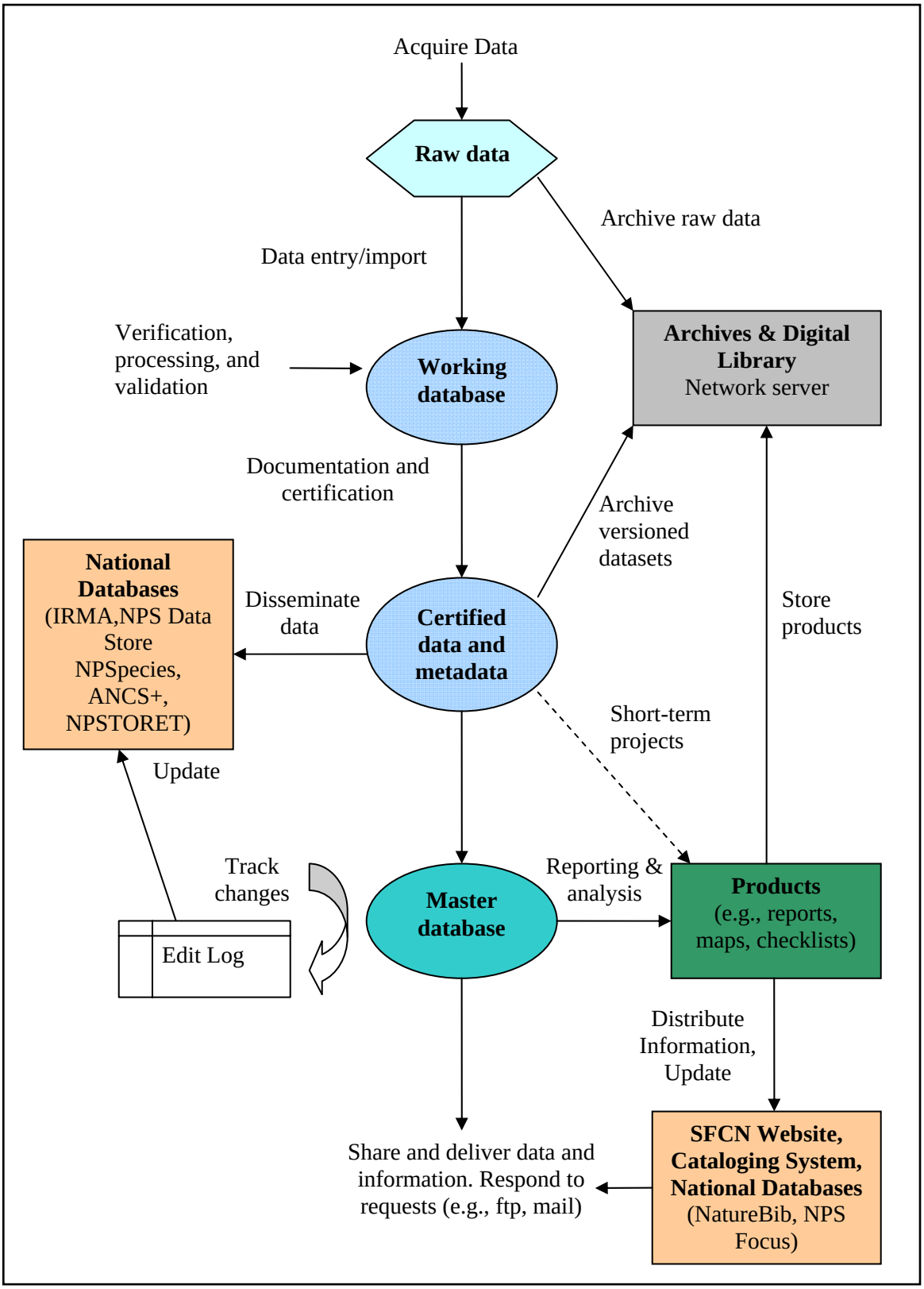
11. *Share data and information* – Data, metadata, reports and other information products can be shared in a variety of ways – by FTP or mailing in response to specific requests, or by providing direct access to project records to park staff and cooperators.

12. *Track changes* **–** All subsequent changes to certified data are documented in an edit log, which accompanies project data and metadata upon distribution. Significant edits will trigger reposting of the data and products to national databases and repositories.

13. *Store products* – Reports and other data products are stored according to format and likely demand, either in the digital library, on off-line media, or in the document archives.

14. *Catalog project products* – Catalog products and all information associated with a project, including results of analyses and paths of dissemination. Project tracking databases can be useful tools for this purpose.

Figure 3.2. The data life cycle.



3.3. References

Boetsch, J. R., B. Christoe, and R. E. Holmes. 2005. Data management plan for the North Coast and Cascades Network Inventory and Monitoring Program. U.S. Department of the Interior, National Park Service. Port Angeles, WA.

Cook, R. R. and P. Lineback, 2006. Sierra Nevada Network Data Management Plan. Natural Resource Report NPS/PWR/SFCN/NRR—2006/000. U.S. Department of the Interior, National Park Service, Three Rivers, CA.

3.4. Appendices

D) Project Data Certification Form

3.5. Credits

This chapter was taken largely from Cook and Lineback (2006) and from concepts and material developed by Boetsch *et al*. (2005).

Chapter 4. Data Management Roles and Responsibilities

Data management is about people and organizations as much as it is about information technology, database theory, and applications. Data stewardship is the assignment and acceptance of responsibility for the oversight of management aspects of information. For the network to work effectively, everyone within the program, and all those in collaboration with it, must take responsibility for the production, analysis, management, and/or end-use of data produced by the program. In order to meet the data management goals and standards developed by the National Park Service and its constituents, program staff must understand what their roles and responsibilities are in this process.

4.1. Objective

The objective of establishing data management roles and responsibilities is to:

- clearly define roles associated with functions
- establish data ownership throughout all phases of a project
- instill data accountability
- ensure that adequate, agreed-upon data quality and metadata metrics are maintained on a continuous basis

4.2. Laws and Policies

There are no laws or NPS policies governing the establishment of roles and responsibilities with respect to data management. The establishment of a data stewardship plan is a good practice so that everyone involved with a project is aware of the data quality and data documentation necessary for a successful project completion.

4.3. General Standards and Guidelines

An increasing demand for more detailed, high quality data and information about natural resources and ecosystem functions requires a group of people working together to manage data and information assets. Knowledgeable individuals from many disciplines must come together to ensure that data are collected using appropriate methods, and that resulting datasets, reports, maps, models, and other derived products are well managed. Datasets and the presentations of these data must be credible, representative, and available for current and future needs.

A role is a function or position (e.g., Data Manager). A responsibility is a duty or obligation (e.g., review data records). Table 4.1 summarizes general types of data stewardship activities and the roles typically associated with them.

Table 4.1. Categories of data stewardship involving South Florida/Caribbean Network personnel

Stewardship Activity	Description of Activities	Principal Positions
Production	Creating data or information from any original or derived source. This includes recording locations, images, measurements, and observations in the field, digitizing source maps, keying in data from a hardcopy source, converting existing data sources, image processing, and preparing and delivering informative products, such as summary tables, maps, charts, and reports.	Ecologists, Biological Technician, GIS/Data Specialist, Data Manager
Analysis	Using data to predict, qualify, and quantify ecosystem elements, structure, and function as part of the effort to understand these components, address monitoring objectives, and inform park and ecosystem management.	GIS/Data Specialist, Ecologists, Data Manager
Management	Preparing and executing policies, procedures, and activities that keep data and information resources organized, available, useful, compliant, and safe.	Data Manager, National-level Data and Information Managers, GIS/Data Specialist
End-Use	Obtaining and applying available information to develop knowledge that contributes to understanding and managing park natural resources.	Park Managers, Superintendents, Ecologists and Others

Although each position is associated with only one category in the table according to overriding responsibilities, many positions contribute to multiple categories. The degree to which specialization can occur with regard to data management responsibilities will depend on program resources (i.e. staff and funding). For a very small program, all of these activities might be accomplished by a single individual. For a large program, such as the SFCN I&M Program, a much higher degree of diversification and specialization are required. Table 4.2 summarizes the roles and responsibilities of personnel that may participate in a program such as this. Roles are listed ‘from the ground up’ to help demonstrate the hierarchy of responsibilities. For example, an ecologist is ultimately responsible for the activities listed in the field level roles of crew leader and crew member. It is possible that one person/position has more than one role. More detail is provided within each monitoring protocol.

Table 4.2. Summary of Roles and Responsibilities for the SFCN Network Inventory and Monitoring Program

Role	Primary responsibilities related to data management
Biological Technician	Record and verify measurements and observations based on project objectives and protocols. Document methods, procedures and anomalies.
Ecologists	Supervise crew members to ensure their data collection and management obligations are met, including data verification and documentation.
GIS/Data Specialist	Perform assigned level of technical data management and/or GIS activities, including data entry, data conversion, and documentation. Work on overall data quality and stewardship with project leaders, resource specialists, and the Network data manager.
Information Technology/Systems Specialist (contractor, park IT support staff)	Maintain local area network, establish and maintain system security, and keep software and hardware systems up to date. Maintain connections between the LAN and the Internet. Work with the Network Data Manager and GIS liaisons to establish a directory structure that provides local access and security for natural resource data. Manage the infrastructure for digital data backups for the local area network.
Network Coordinator	Coordinate with project leaders to ensure that timelines for data entry, validation, verification, summarization/analysis and reporting are met. Review and approve proposed changes to project protocols prior to implementation.
Ecologists	Oversee and direct operations for one or more Network projects. Maintain communication with project staff, Network Data Manager, and resource specialists regarding data management. Understand the objectives of the project, the resulting data, and their scientific and management relevance. Make decisions with regard to validity, utility, sensitivity, and availability of program data. Describe, publish, release, and discuss the data and associated information products. Ensure useful data are collected and managed by integrating natural resource science in Network activities and products, including objective setting, sample design, data analysis, synthesis, and reporting.

Data Manager	Provide planning, training, and operational support for the awareness, coordination, and integration of data and information management activities, including people, information needs, data, software, and hardware. Coordinate internal and external data management activities.
National-level data management support staff	Provide service-wide database design, support, and services, including receiving and processing to convert, store, and archive data in service-wide databases.
End Users (e.g., park managers, researchers, other agency staff, members of the public)	Appropriate use and application of data and derived products and for providing feedback for improvements.

4.4. References

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4.5. Credits

This chapter was taken largely from Cook and Lineback (2006) and from concepts and material developed by Stevens and Entsminger (2004), Beer *et al*. (2005), Daley (2005), Mortenson (2005), and Wilder (2005).

Chapter 5. Databases

5.1. Objectives

The adoption of sound database design principles that will help facilitate interpretability, ensure integrity, and promote compatibility of natural resources data collected in the parks.

5.2. Laws and Policies

To help meet these objectives, the NPS I&M Program has developed a standardized database template for inventory and monitoring projects; the Natural Resource Database Template (NRDT) (http://science.nature.nps.gov/im/apps/template/index.cfm). I&M Network programs are expected to design databases used for natural resource inventories and vital signs monitoring on this template.

For specific laws and policies please see WASO DMP Chapter 5.

5.3. General Standards and Guidelines

The following provide general standards and guidelines that are used during the creation of new databases or in the updating of existing.

5.3.1. The Natural Resource Database Template

The National Park Service Inventory and Monitoring (I&M) Program's Natural Resource Database Template (NRDT) is a set of Microsoft Access relational database tables that parks and networks can use to develop applications for capturing natural resource inventory and monitoring data. For specifics please see http://science.nature.nps.gov/im/apps/template/index.cfm.

5.3.2. Database Development

Communication is a vital part of developing a suitable database design for individual projects. One mechanism for this communication is collaborative development of data models by data managers and project leaders. Data models combine diagrams with associated descriptions and are completed in three stages: conceptual, logical and physical. Each is outlined below, using as an example, a database created for coral index site monitoring in SFCN Parks.

5.3.2.1. Conceptual Data Models

Conceptual data models are constructed to graphically portray processes specifically related to the implementation phase of a project – especially those involving acquisition, processing, and QA/QC of data (Figure 5.1). These models are software-independent, free of details and focus on capturing enough information needed to accurately depict project data design. Conceptual data models contain the following:

- An overview of the sampling scheme in layman’s terms
- A flow diagram of procedures, and when and what information is being collected or produced

- A description or mock-up illustration of how data should be presented

5.3.2.2. Logical Data Models

A logical data model is an abstract representation of database entities, their relationships and key attributes (Figure 5.2). Logical data models are intended to provide a conceptual framework for the database developer as well as a schematic that can be easily interpreted by the layman. They are not intended to provide full representation of the physical database, but rather to facilitate communication and understanding between developers and users. A logical data model should be produced early in project development (ideally beginning with early protocol development) and serve as a guide to the physical data model that documents the actual implementation of the database.

A logical data model should include the following five components:

1. *Database tables* – sufficient to model the sampling scheme. Enough information should be provided to allow users to understand how key information and data are distributed among tables in the database (e.g., sampling location, frequency, and measurements to be taken).
2. *Field attributes* – data types, units of measure, acceptable value ranges, etc.
3. *Logical relationships* – how data tables are logically related (e.g., each location will be visited numerous times, one or more species might be observed at each location per visit)
4. *Structural hierarchies* – the structure and order of relationships between data tables, which can be determined once the logical relationships are known, e.g.,
    - Site (e.g., reef)
        - sampling event (location id, date, time)
5. *Views* – how the data will be viewed or what operations will be performed (e.g., queries to search for out of bound values, summary reports of coral species occurrences per transect).

Figure 5.1. Schematic of a conceptual data model for coral index site monitoring in SFCN Parks.

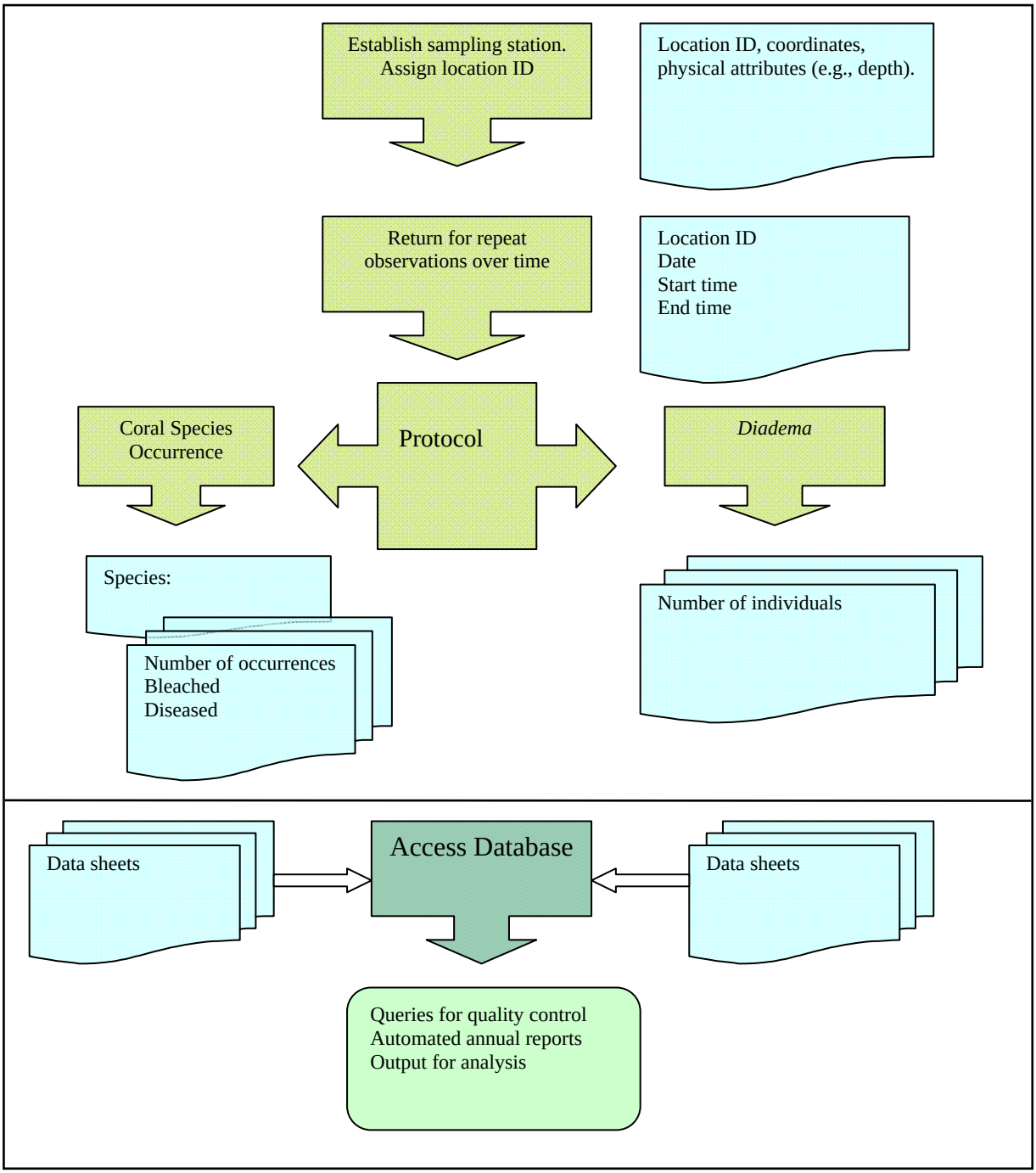
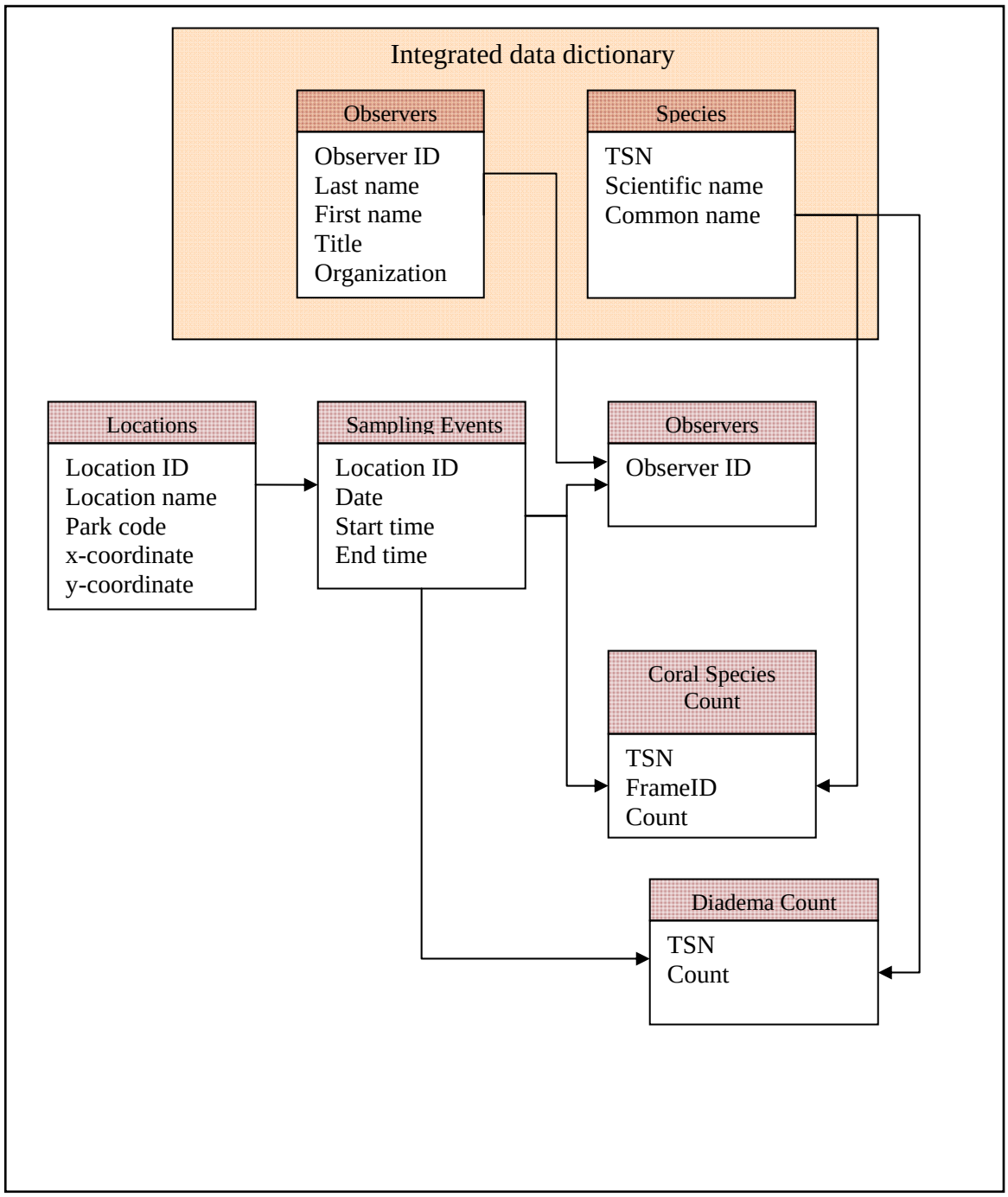


Figure 5.2. Schematic of a logical data model for coral index site monitoring in SFCN Parks.



SFCN will develop a set of master look-up tables or an Integrated Data Dictionary (also referred to as a Buffet of Fields and Tables [BOFAT] by WASO), that will allow databases across projects and disciplines to remain as consistent as possible. Likely lists of standard attributes and values to be developed include park codes, place names, species identifiers, and vegetation or habitat type classifications.

5.3.2.3. Physical Data Models

The physical data model depicts the structure of the actual database, with all of its data tables, field definitions, and relationships (Figure 5.3). Although the logical and physical models might appear similar, the physical model provides enough detail to construct the physical database. The NRDT defines three levels of optionality for core database tables:

- Mandatory – necessary components of all databases. Includes: *tbl_Locations* (for sample site location information), *tbl_Events* (sampling events: location, date, and time), *tbl_DB_Meta* (for metadata) and *tbl_DB_Revisions* (revision history)
- Mandatory if Applicable – standardized tables that become part of a database as needed. Includes *tbl_Event_Contacts* (observers and others), and *tbl_Event_Details* (information on who and when the event record was entered)
- Optional tables and fields – contain results of sampling or laboratory analysis and are therefore project-specific. All inventory and monitoring databases will contain one or more of these tables.

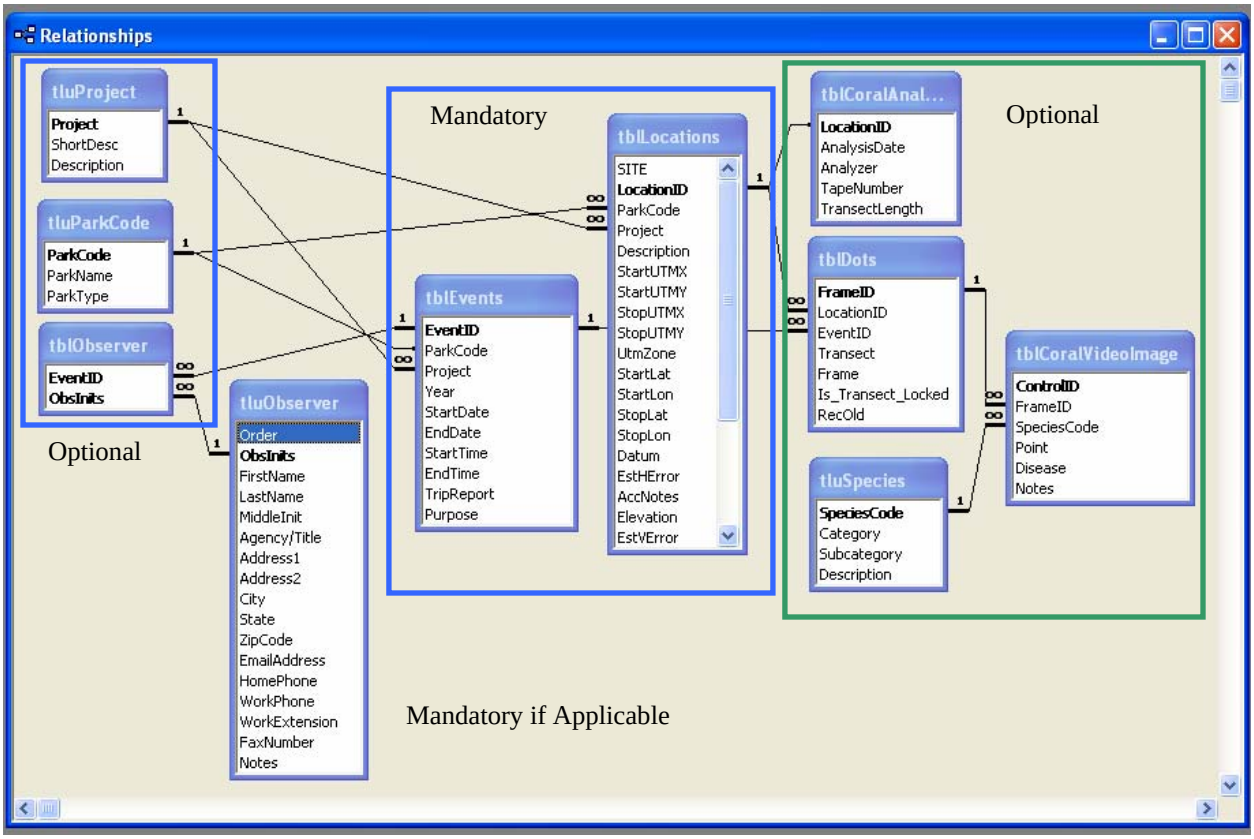
The **coral index site** monitoring database was developed prior to the NRDT table and field naming standards but has been converted to meet current standards.

However, each database must ultimately meet the needs of the network scientists. Considerations for these needs may include interactions with other agencies and ease of use, maintenance, integration, and customization. Where there are differences between local and national standards, documentation of the rationale for these differences will be developed. In addition, documentation and database tools (e.g., queries that rename or reformat data) will be developed to ensure that data exports for integration are in a format compatible with current national standards.

Not shown in Figure 5.3 are the links to the lookup tables in the Integrated Data Dictionary. This has yet to be created by the SFCN, although the Network already possesses a substantial table of place names which are already being used by several database applications. Tables will also be created with the names of park personnel involved in natural resources projects; vegetation types; wildlife habitat types; sampling methods, and others. Species will be identified by ITIS Taxonomic Serial Numbers, available in the Access file *StdClass_Master.mdb* which is part of the NPSpecies desktop database system, and updated annually from the ITIS database.

To the extent possible, SFCN will work with WASO and other I&M networks to develop and utilize shared look-up tables for data consistency and inter-operability at a higher level within the I&M Program.

Figure 5.3. Schematic of the physical database used for coral index site monitoring in SFCN Parks. Note: this diagram does not include data type and length information, or domain specifications, which should be declared as part of a physical database model.



It is especially important to remember that not everything can be thought of from the start and, to support change, data modeling should be iterative and interactive.

5.4. Quality Assurance/Quality Control

The success of any natural resources program is dependent on the quality of the data it collects, manages, and disseminates. The concepts of quality assurance (QA) and quality control (QC) are defined in Chapter 7 and discussed with respect to each phase of a project's lifecycle. Relational Database Management Systems can be designed to incorporate and automate many QA/QC procedures associated with data collection and processing. The following include some of the practices that will help ensure quality data:

- Set unique constraints (or unique key indexes) on every table in a database. Unique constraints are multiple key indexes set to allow no duplication, so as to prevent the entry of the same data record more than once. The index is set on the fields that make the records in a table unique. For child tables, it always includes the foreign key from the parent table. Duplication of entries is a common problem in databases without unique constraints.

- Implement all value constraints and business rules on the backend of the database, not on the forms used for data entry.

- Create separate forms for data entry/editing and review, or use mode control on single forms with both functions.

- Populate lookup tables as much as possible before data entry begins, and restrict access to them by data entry personnel.

- Set value ranges and validation rules on fields wherever possible to control the range of values that can be entered.

- To the extent possible, set the *limit to list* property to *True* on fields that receive input from a value list or lookup table.

- Include queries or programming modules that run checks for logical errors and out of bound values on calculations.

- Create field forms that best match data entry forms.

- When using hand-held computers in the field for data entry, the same set of controls should be placed on data fields as exist in the master database.

5.5. Database Documentation

5.5.1. Basic Requirements

Relational databases will be documented according to the standards outlined above. Complete documentation will also include a narrative overview with a description of the business rules employed, entity relationship diagrams, and documented programming code. Relational databases will also utilize internal documentation such as table and field descriptions and will include a table to track modifications.

MS Access databases should be documented with the built-in Database Documenter tool, and documentation should include all objects. This will produce a pre-formatted report containing complete specifications of properties, relationship types and attributes, table indexes, and user and group permissions on every object in the database. This information, combined with the programming code would enable any developer to recreate the structure and function of the database.

The NPS Metadata Profile currently does not support all of this information, so it will need to be stored independently of the formal metadata, although, as with the formal metadata, it should be stored in a folder with the database.

Some metadata can now be extracted automatically from an MS Access database. The NPS Database Metadata Extractor MS Access add-in, Version 1.0 for MS Access 2003 2002 2000, automatically harvests entity (table) and attribute (field) metadata, including value ranges (domains) from MS Access databases. It further allows the user to edit and review the harvested metadata, make batch edits, and export the metadata to a FGDC-compliant XML file. Exported XML can be used in the Metadata Tools & Editor either by opening it to start a new metadata record or by updating a template to fill in section 5 of an existing record (further described in Chapter 8).

Project databases developed for the I&M Program will include a mandatory table, *tbl_Db_Meta*, which will contain a description of the purpose of the database, and a link to metadata records in the NPS Data Store.

5.5.2 Revisions

Every alteration in a project database that occurs after data collection and entry have begun should be documented. A table of revision history will either be included within the database itself or maintained as a separate log. For I&M project databases, the table *tbl_DB_Revisions* is mandatory. This table includes contact person; date, reason, and description of the revision; and a link to *tbl_Db_Meta.*

5.6. References

Beer, M., E. Nance, A. Wright, M. Powell, and R. DenBleyker. 2005. Northern Colorado Plateau Network, data management plan. U.S. Department of the Interior, National Park Service, Inventory and Monitoring Program, Northern Colorado Plateau Network, Moab, UT.

Boetsch, J. R., B. Christoe, and R. E. Holmes. 2005. Data management plan for the North Coast and Cascades Network Inventory and Monitoring Program. U.S. Department of the Interior, National Park Service. Port Angeles, WA.

Cook, R. R. and P. Lineback. 2006. Sierra Nevada Network data management plan. Natural Resource Report NPS/PWR/SFCN/NRR—2006/000. U.S. Department of the Interior, National Park Service, Three Rivers, CA.

5.7. Credits

This chapter was taken largely from Cook and Lineback (2006) with some material adapted from Beer *et al*. (2005) and Boetsch *et al*. (2005).

Chapter 6. Acquisition, Processing and Reporting

Large, multi-scale natural resources programs increasingly rely on data and information gathered from multiple sources. This chapter describes the general steps involved with acquiring, processing, and reporting data to meet standards established by the NPS I&M Program, although these standards could apply broadly to any of the programs covered by this Data Management Plan. Also included are guidelines for the acquisition and processing of physical objects (photographs, voucher specimens) which are often collected as part of resource management, inventory and monitoring, and other research projects. Instructions specific to particular projects should be developed and included with the protocols for those projects.

6.1. Objectives

- Acquire, through a variety of sources, data and information needed by SFCN Park managers to properly manage and maintain the natural resources of their parks.
- Acquire data and information needed to understand broad-scale changes in the environment that impact ecosystems on a regional or national level in cooperation with NPS and collaborative monitoring efforts.

6.2. Laws and Policies

For specific laws and policies please see WASO DMP Chapter 6.

6.3. General Standards and Guidelines

General standards and guidelines for the acquisition and processing of programmatic and non-programmatic data (as defined in Chapter 1) are provided below. Quality assurance and control procedures, which are essential for ensuring the production of quality data and information products, and which comprise critical components of all stages of the data life cycle (Chapter 3), are discussed in greater detail in Chapter 7.

6.3.1. Programmatic Data

Project leaders and data managers are responsible for ensuring that data collection, data entry, verification, validation, storage, and archiving are consistent with Network standards. In addition to general Standard Operating Procedures (SOPs) that define Network-wide requirements, protocol-specific SOPs may be developed that detail procedures and/or methodologies. Leads and cooperators on I&M projects should always receive a copy of South Florida/Caribbean Network I&M Program Checklist of Project Specifications (DMP Appendix G)

6.3.1.1. Data Collection

Listed below are some of the tools available for field data collection. All methods involve some trade-offs in terms of expense, efficiency, and tendency for data entry/transcription errors.

Project protocols should provide detailed specifications on how the following tools are used with individual projects and some justification for the choice of methods.

Field Forms – the most common method of recording field data. Field forms are inexpensive but require neat, legible handwriting. There generally exists greater opportunities for error during the collection/data entry process compared with other methods because data entered on forms must later be key-entered into project databases. Thus, this method tends to require more data entry time and more rigorous QA/QC.

Field Computers – increase data collection and data entry efficiency. Data can be directly downloaded to office desktops, eliminating the data entry step. QA/QC checks can be built directly into the database, further reducing data entry error and processing time. The drawback to field computers is usually greater expense and sometimes, training time for field crews. There are two types of computers used in the field.

- **Personal Data Assistants (PDAs) –** the small size and relative low cost of these devices make them attractive options for collecting field data. PDAs can be weatherized fairly easily and inexpensively. However, they have limited internal memory and so data must be continually backed-up to larger storage devices. Most run either Windows CE or Palm operating systems which may require additional processing/programming to transfer/create the structure of the master database in the field units. Working with relational database structures can be difficult, or even a practical impossibility if the database is a complex one. In these cases, uploading field data can require great care and special skill.
- **Tablet PCs –** possess the same properties as most laptops and provide the user with the convenience of a touch screen interface. They are bulkier, heavier, more expensive and harder to weatherize than the PDAs, but more powerful as well. They are the best choice for field projects that are very data-intensive or rely on complex data structures. Because they run Windows XP (Tablet Edition) and Microsoft Office software, MS Access databases can be directly transferred from the desktop to field units without additional programming. Data from the field units can in turn, be uploaded to the desktop with minimal effort.

In some cases, the best choice is a combination of field forms and computers, for example, where large amounts of notes or comments need to be recorded in the field.

Automated Data Loggers – are mainly used to collect ambient information such as weather data or water quality information. These units must be properly calibrated and maintained, which requires proper training of field crews and SOPs that outline these procedures. Two types of automated data loggers are available.

- **Permanently deployed devices –** provide continuous or more frequent data (compared to field staff), provide data during conditions unsafe for field staff (i.e., severe storms, flood events), and with proper equipment can provide near real-time data. Data still must be retrieved, although this can be accomplished remotely – via satellite, landline, or cell phone. Providing sufficient and reliable power may be an

issue. Automated data-loggers require proximity to AC power, installation of solar power, or regular site visits to change batteries. Wilderness regulations may restrict the type of and location where a device is deployed. Data loggers deployed in a marine environment may require maintenance due to biofouling.

- **Portable hand-held devices –** are deployed for collecting samples only during site visits.

GPS Units – Two types of GPS units are used during field work in SFCN parks to collect location (geographic coordinates, altitude) information.

- **Recreation Grade Units –** include both self-contained units (e.g., Garmin Map76CSx) and companion units for PDAs (e.g., Holux). These work well for collecting general position information but are not recommended for high accuracy (sub-meter) location information.
- **Survey Grade Units –** such as some Trimble GPS receivers. These are good for collecting accurate sub-meter location information but are expensive.

Tape/digital voice Recorders – Handheld micro-cassette tape recorders and digital voice recorders are useful for recording field data. Recorded observations are subsequently transcribed to paper or directly entered into computer files. As with other technological solutions, there are drawbacks including battery and tape maintenance, low environmental tolerance, and risk of failure. However, if a single data collector is in the field, these recorders can provide an easily operated, high quality, efficient method of collecting data. All audio tapes used for recording field data should be labeled appropriately (e.g., date, site, project) and stored in the fire proof cabinet. Analog audio cassettes degrade over time and are a media that is quickly becoming outdated and obsolete. If analog audio tapes are used then these should be transferred to a more permanent audio format such as CDs or MP3 files.

Photographs – provide an excellent visual record of field visits and are useful for capturing point records of long-term study sites. They also serve well for automated data collection by remotely recording information using web cameras or trip cameras. Slides and photographs should be stored and archived according to guidelines outlined in Chapter 11.

Video – primary means of data collection for **coral index site monitoring**. Video tapes are stored locally and a duplicate is sent to the National Archives for storage. Captured images are stored on the local server as well as backed up on dvds.

Remotely Sensed Data – includes satellite imagery and aerial photography. Remote sensing can be a powerful tool for characterizing and analyzing landscape data, as well as readily capturing data within areas of low accessibility. Considerations for selecting remote sensing imagery are as follows:

- Accuracy and resolution needed
- Frequency of measurement
- Costs
- Licensing for public use

- Ortho-rectification standards

Each remote sensing product is unique. It is imperative that users fully understand the product being used and that products be accompanied by well-documented metadata. Any projects involving remote sensing should include consultation with a professional remote-sensing specialist, and project managers should consider the trade-offs between accuracy and cost among different imagery sources (Table 6.1).

The SFCN GIS library currently includes satellite imagery coverage for most of the parks, along with base cartographic layers, digital orthophoto quadrangles, and natural resource theme layers.

Table 6.1. Satellite resolution, swath width, area, cost, and history of various remote-sensing imagery sources (sorted by cost)

Sensor	Multi-spectral Resolution (m)	Panchromatic Resolution (m)	Swath (km)	Area (sq km)	Cost/sq km ($)*	History
Quickbird [T]	2.4	0.7	16	272	29.73	2001-present
Ikonos [T]	4	1.0	11	121	27.03	1999-present
Spot5 [T]	10	2.5 and 5	60	3599	0.77	2002-present
Spot	66	10	60	3599	0.05**	1986-present
ETM+	30	15	185	34221	0.03	1999-2003
TM	30	NA	185	34221	0.03	1982-1999
ASTER	15	NA	60	3599	0.02	1999-present
MSS (ESTS)	79	NA	185	34221	NA	1972-1997
AVHRR	1100	NA	2700	7290138	NA	1978-present
MODIS	250	NA	2330	5429053	NA	1999-present

* cost uses the multi-spectral unit specifications
** cost for post-1998 imagery (pre-1998 imagery is half-price)
[T] requires tasking

Additional methods of remote sensing employed by the network include LIDAR, multibeam sonar, and interferometric sonar. Any additional remote sensing data acquired will likely require some spatial or spectral processing depending on how they are received. All such datasets should be received in a geo-referenced format although some may need to be transformed to the SFCN standard (UTM NAD 83). Large datasets (greater than 50GB) are currently stored on external hard drives. The extent of any additional processing will depend on how the data are to be used and what type of information is to be extracted from them. Specific requirements and procedures should be outlined in project protocols or SOPs.

6.3.1.2. Data Processing

Ideally, each project will have a database developed prior to the collection of any data in the field. SFCN I&M program databases will be developed in conjunction with project protocols and

will be based on the I&M Natural Resources Database Template (NRDT) (Chapter 5) and will include built-in procedures for QA/QC. Ideally, data processing should proceed as follows, and as soon as possible after data are collected, if using field forms.

- Field crews enter all data into an approved project database, under the supervision of the project manager.
- Field crews periodically forward project data files to the project leader and/or data manager (refer to individual protocols for specific requirements).
- All data undergo QA/QC procedures (see Chapter 7 for more specifics on data verification and validation).
- The data manager maintains the master copy of the database and updates it with certified data files received from the project leader.
- National databases are updated as per the procedures outlined in Chapter 10.

6.3.1.2.1. Spatial data

See Field Data Collection with Global Positioning Systems (DMP Appendix H) and Spatial Data Standards (DMP Appendix I) for complete details on methods for data collection and processing of spatial data.

6.3.1.2.2. Photographs

Photos taken as part of a project's data collection protocol constitute data and need to be organized, documented and preserved in conjunction with all other project data. In general, the level of processing required will depend on the purpose of the photograph. Photos are regularly used by many park programs such as resource management, maintenance, fire, and research.

Editing of digital photos may be done to improve orientation or correct for lighting conditions (e.g., rotation to best orientation and removal of 'red eye'), but should never include alterations that change the original content of the photo. Photos may be cropped to remove edge areas that grossly distract from the subject. Poor quality photos can be deleted or destroyed, except where the subject is unique. Photos of medium quality should be assessed against existing photos of the same subject; if they duplicate a subject with no enhancement of quality or perspective, they may be deleted or destroyed. Working photos should be stored either in a workspace within a specific project or within a user's photo library. Digital aerial photos and imagery should be georeferenced. All digital data photos should have geographic coordinates associated with them. For more detail please see Chapter 8.3.1.

6.3.1.2.3. Remote Sensing Data

The processing of remotely-sensed data is often project specific. Therefore, project plans, protocols, and SOPs should document these procedures. Some steps will be common to all datasets, including:

- Images are geometrically registered using nearest-neighbor resampling methods and co-registered to UTM NAD83. Registration accuracy is assessed
- Images are radiometrically corrected and converted to exo-atmospheric reflectance

- Atmospheric corrections are made, if applicable
- All iterations (raw, intermediate corrections, and final) are maintained until project completion when raw and final products are archived

6.3.1.2.4. Vouchers

See Chapter 11 and the WASO DMP for more details.

6.3.2. Non-programmatic Data

A large amount of the data used to manage the natural resources of SFCN parks is collected by entities outside of the Network (universities and other parks, agencies, and NPS programs). These kinds of data collection efforts are referred to as *data discovery* or *data mini*ng. Data collected and products produced by such efforts provide a great deal of information about park natural resources and are therefore relevant to many of its programs. These data can be classified as follows:

Current or ongoing – These are data that are currently being acquired or were recently acquired, but are known to be of value and are targeted for incorporation into existing or planned Network projects. Their acquisition and use should follow very specific guidelines identified by project protocols. Sources can be other Network park programs or external NPS sources. These data might be used to complement program data collection, to fill in gaps of missing data, or as a basis for comparison.

Legacy - Those data found and compiled through the data mining process. These may include vertebrate and vascular plant species data, other important natural resource inventory data, specimen or voucher data, bibliographic data, and existing monitoring datasets.

Data discovery is the process of locating and identifying these useful datasets. Non-programmatic data can be obtained from academia, private organizations and non-profit groups, as well as local, state, and federal government agencies. Within the NPS, park, regional and national programs are all potential sources of information.

Parks within the SFCN may use base funds or receive funding through Natural Resources Protection and Preservation (NRPP) programs to support park-level projects. Typically, these include:

- **Park-based biological inventories** - Network parks often conduct their own park-based inventory projects.
- **Park-based monitoring projects** - Parks also engage in monitoring (such as vegetation or water quality) which can produce information valuable to other programs, such as I&M.
- **Park and multi-park based projects** - include other studies or projects conducted at the park or regional level that do not fall into one of the previous two categories (e.g., restoration projects).

NPS regional and national programs support all parks within the Southeast Region and are good resources for natural resources information. These include:

- **Air –** National-level programs collect data, maintain databases, assure data quality, and perform the trend analyses relevant to SFCN air quality issues.
- **EPMT -** Exotic Plant Management Teams (EPMT) collect and maintain data regarding the presence of exotic species in many parks, and develop and document the methods used to treat these species. Data are stored in the Alien Plant Control and Monitoring Database (APCAM) and maintained by the EPMT data manager.
- **Fire Program –** Data on fire occurrence within the SFCN are maintained both at individual park and regional levels. National databases such as Fire-Pro, SACS and Fire Program Analysis (FPA) have been, and will be, used to maintain information regarding fire incidence and the resources dedicated to fire management.
- **GIS –** The SFCN is supported by regional GIS specialists to help ensure regional GIS data are available and accurate. Much of these data are also available through the NPS GIS Clearinghouse.
- **Geologic Resources Division –** Geologic Scoping summaries detail the results of meetings held with parks to discuss existing geologic map coverage, geologic features and processes of significance, and geologic resource related issues of concern to park managers.
- **Wildlife Management -** The regional Threatened and Endangered (T&E) Species Specialist provides management support and coordinates reporting of T&E species populations.
- **WRD-** Horizon reports are designed to characterize baseline water quality at all units of the National Park System containing significant natural resources. The goal of this effort is to provide descriptive water quality information to every national park unit in a format usable for park planning and management.

Future data mining efforts within the SFCN should adhere to the guidelines and protocols outlined in South Florida/Caribbean Network Guidance for Data Mining (DMP Appendix J). Information collected during the data discovery process should be maintained either electronically or in hard copy format depending on how it was collected, and should be documented as fully as possible (Chapter 8). Data should be disseminated to the appropriate repository as summarized in Table 6.2 and discussed in Chapter 10.

Table 6.2. Summary of possible data sources for different types of information and repositories where they are maintained

Type of Data	Possible Source	Repository
Bibliographic / Literature	• Online literature databases (e.g., First Search or Biosis) • Library catalogs (e.g., academic or research institutions) • Park archives through ANCS+	• NatureBib • Reference cabinets for hard copy materials • Digital archive for electronic materials
Geographic Data	• Regional centralized GIS data • Federal and state geographic data clearinghouses	• IRMA • NPS Data Store • Digital archive

	• Local, state, and federal government offices • Regional and park GIS specialists	
Biologic / Natural Resource Data	• Voucher collections (museums, parks, universities) • Network parks	• IRMA • NPSpecies • Digital archive

Data discovery is an integral part of project development, but efforts should not be limited solely to project development needs. This should be an ongoing process requiring regular data searches and visits to Network parks to ensure that Network parks maintain as much material relevant to managing their natural resources as possible. Encouraging data sharing among parks will assist in this process and may alleviate the need for regular searches of park records.

6.3.2.1. Data Collection

The collection of data from non-programmatic sources should follow program specifications as outlined by project protocols or SOPs. Procedures should be standardized as much as possible and include:

- Contacting data stewards and informing them of program needs.
- Establishing Memoranda of Understanding (MOUs) if needed.
- Developing a contingency plan in case the data source is no longer available.
- Determining whether data can be consistently exported/imported and establishing a schedule.
- Determining how the data will be stored and integrated into the program.
- Determining how errors will be addressed.
- Determining if documentation is adequate and if not, completing where necessary.
- Identifying any interest in the exchange of program data and information with the outside program.

Agency or organizational stewards of these data often have the expertise to conduct proper quality control procedures and the capability to function as a repository and clearinghouse for validated data. In some cases, portions of external databases may be incorporated into SFCN databases and thereby made more accessible to staff.

6.3.2.2. Data Processing

Much of the data identified during the discovery process are likely to be the legacy type. As time and resources permit, legacy data should be converted to file formats compatible with current software standards. Hardcopy references and other materials containing legacy data can be scanned and saved as .pdf files and stored in a program's digital library (Chapter 11). All legacy datasets should be reviewed and cataloged as follows:

- Enter all biodiversity data into NPSpecies (this is especially important for park-based biological inventories).

- Enter all natural resource reports and publications related to SFCN parks into NatureBib. Hard copies should be stored in the appropriate park collections and electronic copies archived in the proper directory on the Network file servers (Chapter 11).

All GIS data should be stored in the proper projection (UTM NAD83) and accompanied by FGDC-compliant metadata (Chapter 8).

6.3.3. Analysis and Reporting

Obtaining meaningful results from data summary and analysis is essential to providing useful information for natural resource managers and scientists. Thus, it is incumbent on data managers and stewards to provide valid data in formats that support scheduled and ad hoc display, query, analysis, summary, and reporting. Routine and scheduled data summary, analysis and reporting requirements and procedures should be identified in project protocols.

The development of data products should be guided by project objectives, protocols and data management SOPs. Products defined in advance, such as routine summaries and output formats can be automated through the use of queries and reports stored in a project's database. Project leaders should work with data managers to create, and test these queries. Queries can be used to view raw or summarized data, or to output either type as custom-formatted reports or as files that can be imported by other analytical tools (e.g., statistics software). Other queries can be built to facilitate data exploration and unscheduled analysis. Specific needs should be determined by individual projects.

Most likely, data will be exported from project databases for most statistical analyses beyond means, standard deviations, and other descriptive statistics. SFCN will use third party statistical software (i.e., R, SAS, and SPSS) for generating frequency distribution plots, tests for normality analysis of variance, time series analysis, and others.

6.3.4. Changes to Procedures

Changes to established data collection procedures are discouraged unless there are acceptable, valid reasons for altering the methodologies. Ideally, all problems should be identified during the design and testing stages of the project and changes implemented prior to the collection of any field data. Protocols should attempt to identify any foreseeable issues that might occur as well as contingencies to address them. Inevitably, unforeseen problems may occur which require procedure/protocol revision after data collection has begun. Significant changes to protocols should be approved by the principal investigator, project leader and data manager. The key official should evaluate the proposed changes and determine if additional peer review is required before accepting them. All changes should be carefully documented within project SOPs and any associated databases.

6.3.5. Maintaining an Edit Log

Any changes that occur as a result of a change in a project's protocol will be documented in the formal documentation developed for the database (Chapter 5).

6.4. References

Boetsch, J. R., B. Christoe, and R. E. Holmes. 2005. Data management plan for the North Coast and Cascades Network Inventory and Monitoring Program. U.S. Department of the Interior, National Park Service. Port Angeles, WA.

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6.6. Credits

This chapter was taken largely from Cook and Lineback (2006) and from concepts and material developed by Stevens and Entsminger (2004), Boetsch *et al.* (2005), Daley (2005), and Mortenson (2005).

Chapter 7. Quality Assurance and Quality Control (QA/QC)

The success of any natural resources program is dependent on the quality of the data it collects, manages, and disseminates. Analyses performed to detect ecological trends or patterns require data that are recorded properly and have acceptable precision and minimal bias. Low quality data can limit detection of subtle changes in ecosystem patterns and processes, can lead to incorrect interpretations and conclusions, and could greatly compromise the credibility of the program managing it.

Quality assurance (QA) can be defined as an integrated system of management activities involving planning, implementation, documentation, assessment, reporting, and quality improvement to ensure that a process, item, or service is of the type and quality needed and expected by the consumer; quality control (QC) is a system of technical activities that measure the attributes and performance of a process, item, or service relative to defined standards (Palmer 2003). While QA procedures maintain quality throughout all stages of data development, QC procedures monitor or evaluate the resulting data products.

7.1. Objectives

- Ensure natural resources projects produce high quality and credible data that can be confidently used by managers, researchers and the public
- Implement standard quality assurance and quality control procedures to meet the first objective

7.2. Laws and Policies

For specific laws and policies please see WASO DMP Chapter 7.

7.3. General Standards and Guidelines

To ensure that the SFCN produces and maintains data of the highest possible quality, procedures have been established to identify and minimize errors at each project stage associated with the data life cycle (Figure 7.1). QA/QC procedures specific to any project should be specified in a project's protocols and SOPs. However, some general concepts apply to all Network projects. The general guidelines presented below were primarily adapted from the I&M Program's *Draft Data Management Protocol* (Tessler & Gregson 1997) and ideas contained in Michener and Brunt (2000).

Although a dataset containing no errors would be ideal, the cost of attaining 95%-100% accuracy may outweigh the benefit. Therefore, at least two factors are considered when setting data quality expectations:

- Frequency of incorrect data fields or records, and
- Significance of error within a data field.

Errors are more likely to be detected when datasets are clearly documented and what constitutes a ‘significant’ error within *that* dataset is understood. The significance of an error can vary both among datasets and within a single dataset. For example, a two-digit number with a misplaced decimal point (e.g., 99 vs. 9.9) may be a significant error while a six-digit number with an incorrect decimal value (e.g., 9999.99 vs. 9999.98), may not. However, one incorrect digit in a six-digit species' Taxonomic Serial Number could indicate a different species. QA/QC mechanisms are designed to prevent data contamination, which occurs when a process or event introduces either of two fundamental types of errors into a dataset:

- Errors of commission include those caused by data entry or transcription, or malfunctioning equipment. They are common, fairly easy to identify, and can be effectively reduced up front with appropriate QA mechanisms built into the data acquisition process, as well as QC procedures applied after the data have been acquired.
- Errors of omission often include insufficient documentation of legitimate data values, which could affect the interpretation of those values. These errors may be harder to detect and correct, but many of these errors should be revealed by rigorous QC procedures.

Selected QA/QC procedures relative to the amount of planning and quality control necessary to have confidence in the data are illustrated in Figure 7.2. The most effective mechanism for ensuring that a project produces high-quality data is to determine procedures that direct project staff through accurate data collection, entry, and validation, and adhere to them.

Figure 7.1. General course of data and associated Quality Assurance/Quality Control procedures. Quality Control with regards to data analysis is specific to each project and addressed in appropriate standard operating procedures.

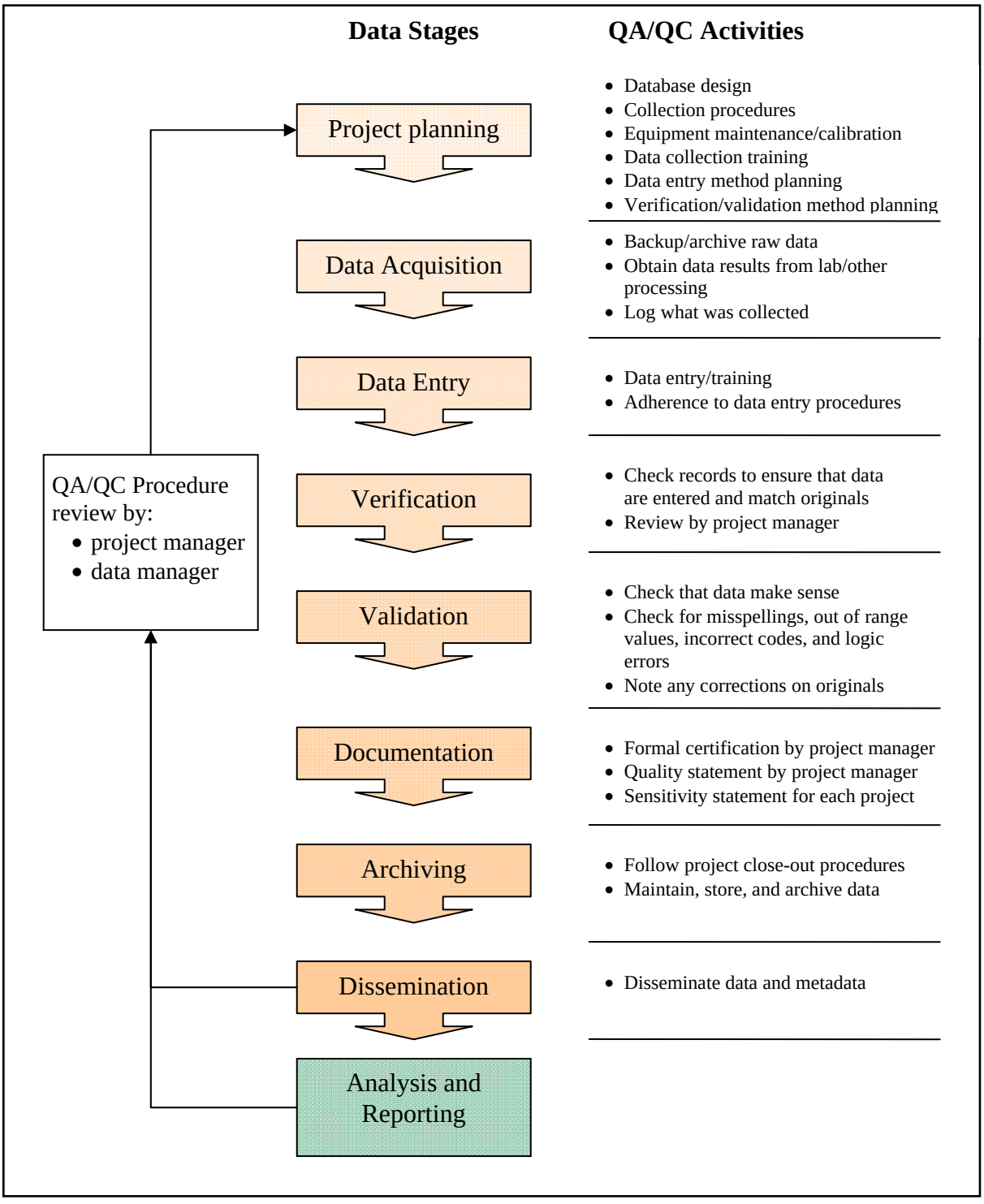
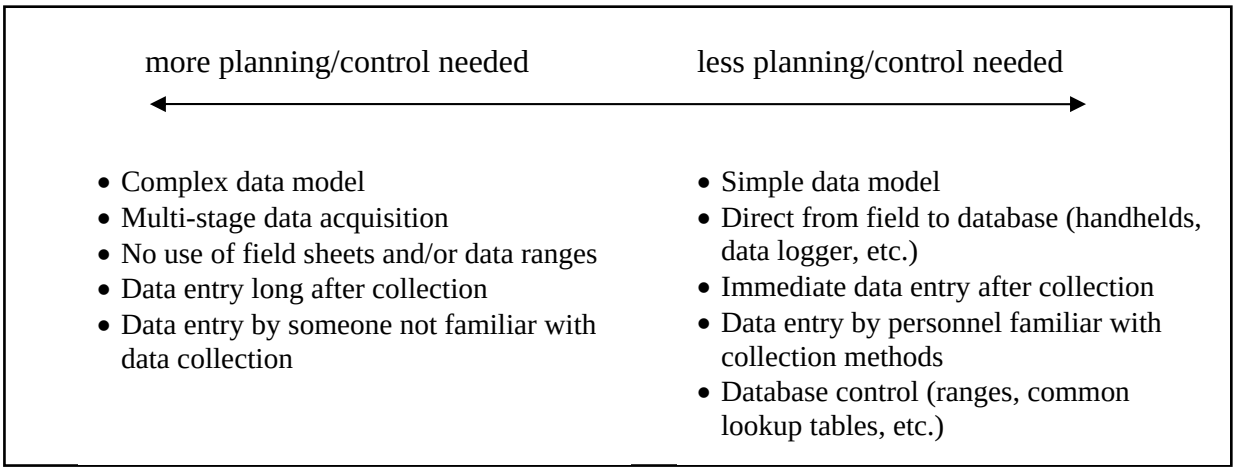


Figure 7.2. Some common information management elements influencing the amount of QA/QC needed.



7.3.1. Project Planning and Data Design

Quality assurance begins with choice of project methods and information to be gathered. Quality assurance will be achieved by stipulating that:

- Common lookup tables are created for parameter values recorded by multiple projects (e.g., weather variables, standard equipment, field personnel, etc).
- Each vital sign protocol has SOPs that address core information management practices (e.g., field crew training, use of handheld computers, equipment maintenance and calibration, and data backup, entry, verification, and validation, etc.).
- Each project uses handheld computers for data collection if possible. If not, at a minimum, standardized field sheets are used.
- Databases adhere to the standards outlined in Chapter 5.
- Database data entry forms, if necessary, resemble the field sheets.
- Automated error checking features will be included in database applications.
- Database application design will maximize the use of auto-fill, auto-correct, range limits, pick lists, and other constraints specific to projects.
- Database applications will include a means to track the date a record is created or modified, the name of the person creating/modifying the record, and errors reported on the data after dissemination.
- Database maintenance logs will be maintained for each SFCN database and housed in association with database files.

7.3.2. Data Collection

Chapter 6 addressed general data acquisition and initial handling as well as changes to data collection protocols. Attention to detail during the data collection phase, however, is crucial to overall data quality. Unlike a typographical error that occurs during data entry, an incorrect observation in the field is not easily corrected.

The SFCN adopts the following guidelines regarding data collection that affect data quality:

- Field crews will receive proper training.
- Any project using field equipment will include a calibration and maintenance SOP that will also specify establishment of an equipment maintenance log.
- Wherever possible and appropriate, data loggers or field-based computers will be used to collect data. When this is not possible, data will be recorded on formatted, project-specific data sheets that reflect the overall design of the project and are designed to minimize the amount of writing necessary to effectively record observations.
- When field sheets are necessary, or more appropriate, the format will reflect the computer data entry interface to help ensure all relevant information is recorded and subsequent data entry errors are minimized.
- Completed field forms will be proofed for errors each day in the field. Edits will be made by drawing a single line through the information to be changed, adding any replacement information in clear writing next to the original entry, and initializing the changes.
- Separate SOPs will describe the use of data loggers or field-based computers and will include direction for daily review and back-up.

7.3.3. Data Entry

Data entry is the process whereby raw data are transferred from paper field forms into an electronic data format. When data are gathered or stored digitally in the field (e.g., on a data logger), data entry consists of the transfer of data (downloading) to a file in an office computer where they can be further manipulated. The goal of data entry is to transcribe field observations into a computer database with 100% accuracy, although errors are unavoidable. Subsequent data verification is conducted to ensure that raw data matches entered data. Following verification, data validation may result in changes *to the entered data.* Data entry is a separate operation from data validation and care must be taken to not impose validation (beyond that automatically imposed by programming rules in a database) during data entry.

The SFCN adopts the following guidelines regarding data entry:

- To the extent possible, data entry will be automated. This may simply entail downloading data from field-based computers but may include the application of new technology to allow for machine-driven data entry (e.g., voice-recognition software).
- Data will be entered as soon as reasonably possible after collection.
- Data entry will be completed by someone familiar with data collection. The project leader (with assistance from the data manager if needed) must ensure that data entry staff are familiar with the database software, database structure, and any standard codes used by the Network. At a minimum, data entry technicians should know how to open a data entry form, create a new record, and exit the database properly. They must also learn how to correct mistakes made while typing.
- If feasible, data will be entered by two qualified persons; one person will read the observations and the other will enter the data.

- Data will be entered into pre-designed database forms that resemble field sheets and maximize error control.

7.3.4. Data Verification

Data quality is appraised by applying verification and validation procedures as part of the quality control process. These procedures are more successful when preceded by effective quality assurance practices (i.e., planning). *Data verification* checks that the digitized data match the source data, while *data validation* checks that the data make sense. Although data entry and verification can be handled by personnel who are less familiar with the data, validation requires in-depth knowledge about the data.

The SFCN adopts the following guidelines regarding data verification:

- Project leaders are responsible for specifying in the project protocol one or more of the data verification methods available and ensuring proper execution. At the discretion of the project leader, additional verification methods may be applied.
- Data verification is carried out by staff thoroughly familiar with data collection and entry.
- All records (100%) will be verified against original source data.
- A subset of randomly selected records (10%) will be reviewed after initial verification by the project leader. If errors are found, the entire dataset will be verified again.
- A record of the verification process for each dataset, including number of iterations and results, will be prepared by the project leader as part of formal metadata generation (see Chapter 8 for more details).
- Spatial data collected as part of the project will be viewed in a GIS and visually inspected for accuracy (e.g., points located outside park boundaries, upland locations occurring in water).

7.3.4.1. Methods for Data Verification

Each of the following methods has a direct correlation between effectiveness and effort. The methods that eliminate the most errors can be very time consuming while the simplest and cheapest methods will not be as efficient at detecting errors.

1) *Visual review at data entry.* The data entry technician verifies each record after input and immediately corrects any errors. This method is the least complicated since it requires no additional personnel or software. Its reliability depends entirely upon the person keying data and thus, is probably the least reliable data verification method.

2) Visual review after data entry. Upon completion of data entry, all records are printed and compared with the original values from the hard copy. Errors are clearly marked and corrected in the database as soon after data entry as possible. Reliability increases if someone other than the person keying the data performs the review. Alternatively, two technicians (one reading from the original data and one checking the entered data) can perform this review.

Data verification can be improved by calculating summary statistics and identifying duplicate or omitted records. For example, the number of known constant elements, such as the number of sampling sites, plots per site, or dates per sample can be evaluated. Databases can also be built with controls to prevent duplicate records (Chapter 5), although tests must be performed to identify missing records. The more checks that are devised to test for completeness, the greater one's confidence will be in the quality of the dataset data.

7.3.5. Data Validation

Validation is the process of reviewing computerized data for range and logic errors and may accompany data verification *only* if the operator has comprehensive knowledge of the data and subject. More often, validation is a separate operation carried out *after* verification by a project specialist who can identify generic and specific errors in particular data types. It is essential that we validate all data as truthful and do not misrepresent the circumstances and limitations of collection.

General step-by-step instructions are not possible for data validation because each dataset has unique measurement ranges, sampling precision, and accuracy. Specific guidelines should be written into all project protocols and SOPS. Invalid data commonly consist of misspelled species names or site codes, wrong dates, or out-of-range errors in parameters with well defined limits (e.g., pH). More interesting and often puzzling errors are detected as unreasonable metrics (e.g., stream temperature of 70°C) or impossible associations (e.g., a tree 2 feet in diameter and only 3 feet high). These types of erroneous data are called *logic errors* because they produce illogical (and incorrect) results. The discovery of logic errors has direct, positive consequences for data quality and provides important feedback to the methods and data forms used in the field. Histograms, line plots, and basic statistics can reveal possible logic and range errors.

The SFCN adopts the following guidelines regarding data validation:

- Project protocols will address a process for data validation that includes at least one of the available methods.
- Corrections or deletions as a result of data validation require notations in the original paper field records about how and why the data were changed, with the editor’s initials.
- Modifications of the field data will be clear and concise while preserving the original data entries or notes (i.e., no erasing).
- Validation efforts will also include a check for the completeness of a dataset since field sheets or other sources of data could easily be overlooked.
- Use of automated routines and/or data summary and visualization (e.g., histograms, line plots, and basic statistics) will be maximized to identify possible logic and range errors.
- Use of database programming will be maximized to control data entry. This will be achieved via the use of lookup tables and/or field-type design in a database (e.g., yes/no field-types).

7.3.6. Methods for Data Validation

The following general methods can be used as guidelines:

1) *Data entry application programming.* Certain components of data validation are built into data entry forms. This method is essentially part of the database design and is discussed earlier in this chapter. Not all fields, however, have appropriate ranges known in advance. Caution must be exercised when using lookup tables to constrain variable values. Values occurring outside the range set by a lookup table (established during database design) may not always be invalid. As part of data validation procedures, the project leader is responsible for correct use of lookup tables or other automated value range control (see Chapter 5 for more detail).

2) *Outlier Detection.* According to Edwards (2000), "the term outlier is not (and should not be) formally defined. An outlier is simply an unusually extreme value for a variable, given the statistical model in use." Any dataset will undoubtedly contain some extreme values, so the meaning of 'unusually extreme' is subjective. The challenge in detecting outliers is in deciding how unusual a value must be before it can (with confidence) be considered 'unusually' extreme.

Data quality assurance procedures should not try to *eliminate* outliers. Extreme values naturally occur in many ecological phenomena; eliminating these values simply because they are extreme is equivalent to pretending the phenomenon is 'well-behaved' when it is not. Eliminating data contamination is perhaps a better way to explain this quality assurance goal. When an outlier is detected (via GIS, database, graphic, and statistical tools for ad-hoc queries and displays), the possibility of contamination will be evaluated and noted.

3) *Other exploratory data analyses.* Palmer and Landis (2002) suggest calculations for assessments of precision, bias, 'representativeness', completeness, and comparability may be applicable and, for certain types of measurements, evaluation of detection limits may also be warranted. Normal probability plots, and simple and multiple linear regression techniques may also be used (Edwards 2000).

7.3.7. Review, Conformance and Communication

The National Park Service requires QA/QC review and approval prior to communicating or disseminating data and information. Documentation of the QA/QC standards used in producing the information and that substantiate the quality of the information must be formally certified and distributed with the related data and information. Mechanisms must also be in place for receiving and addressing comments or complaints pertaining to data quality (see also Chapter 10).

As part of the close-out and evaluation stage of each SFCN project, QA/QC procedures will be reviewed by the project leader and recommendations for change will be included in the annual report. Similarly, SFCN data management staff will review and revise the QA/QC procedures included in this information management plan and/or SOPs as needed.

To ensure the highest quality, data custodians should conduct periodic audits to ensure compliance with the information management plan and protocol QA/QC procedures. Such

quality checks promote a cyclic process of continuous feedback and improvement of both the data and quality planning process. Audits may include verification of the following:

- Data collection and reporting requirements are being met
- Data collection and reporting procedures are being followed
- Verification and validation procedures are being followed
- Data file structures and maintenance are clear, accurate and according to plan
- Revision control of program documents and field sheets are adequate
- Calibration and maintenance procedures are being followed
- Seasonal and temporary staff have been trained in data management practice
- Metadata collection and construction for the program proceeds in a timely manner
- Data are being archived and catalogued appropriately for long term storage

The final step in the QA/QC process is preparation of summary documentation that assesses overall data quality. The statement of data quality is composed by the project leader and incorporated into formal metadata for the dataset. Metadata should also provide information on the specific QA/QC procedures applied and the results of review. Typically, data quality information will be conveyed as part of FGDC-compliant metadata (Chapter 8) and will be available via the NPS Data Store (Chapter 10).

7.3.8. Roles and Responsibilities

Producing and maintaining high quality data is the responsibility of everyone involved with the handling of project data. It is essential that each member of the team have a stake in data quality, and is responsible for the quality of the results generated from his or her tasks. While Chapter 4 discusses data management roles and responsibilities, selected QA/QC duties are emphasized here.

Project leaders need to:

- Be aware of QA/QC procedures in protocols and convey their importance to technicians and field crews
- Ensure compliance with the protocols
- Plan for and ensure proper execution of data verification and validation
- Review all final reports and information products

Project technicians must:

- Follow established protocols for data collection, data entry, and verification
- Inform the project leader or data manager of quality-related problems or difficulties

The data manager is responsible for:

- Developing Network-wide SOPs to ensure data quality
- Making project leaders, technicians, and others involved aware of the established procedures and enforcing adherence to them

- Evaluating the quality of all data and information against NPS standards before dissemination outside the Network
- Performing periodic data audits and quality control checks to monitor and improve quality control operations

7.4. References

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7.5. Credits

This chapter was taken largely from Cook and Lineback (2006) and from concepts and material developed by Angell (2005), Beer *et al*. (2005), and Hart and Gafvert (2005).

Chapter 8. Dataset Documentation

Documenting data is a time-consuming task for NPS staff and cooperators. Thorough documentation however, is essential for preserving the integrity and longevity of data and the products of its analysis, and is therefore, an essential component of sound data management.

8.1. Objectives

- Document all significant spatial (GIS) and tabular datasets to SFCN standards described in this chapter.
- Maintain and leverage the investment made by NPS staff and cooperators in producing quality data.
- Aid the discovery of relevant data by NPS staff, collaborators, and the public.
- Preserve integrity and longevity of data and its documentation indefinitely.

8.2. Laws and Policies

For specific laws and policies please see WASO DMP Chapter 8.

8.3. General Standards and Guidelines

From project development through final delivery of information products, the Network Data Manger and project leaders will place a high priority on documenting the purpose, quality, and meaning of data, and allow for the time this will take when scheduling. Detailed protocols provide an important source of information about the data produced by a project and therefore project leaders will track and document protocol versions (Chapter 12). Metadata will adhere to strict standards, and their development will be guided by the practices described below. Crews will be trained to record decisions made in the field that affect data quality or meaning. Project leaders will start metadata at the onset of the project and set the tone for record-keeping throughout the course of the project.

8.3.1. Content Standards

Network metadata content standards will adhere to those set by FGDC and NPS policy as described above. The Concept Standards for Digital Geospatial Metadata (CSDGM) consists of seven sections (Sections 1-7), all of which contain elements required for spatial data. The NPS Metadata Profile adds another section (Section 0). The Biological and ESRI Profiles are added as elements to Sections 1-7. A summary of the CSDGM and NPS Metadata Profile sections is provided below.

***Section 0, NPS Information* –**purpose of the metadata, relevant park unit(s), and data steward.

***Section 1, Identification Information* –** who produced the dataset, when and why it was produced, and where it is from. Constraints on access (e.g., for sensitive data) and use are also

recorded in this section. Also includes the geographic extent, bounding altitudes, taxonomy, and analytical tools used in processing (for biological data).

Section 2, Data Quality – the accuracy of attributes and geographic positions and the procedures used to ascertain accuracy. This section also documents the completeness and lineage of the dataset. Lineage includes source(s) of the data and processing steps, and methodologies used (for biological data).

Section 3, Spatial Data Organization – methods of spatial reference. Mandatory for spatial data.

Section 4, Spatial Reference Information – coordinate system definitions. Mandatory for spatial data.

Section 5, Entity and Attribute Information – attribute names, definitions, codes and their meanings and other information essential to a basic understanding of the data.

Section 6, Distribution Information – methods and contacts used for obtaining data. Also documents information critical for using biological data formatted in ASCII.

Section 7, Metadata Reference Information – includes who created the metadata, when it was created, the profile used, and the frequency of update.

Metadata that are *fully compliant* with FGDC and NPS standards have entries in Section 0 and all element fields in Sections 1-7 where the *Optionality* field contains the term ‘mandatory’ or ‘mandatory if applicable’. A mandatory element is one which must be populated for every dataset. A mandatory if applicable element is one which must be populated if the dataset exhibits the characteristic being documented by the metadata element. For example, the element defining the vertical coordinate system would be mandatory if a dataset contains elevation or depth data.

Metadata that are *minimally compliant* with FGDC and NPS standards have entries in Section 0 and all ‘mandatory’ and ‘mandatory if applicable’ element fields in Sections 1, 6, and 7, and Section 2 for biological data. These include the fields used by the NPS Data Store. Datasets documented to this extent can be distributed via the Data Store's online upload utility. See DMP Appendix K for guidance on creating metadata for the NPS Data Store.

Different types of data and information require different kinds and levels of documentation. Standards for documentation of SFCN datasets are as follows:

Spatial Data will contain, at a minimum, all of Section 0 and the required elements of Sections 1-7.

Non-Spatial Data will include, at a minimum, all elements of Section 0, the required elements of Sections 1, 6, and 7, and Section 2 for biological data. The minimum requirements for non-spatial data therefore meet the requirements for minimum compliance with the FGDC and NPS standards.

Relational Databases will be documented according to the standards outlined above. Complete documentation will also include entity relationship diagrams, business rules, and programming code. The NPS Metadata Profile currently does not support this type of documentation, so it will be stored separately from the formal metadata, in a folder with the database. Relational databases will also utilize internal documentation such as table and field descriptions and will include a table to track modifications. See Chapter 5 for more information on documenting relational databases.

Legacy Data will be documented to the extent possible according to the standards outlined above. Metadata that accompany legacy spatial and non-spatial datasets are suitable for upload to the NPS Data Store if they include entries sufficient for minimum compliance with FGDC and NPS standards. Priority for documentation will be:

- Datasets needed for current project development
- Datasets used frequently by park staff or cooperators
- Historic datasets archived for possible future use

Any contracts entered into by the SFCN with data miners will stipulate the submission of FGDC and NPS-compliant metadata. The Network Data Manager or project leader will assist with metadata acquisition by providing tools, format protocols and file transfer services.

Data from Outside the Network are data that are generated and/or managed outside of SFCN programs but used in analysis with SFCN data or distributed in any manner by the NPS. These data require the same level of documentation produced for SFCN-generated data, including but not limited to, data produced under contract with the NPS. Metadata will be requested from the originating entity by the Network Data Manager or project lead.

Generally, external data will not be posted on Network or park local or wide area networks (LAN/WAN) without accompanying metadata. This will include any metadata downloaded with the data, plus additional information regarding date of download and any alterations made to the data by NPS staff. Staff posting data to the SFCN LAN or WAN will make a reasonable effort to make up for any deficiency in the original metadata, but should not create new metadata for data from well-known sources such as USGS digital line graph (DLG) data. NPS staff will occasionally post 'value added' external data (e.g., a digital elevation model clipped to park boundaries and converted to the standard projection) to the NPS Data Store, and associated metadata will reflect the source data as well as processing prior to upload.

Sensitive Data. Metadata documentation (Section 1, Constraints on Access) provides one means of labeling sensitive data in order to ensure their protection and integrity over time. Sensitive data will be documented according to the standards outlined above, although only their metadata will be uploaded to the NPS Data Store. Actual data will be archived in secure locations on Network and/or Park servers.

Digital Photos. A national metadata standard for digital photos is currently under development by WASO. In the meantime, digital photos will be documented with the following categories:

- Author – who took the photo, with agency affiliation
- Title – who or what is in the image
- Location – where the image was taken
- Habitat
- Fauna – general category of fauna
- Flora – general category of flora
- Common Name
- Scientific Name
- People – people in the photo
- Equipment – type of equipment shown in photo
- Date – when the image was taken
- Park Unit
- Access constraints – who may view the image
- Copyright information – restrictions on using the image
- Contact information – who to contact for further information

8.3.2. Format and Storage Standards

To enable uploading to the NPS Data Store and further public distribution by NPS servers, metadata must be formatted in a manner that will allow parsing with the USGS Metadata Parser (see below). Proper formatting can be most easily accomplished using the metadata tools described below.

Metadata and other documentation will be stored as close to their associated data files as possible, with formal metadata files saved in XML. Metadata may be exported in text, Hypertext Markup Language (HTML) or other formats as needed but the original XML file will be maintained with the data as the master copy.

Hypertext links within the metadata document will point to accompanying datasets stored on Network servers. In general, a single metadata document will apply to both raw and certified versions of the data.

8.3.3. Metadata Tools

ESRI's ArcCatalog© is a multifunction application for managing spatial data and for editing FGDC compliant metadata. ArcCatalog© uses stylesheets to display XML metadata in a format for easy viewing and editing. Because ArcCatalog© metadata are linked to the datasets they describe, certain inherent properties of datasets, such as bounds, coordinate system, feature count, and attribute names, can be automatically populated and maintained in the metadata.

NPS Metadata Tools and Editor (DMP Appendix L) is a custom software application for authoring and editing NPS metadata. It extends the basic functionality of ArcCatalog© for managing spatial metadata and provides a stand-alone tool for creating and manipulating non-spatial metadata outside of ArcCatalog©. The Metadata Editor formats metadata according to the NPS Metadata Profile. Like ArcCatalog©, editing is done with stylesheets. A variety of stylesheets are offered, each tailored to a specific type of metadata and displaying only the

elements or sections pertinent to that type. NPS-specific stylesheets are based on the NPS Metadata Profile extension and contain all elements in the FGDC, ESRI, and Biological metadata standards and profiles plus NPS-specific elements. Metadata can be parsed with the USGS MetaParser which comes bundled with the Metadata Tools. Output format is XML, suitable for upload to the NPS Data Store. Metadata Tools includes utilities for searching, cataloging, parsing, and spell-checking metadata records.

NPS Database Metadata Extractor is an add-in for MS Access 2000-2003. The extractor automatically harvests entity (table) and attribute (field) metadata from MS Access databases, including domains. It further allows the user to edit and review the harvested metadata and make batch edits and to export metadata to a FGDC-compliant XML file. Exported XML can be used in the Metadata Tools & Editor either by opening it to start a new metadata record or by updating with template to fill section 5 of an existing record. This tool will eventually become part of the NPS Metadata Tools & Editor.

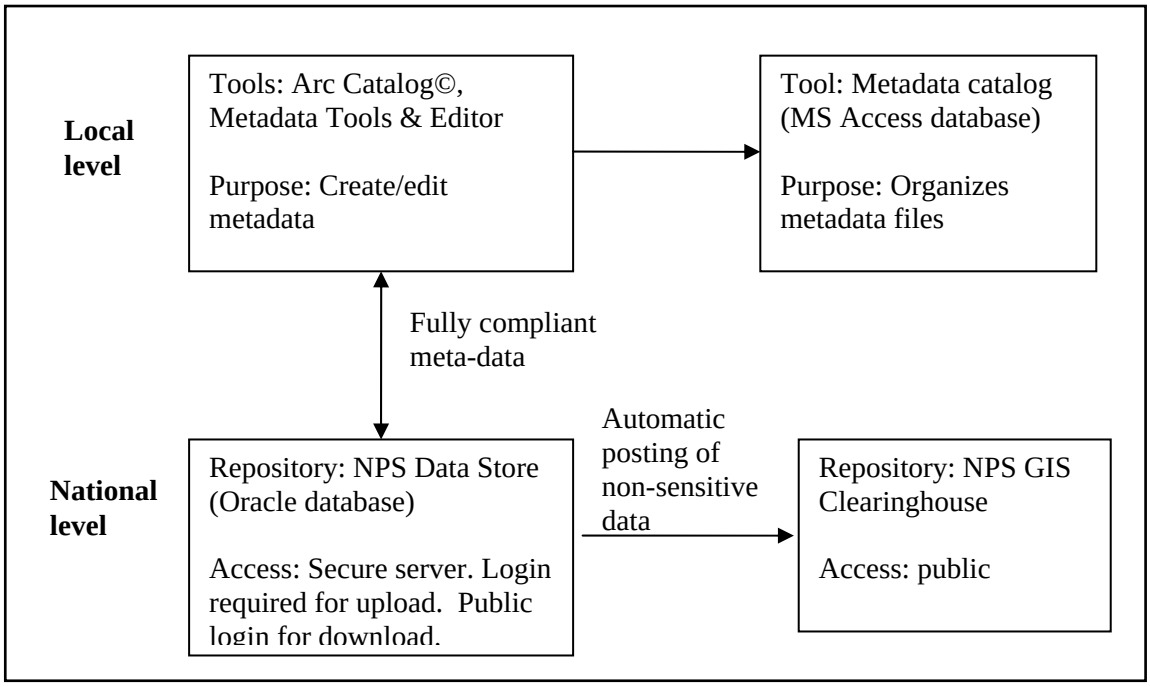
Metadata Parser (mp) is a program developed by the USGS that comes bundled with both ArcCatalog© and the NPS Metadata Tools and Editor. It is used to validate metadata records by checking the syntax against the CSDGM and to generate compliant output files for posting to clearinghouses. The parser generates a textual report indicating errors in the metadata, primarily in the structure, but also in the values of some of the scalar elements where values are restricted by the standard.

The "Metadata in Plain Language" questionnaire (Schweitzer 2006) is a user-friendly information sheet (MS Word© document) that can be used to elicit metadata needed to complete all FGDC required elements for datasets not formatted for geographic information systems (e.g., shapefiles, coverages, and geotiffs). It currently does not include questions specific to the Biological Data Profile nor the NPS Profile and therefore, does not alone, meet the content standards specified by the NPS Metadata Profile. Additional information must be obtained to comply with these specifications.

8.3.4. Work Flow Process

The Network will establish a standard operating procedure for metadata generation and maintenance (DMP Appendix M). In general, metadata development begins with project design and planning (Chapter 3). Metadata documents should be created with the tools recommended above to ensure standardization and the ability to upload to the NPS Data Store. Other tools may be used as long as the metadata produced meet the appropriate requirements for content, format and organization. Initially, some sections may be populated by SFCN staff with information from formal written project protocols. As the project progresses, the document will be completed with information such as field season dates, protocol changes, and taxonomy information. Completion will occur after the dataset is certified by the Network Data Manager or project leader. The Network Data Manager or project leader ensures that updated metadata are uploaded to the NPS Data Store. The relationship between local applications and tools, and national-level storage and delivery system is illustrated in Figure 8.1. See details for data dissemination in (Chapter 10).

Figure 8.1 The NPS integrated metadata management system.



8.3.5. Maintenance and Access

Once metadata are complete, the Network Data Manager or project leader saves one copy with the primary dataset at the local level, and uploads an XML-formatted copy to the NPS Data Store.

Metadata can easily be searched with Metadata Catalog, one of the tools in the NPS Metadata Tools and Editor. Metadata Catalog creates a Microsoft Access database that stores the location, filename and other information about all metadata files in a selected directory. Metadata is also linked to the original data file using NPS Theme Manager.

8.4. References

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8.5. Credits

This chapter was taken largely from Cook and Lineback (2006) and from concepts and material developed by Mortenson (2005) and information provided by Ginger Bradshaw and Chris Dietrich.

Chapter 9. Data Ownership and Sharing

For the purposes of releasing data, the term *sharing* means releasing to an individual or entity upon request or as part of an agreement to do work that benefits the parks. The term *dissemination* includes releases to the public via publications or other standard routes of delivery such as the NPS Data Store. Chapter 10 provides detailed standards and guidelines for data dissemination. Guidelines for data sharing, including sensitive data procedures, are described in this chapter.

9.1. Objectives

- Establish clear guidelines for the ownership and sharing of natural resources data and information.
- Protect sensitive data from unauthorized access and inappropriate use.

9.2. Laws and Policies

In general all data and materials collected or generated using National Park Service personnel and funds become the property of the National Park from which they were collected.

For additional information see WASO DMP Chapter 9

9.3. General Standards and Guidelines

Data and information will be shared internally through Network channels, externally through online databases and repositories, and by special request as appropriate, and only after quality control procedures have been fully implemented.

9.3.1. Collaborative Agreements

To ensure that proper ownership, format, and development of Network products are maintained, all cooperative or interagency work must be conducted as part of a signed collaborative agreement. Every cooperative or interagency agreement or contract involving the Network must cite the Office of Management and the Budget, Circular A-110 under the *Reports and Deliverables* Section. The following shows appropriate language to use when citing Circular A-110:

> *"As the performing organization of this agreement, [institution or organization name] shall follow the procedures and policies set forth in OMB Circular A-110."*

Every cooperative or interagency agreement or contract must include a list of deliverables and products clearly defined within each agreement or contract. Details on formatting and media

types that will be required for final submission must be included. Agreements and contracts must list all products expected to result from the project. These include, but are not limited to, field notebooks, photographs (hardcopy and digital), specimens, raw data, and reports.

The following statement must be included in the Reports and Deliverables section of all agreements and contracts made by the SFCN Inventory and Monitoring Program:

> *"All reports and deliverables must follow South Florida/Caribbean Network Product Specifications".*

See South Florida/Caribbean Network I&M Program Checklist of Project Specifications (DMP Appendix G) and the documents referenced therein for further details on data acquisition, documentation, and reporting standards and requirements.

Project leaders should provide a schedule of deliverables that includes sufficient time for the NPS to review drafts before scheduled final submissions.

9.3.2. Due Notification

SFCN staff will notify investigators prior to making datasets available to the public. This will allow each investigator the opportunity to make a request in writing to further restrict access of the dataset to the public. Network staff will review the investigator's request and determine whether the request will be granted and for how long the dataset will remain restricted. Details on how data and information products will be made available to the public are provided in Chapter 10.

9.3.3. Access Restrictions on Sensitive Data

With regard to natural and cultural resources, sensitive data and information are those that could be used to harm, remove, or destroy sensitive resources protected by units of the National Park System. Network staff members are responsible for managing access to sensitive data handled by their programs. These responsibilities include:

- Identify and classify all potentially sensitive park natural resources and information.
- Provide to superintendents, a complete list of potentially sensitive park natural resources for which data may be collected as part of any project. The superintendent then determines what information should be protected.
- Ensure that all protected information, digital and hardcopy, is properly identified and marked.
- Ensure that all references to protected information are removed or obscured in any reports, publications, maps, data, or other form made available to the public.
- Inform investigators working on Network projects that:
  - All data and associated information must be made available for review by Network staff prior to release in any format.
  - Any information classified as protected should not be released in any format except as approved in advance by the National Park Service.

- The Network Coordinator, NPS project liaison, or Data Manager will identify all potentially sensitive park natural resources to the principal investigator for each project. Reciprocally, the principal investigators for each project must identify any known references to potentially sensitive park natural resources.

Agreements with partners will include a standard confidentiality agreement which states that, among other things, the researcher will not share protected data or information with any other party, public, private, or academic, without channeling requests through the NPS project lead. Example language is provided in DMP Appendix N. Researchers may fulfill such requests, but there will be a confidentiality agreement between NPS and the new holder of the data.

When sharing data and information on sensitive resources with other federal agencies, the other agency will be told of the need to channel any requests for the data or information through the NPS, as per NPS Director's Order #66 (National Park Service 2004a) and accompanying Reference Manuals 66A (National Park Service 2004b) and 66B (National Park Service 2004c).

9.3.4. Answering Requests under the Freedom of Information Act

Data stewards will forward records requested pursuant to the Freedom of Information Act (FOIA) to the requester via the Park FOIA Officer in a timely manner. Data stewards will maintain records subject to the FOIA in a manner so as to make them rapidly available and to leave no doubt that the most recent version of accurate, non-sensitive information is provided to requesters. Data stewards are responsible for reading, understanding, and following applicable laws, policy, and procedural guides.

If information requested under the FOIA has not already undergone sensitivity classification, it will be thoroughly but rapidly assessed for presence of sensitive information and, if such information is found, the data steward will work with the appropriate Park and regional FOIA Officers to formulate a response to the requester, which may include complete denial, complete fulfillment, or partial fulfillment once sensitive information have been cleared from the requested records.

9.4. References

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9.5. Credits

This chapter was taken largely from Cook and Lineback (2006) and from material developed by Stevens and Entsminger (2004) and Hart and Gafvert (2005).

Chapter 10. Data Dissemination

Under the terms of Freedom of Information Act (5 U.S.C. § 552), public agencies must make non-protected data (described in Chapter 9) and information available for inspection and copying in public reading rooms, the Internet, or via requests through a specified process. Providing well-documented data in a timely manner is one of the most important goals of the I&M Program, and critical to the success of the program. This chapter describes the methods by which quality natural resource data and information collected by the SFCN are made available to park managers, researchers, educators, and the general public.

10.1. Objectives

- Ensure non-sensitive data are easily discoverable and obtainable.
- Ensure data that have not yet been subjected to full quality control are not released to the public, unless necessary in response to a FOIA request.
- Distribute data with complete and accurate metadata that clearly identify who collected the data, what data were collected, and where, when and how the data were collected.
- Identify and protect sensitive data from unauthorized access.
- Maintain a complete record of data distribution/dissemination.

10.2. Laws and Policies

For specific laws and policies please see WASO DMP Chapter 10.

10.3. General Standards and Guidelines

The SFCN will employ a number of distribution methods that ensure information collected and developed as part of Network programs are made widely available to park employees and the public.

SFCN parks develop and implement a map center concept that focuses on delivering both electronic and hardcopy maps. Map delivery should be efficient and meet the primary and contemporary mapping needs of all park program staffs.

Data and information will be disseminated principally through the Internet and only after quality control procedures have been fully implemented, unless a request is made pursuant to the FOIA with consideration to sensitivity and ownership classification (Chapter 9).

SFCN staff will notify investigators prior to making datasets available to the public. This will allow each investigator the opportunity to request in writing to further restrict access to the dataset by the public. Network staff will review the Investigator's request and determine whether the request will be granted and for how long the dataset will remain restricted.

10.3.1. Data and Information Distribution Mechanisms

According to FOIA (specifically the 1996 amendments), all information routinely requested must be made available to the public via reading rooms and/or the Internet. The Network's principal means of distributing inventory and monitoring data will be the Internet (Table 10.1). A number of Internet-based databases and repositories have been developed as part of the NPS I&M Program to store and disseminate a variety of natural resource information. They include:

- The South Florida/Caribbean Network public website
- National public applications, NPSpecies and NatureBib
- IRMA
- The NPS Data Store
- The Biodiversity Data Store

Table 10.1 Repositories of SFCN public and sensitive data and information.

Item	**Repository**
Reports (public) - digital	SFCN LAN servers, SFCN public website, NPS Data Store, NPS Focus
- hard copy	SFCN I&M library, BICY, BISC, BUIS, EVER, VIIS Libraries, USGS Libraries
- bibliographic	NatureBib
Network-generated digital datasets and data products (public, non-sensitive) • Certified data and data products (including photographs) • Metadata	SFCN LAN servers, SFCN Park servers, NPS Data Store, Biodiversity Data Store, NPSpecies, EPA STORET,)
Network-generated digital datasets and data products (NPS staff, sensitive) • Raw, validated data • Analytical products • Metadata • Reports • Digital photos • Digital presentations, etc.	SFCN LAN servers, applicable park server
Project products • Specimen vouchers • Photographic film	EVER Museum or other curatorial facilities, according to project protocol

10.3.1.1. The SFCN Website

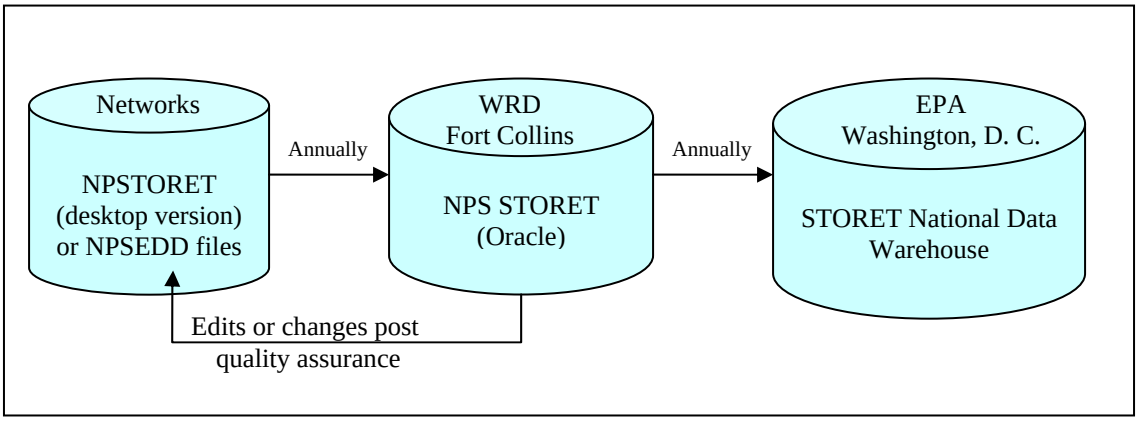
The Network will regularly provide updated information about inventories and monitoring projects, including annual reports and detailed project reports through its public web site (http://science.nature.nps.gov/im/units/SFCN/index.htm). Links, and a brief description, will be provided to each of the national databases and repositories described below.

10.3.1.2. National Databases

NPSpecies will be updated with observations and vouchers collected during the course of SFCN projects, if these data are deemed important to the further documentation of species already present on certified park species lists, or constitute additions to these lists. Data will either be manually entered into the online databases by I&M data management staff, or if present in sufficient quantity (e.g., more than 100 records), sent to the WASO office for upload after first ensuring proper formatting. NatureBib will be updated as new documents become available. Each of these databases are available via both a secure server and a public server. The public can only access records not flagged as 'sensitive.'

Water quality data collected to meet federal regulatory requirements are managed according to guidelines from the NPS Water Resources Division (WRD), which also oversees the integrated water quality monitoring portion of the I&M Program. NPS requires all water resource related I&M data to be uploaded to EPA's STORET National Data Warehouse. WRD developed NPSTORET – a desktop database application for I&M networks to help manage data entry, documentation, and transfer. Data from NPSTORET are transferred periodically to STORET (Figure 10.1). Individual networks are free to use NPSTORET for data entry and maintenance, or to develop a customized database compatible for data exchange and delivery.

Figure 10.1 Flow diagram for water quality data from I&M Networks to the National Data Warehouse.



Data from short-term studies (such as biological inventories) will be provided to the public through the NPS Data Store and/or IRMA within two years after data collection was completed, or following publication of the investigator's results (whichever comes first).

Data from long-term air quality monitoring conducted by Network parks or by cooperators working with the parks, including visibility, gaseous pollutants (mainly ozone), atmospheric deposition (wet and dry), and meteorology are available through the NPS Air Resources Division website at: http://www2.nature.nps.gov/air/monitoring.

Long-term monitoring data collected as part of the I&M Vital Signs Monitoring Program will be made available on the NPS Data Store at four or five year intervals, or when trend analyses have been completed and reported on by the Network. The NPS Data Store is available on a secure server and open to individuals approved for access. All data distributed to the Data Store and not defined as sensitive will be available to the public through the NPS GIS Clearinghouse. Before

data are posted, the investigator or project leader will be asked to verify the final dataset and metadata, and to identify any sensitive data or information. Sensitivity will be documented in the metadata which will accompany all datasets (Chapter 8).

The network will also be working with the Physical Resources Branch of Everglades National Park to ensure that water quality information stored within DataForEver is transferred to the Water Resource Division on an annual basis. SFCN will obtain a download of all relevant data for a specific water year and will transfer the file to the Water Resources Division for upload into STORET.

Non-sensitive digital imagery, including photos, drawings, maps, text, and GIS DOQ/DRG images will be made available to the public through the NPS Focus digital library.

Data from the Basic Natural Resources Inventories conducted through the NPS Natural Resource Program Center and the I&M Program are stored in a variety of locations.

10.3.2. Sensitive Data

Data released outside of the federal government without a confidentiality agreement is considered a release of information under the Freedom of Information Act and triggers the application of the "release to one, release to all" principle. There are many venues for release of sensitive data that constitute release to the public. Therefore, information should be reviewed for sensitivity by qualified NPS staff prior to inclusion in these media. They include:

- Internet posting
- Interpretive programs, media, and activities
- News releases
- Resource management storing and sharing activities
- NEPA compliance documents

Inadvertent access may be deemed a release depending on the circumstances. Network staff will institute quality control and quality assurance measures to ensure that any person uploading records to public databases is familiar with the procedures for identifying and entering protected sensitive information (DMP Appendix N).

10.3.4. Feedback Mechanisms

The SFCN website will provide an opportunity for NPS staff, cooperators and the public to provide feedback on data and information gathered as part of Network programs. A "comments and questions" link will be provided on the main page of the site for general questions and comments. A more specific "data error feedback" link will direct comments to SFCN staff pertaining to errors found in website-accessible data.

The following procedure describes the process that the SFCN will use to receive, verify, and correct data errors identified by public users.

- Users send a notification through the SFCN website.
- An acknowledgment of receipt is sent to the user.
- Information is input into an error log table incorporated either in the project database or a specific error tracking database developed for the Network.
- Network staff determine whether the data in question are correct or incorrect. If correct, the user is informed that no corrections are to be made and the information stands. If incorrect, Network staff make the appropriate corrections and notify the user and original data collectors.
- The Network website is refreshed with the corrected information.

10.4. References

Cook, R. R. and P. Lineback. 2006. Sierra Nevada Network data management plan. Natural Resource Report NPS/PWR/SFCN/NRR—2006/000. National Park Service, Three Rivers, CA.

Harmon, D. 1999. The new research mandate for America's National Park System: Where it came from and what it could mean. George Wright Forum **16**(1):8-23.

Mortenson, D. 2005. Data management plan for the Inventory and Monitoring Program, Southwest Alaska Network. U.S. Department of the Interior, National Park Service. Anchorage.

Office of Management and the Budget. 1999. Circular A-110. (http://www.whitehouse.gov/omb/circulars/a110/a110.html#1).

Stevens, S. M. and G. Entsminger. 2004. Information management plan for the Inventory and Monitoring Program, Northeast Coastal and Barrier Network. U.S. Department of the Interior, National Park Service. Kingston, RI.

10.6. Credits

This chapter was taken largely from Cook and Lineback (2006) and from information provided by Ginger Bradshaw and material developed Stevens and Entsminger (2004) and Mortenson (2005).

Chapter 11. Records Management and Object Curation

Documenting park natural resources and their management is an essential part of National Park Service administration. The potential for loss of data, documents, or objects can come from a variety of sources, including catastrophic events (e.g., fire, flood, and earthquake), user error, hardware failure, software failure or data corruption, theft, and intentional acts of vandalism. The responsibility for the preservation of park records begins with each employee and thorough implementation of effective best practices is crucial to ensuring long-term preservation and accessibility of park records.

The Federal Records Act (44 U.S.C. 3301) defines records as:

> *"… all books, papers, maps, photographs, machine readable materials, or other documentary materials, made or received by an agency of the United States Government under Federal law or in connection with the transaction of public business and preserved as evidence of the organization, functions, policies, decisions, procedures, operations, or other activities of the Government or because of the informational value of data in them".*

The law includes records created under contracts or other agreements with other agencies, organizations, or individuals.

Documents most necessary for fulfillment of the NPS mission are considered *mission critical* records. The Records Management Handbook (National Park Service 2005a) defines such records as resource management records – "*the permanently valuable, substantive program records documenting the actual work of the Park Service in managing critical cultural, natural, and informational resources.*" Records documenting natural and cultural resources and their management contain information that may affect the future management of these resources and are irreplaceable. They should receive the highest priority in records management activities and resources and should receive archival care as soon as practical after their creation.

Resource management records may include inventories, drawings, field notes, maps, photographic negatives, prints and slides, audio and video recordings, and electronic files and media. All are considered records and their management and preservation are addressed in this chapter.

This chapter also provides guidelines and standards for the curation of natural history specimens and other non-record objects. Such collections, and their associated records, are by definition museum objects, but have much in common with resource management records. Most significantly, both result from park studies as defined in Management Directive 4 of the Records Management Handbook:

> *"The term* studies *means short- or long-term scientific or scholarly investigations or educational activities that may involve natural resource surveys, inventories, monitoring, and research, including data and specimen collection. Studies include projects conducted by researchers and scholars in universities, foundations and other*

institutions; tribal colleges and organizations; other federal, tribal, and state agencies; and NPS staff. The data and information acquired through studies conducted in parks will be made publicly available."

Digital data pose particular challenges to long-term preservation. Technological obsolescence is a significant cause of information loss, and data can quickly become inaccessible to users if stored in out-of-date software programs or on outmoded media. Effective maintenance of digital files depends on proper management of a continuously changing infrastructure of hardware, software, file formats, and storage media. Major changes in hardware can be expected every 1-2 years, and in software every 1-5 years (Vogt-O'Connor 2000). As software and hardware evolve, datasets must be consistently migrated to new platforms, or they must be saved in formats that are independent of specific platforms or software (e.g., ASCII delimited files). This chapter describes procedures for both *short* and *long-term* preservation and management of electronic files storage.

An essential part of any archival holding (digital or non-digital) is it's accompanying explanatory materials (Olson and McCord 1998). Thus, effective long-term maintenance of these products depends on thoughtful and appropriate data documentation. Chapter 6 provides detailed policies, guidelines, and practices for documenting data. Chapter 12 provides detailed policies on project tracking and organization.

11.1. Objectives

- Adopt and implement robust standard file directory structure specifications.
- Where practical, maintain *mission critical* and *permanent* paper records in both hardcopy and electronic file format, and protect and preserve them indefinitely.
- Maintain datasets no more than two versions behind current software versions, or store in American Standard Code for Information Interchange (ASCII) format, complete with data and file documentation.
- Ensure information can be easily obtained, shared, and properly interpreted by a broad range of users.
- Ensure backup, storage, and recovery practices for electronic files equal or exceed the minimum standards established by the NPS Office of Chief Information Officer.
- Store all electronic files on servers in a networked environment using approved file-naming standards and file directory structures.
- Maintain all data, programmatic, and administrative electronic files indefinitely.
- Ensure all short and long term projects are well-documented, organized, and protected according to local and national standards and guidelines.
- Ensure all collected natural history specimens and objects are well-documented and preserved in perpetuity.

11.2. Laws and Policies

The most relevant guidance for managing NPS records and object curation are found in the following references:

- The NPS Records Management Handbook (National Park Service 2005a)
- Management Directive 4 of the NPS Records Management Handbook: Studies and Collections. Provides direction for approving and managing scientific research
- NPS Director's Order 19: Records Management (National Park Service 2001a). Provides direction for managing and preserving records
- NPS Director's Order 19, Appendix B: Records Disposition Schedule (National Park Service 2001b). Determines the long term disposition of specific NPS records
- NPS Director's Order 24: Museum Collections Management (National Park Service 2000). Provides direction for managing and preserving museum collections
- 36 CFR 2.5: Research Specimens (Code of Federal Regulations, 2001). Provides direction for managing natural history collections
- NPS Management Policies (National Park Service 2006). Describes requirements for the long term housing of records and objects
- NPS Museum Handbook (National Park Service 2005b). Provides the overarching guidance for archival procedures
- NPS Museum Handbook Part II Appendix H. Deals specifically with the handling and processing of natural history specimens

For additional laws and policies please see WASO DMP Chapter 11.

11.2.1. Records

NPS Records Disposition Schedule (National Park Service 2001b) defines the appropriate disposition of specific record categories. The term "disposition" applies to records no longer needed for active, on-going business; it can mean permanent archiving, transfer to a Federal Records Center, or destruction. Section N of this Appendix (Natural and Social Sciences) states that all natural resource records are considered *permanent* and need to be retained in an appropriate park museum facility or at the National Archives. It also states that even non-archival copies of natural resource-related materials are "potentially important for the ongoing management of NPS resources" and should not, in any instance, be destroyed.

Directors Orders 19, Section 6.2 provides specific guidelines and standards for electronic records. Under these guidelines, an electronic or digital recordkeeping system may be used as the primary recordkeeping system only under the following circumstances:

- When the records in the system are, or can be made, software- and hardware-independent, and meet current National Archives and Records Administration (NARA) format standards for electronic records.
- When the records to be stored are temporary, with a retention period of 5 years or less. This includes most records typically created during routine administrative functions in offices on electronic mail and word processing programs.

- Inherently electronic records where there is little practical choice (generally geo-spatial data and web pages).
- If the records to be stored are temporary, with a retention period of more than 5 years.

In all other circumstances, traditional media records of paper, photography, film, microfiche and magnetic recordings must be used for archival storage.

11.2.2. Collections

Regarding the collection of natural history specimens, NPS Management Policies states the following:

> *"Field data, objects, specimens, and features obtained for preservation during inventory, monitoring, research, and study projects, together with associated records and reports, will be managed over the long term within the museum collection. Specimens that are not authorized for consumptive analysis remain federal property and will be labeled and cataloged into the NPS cataloging system (ANCS+, or its successor) in accordance with applicable regulations."*

The overarching technical guidance for archival procedures is found in the NPS Museum Handbook. In particular, Part II, Appendix A – Mandates and Standards for NPS Museum Collections lists the cultural and natural history laws, regulations and conventions for NPS museum collections and should be reviewed prior to object collections.

11.2.3. Local Network Policies

These policies supplement or reinforce certain national policies deemed very important to the Network.

- To the extent practicable and consistent with the other goals and policies identified in this plan, backup and archival storage of electronic files will comply with relevant existing federal, department, and bureau policy, rules and regulations.
- Park IT staff are responsible and accountable for maintaining, backing-up, and restoring electronic files on all Network servers.
- Regular and complete backups of electronic files on personal computers are the responsibility of each staff member.
- The rotating configuration for media backups will be five years duration with at least quarterly offsite media backups supporting long-term storage.
- To the extent practicable, any electronic file that meets the definition of both *mission critical* or a *permanent* record will be printed out and managed as a hardcopy record.
- Local area network temporary, permanent, and disposition-suspended federal records and objects will meet the minimum physical and security conditions required by federal, department, and bureau laws, mandates, and policies.

11.3. General Standards and Guidelines

The following section discusses records management with regards to file naming conventions and directory structure.

11.3.1. Records Management

11.3.1.1. Electronic File Naming Guidelines and Standards

All electronic files will be named according to guidelines and standards outlined in DMP Appendix O – Electronic File Naming Guidelines and Standards. These will apply to all SFCN electronic files created or maintained by staff or cooperators. Network programs that are adopting them will be clearly identified in Part 2 of the appendix.

Highlights of SFCN file naming standards:

- File names should be as short as possible, but include all mandatory information.
- The electronic file name should be unique, such that the chances for another electronic file having the same name on a local area network are unlikely.
- Version numbers (e.g., version1, version2, final, etc.) are not to be used on documents. The date of file creation (yyyymmdd) will represent the version.
- Generally, use lower case characters. However, it is an acceptable practice to mix upper and lower case letters in a filename to separate a concatenation of words, such as words in a title.
- Do not use spaces in file names.
- Do not use special characters, other than the underscore (_), and periods.
- Use the underscore to separate categories in an electronic file name.
- Use generally recognizable abbreviations or spell words out.
- Avoid uncommon acronyms, abbreviations and codes. Generally, avoid codes that require users to refer to another source for the code description. NPS codes such as park code (e.g., BICY, SARI) are acceptable.
- Use leading zeroes for numbers 1 through 9.
- File extensions: Use the default extension recommended by the software application associated with the document. (Examples: doc, xls, mdb, rtf)

11.3.1.2. Directory Structure

Directory file structures already exist on Network servers but are generally inadequate. Electronic files will be managed within a hierarchical set of file directory structures. DMP Appendix P provides an example of a very detailed layout of the directory structure for the SFCN I&M program which includes folders for administrative files, data, publications, and reports. All Network programs will shift toward a file directory structure like this one. The SFCN South Florida local area network will be the primary repository for all Network I&M electronic files, but will provide access to Caribbean based I&M staff. Park based Local area network file servers will remain the repositories for individual park programs.

Key aspects of the SFCN file management strategy include the following:

- To the extent possible, all applications work (e.g., spreadsheets, GIS, documents, databases) will be conducted on a SFCN server.
- The local area network copy of all electronic files will be the primary version. Any local electronic file versions on personal computers should be considered backup files.
- Generally, only one copy of an electronic file will be maintained on a Network server. One exception to this situation would be a *master* database that is read-only, but may also have a working database copy that is being actively updated.
- Generally, all electronic files will be maintained in a networked environment that enables immediate retrieval. Although there are some exceptions, generally offline storage and retrieval of electronic files from media will be discouraged.
- Working files are kept separate from finished products.
- Finished products are typically read-only, except for "inbox" folders where users can drop things off to be cataloged and filed.
- Standards, such as naming conventions and hierarchical filing, are enforced within shared and archived sections (e.g., libraries, GIS, databases). Although less stringent in other sections, these conventions are encouraged as good practice.
- Version control is implemented in both active and archived directories. Generally, previous versions of databases will be saved in their native format and archived using the same best practices as used for current versions. Documentation of version updates and associated details will be part of the archive metadata document, and revision information and history will also be included in tables within the database files themselves.

A *Project Template Directory Structure* for short-term projects has been created (DMP Appendix P). The data manager or designated staff will create a working directory based on this template for each project, which project leaders can then modify as needed (e.g., deleting directories not being used). Upon completion, projects and products are certified by project leaders and moved if needed.

11.3.2. Archival, Backup, and Storage

11.3.2.1. Project Process and Workflow

Both electronic and hardcopy files should be consolidated and packaged for archival when a project is complete or when milestones are reached. Project leaders are responsible for packaging electronic files and data and for preparing materials for the curator. Project protocols should designate who will be responsible for product archiving, integration, backup, and distribution. The workflow diagram below illustrates the paths that product archival and storage follow (Figure 11.1). Museum staff will follow a much more detailed procedure for actual curation.

For **digital** data, the project leader should prepare files as follows:

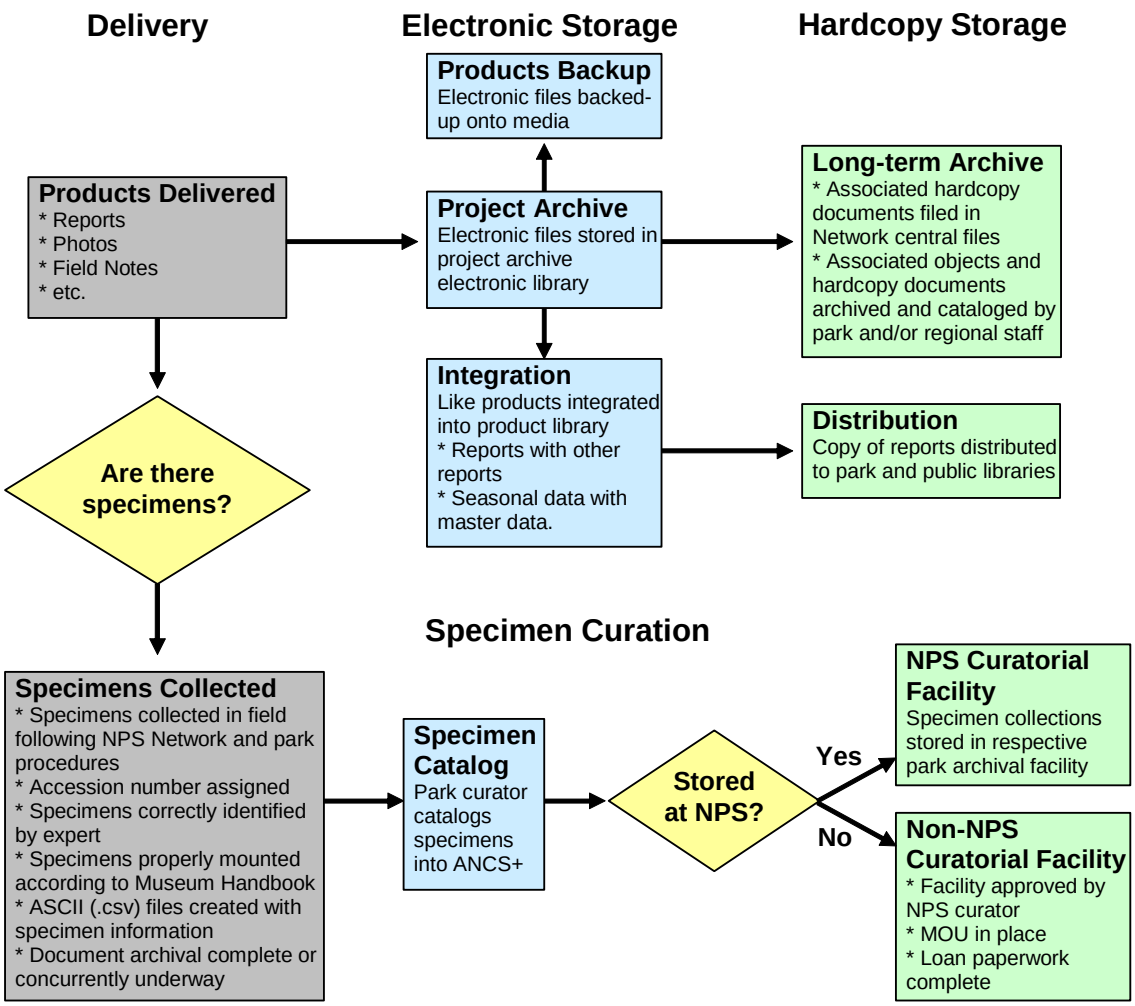
- Comply with SFCN electronic file naming standards

- Verify that all electronic files are organized on an NPS server according to SFCN file directory hierarchy standards.
- Comply with SFCN data documentation standards (Chapter 8).
- Include all related documents listed in the SFCN project deliverables guidance document (DMP Appendix G).
- Assure that hardcopy records are printed for all mission critical or permanent records.
- Make a clear distinction between public and sensitive information.
- For I&M Projects, ensure that the I&M Project Tracking Database (Chapter 12) has been updated and is complete.

For **digital** data, the data manager or other designated staff is responsible for the following:

- Archive project information on an SFCN server according to SFCN file directory hierarchy standards.
- Assure that proper securities are assigned to electronic files.
- Complete a project backup on CD or DVD that is placed in an approved location.
- Integrate deliverables, such as final reports, into appropriate catalogs, electronic libraries and NPS clearinghouses, as described in this plan or specific project protocols.

Figure 11.1. General workflow for storage and archival of electronic (in blue) and hardcopy (in green) scientific research products.



For **non-digital** records and objects, the project leader should package information as follows:

- Complete a coversheet listing contact information, project abstract and purpose, sensitivity, use of materials, and all materials included in the package (DMP Appendix Q).
- Clearly label materials with park acronym, date(s), accession number, project number.
- Comply with paper and folder type requirements (e.g., acid free paper).
- Print and document selected photos.
- Label voucher specimens according to the Museum Handbook and complete loan paperwork if necessary. Specimens not residing in NPS repositories should be stored in a selected facility that meets NPS museum collection standards.
- Address specimen curation in project protocols and specify name and address of facility, Memorandum of Agreement (if applicable), list of items to be curated or loaned.
- Create a CD or DVD of all related, electronic materials and label with park acronym, date created, date(s) of information, accession number, project number, list of contents.

For **non-digital** records and objects, museum staff are responsible for the following:

- Catalog information into ANCS+ and properly store materials according to the Museum Handbook.

11.3.2.2. Electronic Files

Performing regular backups of data and arranging for offsite storage of backup datasets are important safeguards against data loss. Recently, the NPS developed general standards and guidelines for backup, storage, and retrieval of electronic files (DMP Appendix R). This document describes high level procedures at the bureau level that provide *minimum* standards for data backup, storage, and recovery. It was produced by the NPS Office of the Chief Information Officer to provide high-level procedures for the NPS General Support System. These efforts center on providing the NPS with the ability to quickly reinstate information systems and the data required to run those systems.

A primary requirement of the NPS General Standards and Guidelines for Backup, Storage, and Retrieval of Electronic Files is that each NPS organizational unit creates a formal set of backup procedures for critical system-level and user-level information. The procedures should address documenting backups and enforcing backup policies. These requirements have been met through the development of Backup Plan for SFCN (DMP Appendix S). These plans outline specific and consistent backup routines for the Network, including: frequency and types of backups; media rotation schedules; hardware, software and media specifications; offsite storage locations; testing procedures; and staff responsibility.

11.3.2.2.1. Individual Employee Responsibility

Backups of electronic files on personal computers are the responsibility of each staff member. SFCN policy discourages electronic file storage on personal computers and, to the extent possible, electronic files should be managed on a Network server. The primary advantage for shifting from personal computer to local area network storage is that backup management and security are shifted to the data management staff who use well-defined protocols and optimize protection and backup of electronic files.

11.3.2.2.2. Data Management Staff Responsibility

Data management staff will adhere to Backup Plan (described above).

11.3.2.2.3. Short-term Projects

Short-term projects usually last from one to three years and include individual research projects, inventories, or pilot work done in preparation for long-term research or monitoring.

Upon project finalization, a set of ASCII comma-delimited text files will be created for each data table comprising the dataset. These files will be accompanied by a *readme.txt* file that explains the contents of each file, file relationships, and field definitions. The ASCII files are in addition to the native version of the dataset (typically in database format) and will help ensure the data are usable in a wide range of applications or platforms.

The SFCN will employ a utility created by the Gulf Coast Network called *Access_to_ ASCII.mdb,* which automates the creation of these ASCII files from Access databases. All ASCII files created from databases will undergo quality control to ensure the number of records and fields correspond to the source dataset and that conversion has not created errors or data loss. A second reviewer (preferably the project leader) will evaluate the ASCII files and documentation to verify that tables, fields, and relations are fully explained and presented in a way that is useful to secondary users. All finalized files will be stored in the archive section of the project directory folders.

In addition to creating ASCII files, SFCN will also update completed and archived datasets that may be in older versions of MS Access, with the goal of having no dataset more than two versions behind the current version used by the Network. Converted databases will require thorough quality control if they are actively being used for data entry or analysis and if no documentation of prior quality assurance/quality control measures is available. Forms, queries, reports, and data entry will be thoroughly tested, and corrected where any problems occur. All previous versions of the dataset will be saved.

11.3.2.2.4. Long-term Projects

Long-term projects include vital sign monitoring and other multi-year research and monitoring projects performed by the parks, other agencies and cooperators and for which data acquisition and entry will continue indefinitely.

Long-term monitoring databases will require occasional conversion to current database formats. All active or long-term databases will conform to the current NPS software version standards.

Long-term projects also will have variable long-term data archiving requirements. Raw data should always be stored in perpetuity. Processed datasets should be archived complete before any modifications are made to project protocols. Depending on the project, it might also be necessary to preserve interim datasets (data “milestones”) over the long term. Archived datasets or subsets destined for long-term archival will be saved, whenever possible, in their native formats in addition to ASCII text files. Specific data archiving requirements for ongoing projects should be spelled out in the Standard Operating Procedures for each project.

11.3.2.2.5. Spatial Data

Spatial datasets essential to the SFCN will be maintained in a format that remains fully-accessible by the current ArcGIS version. ArcGIS has maintained compatibility with previous data formats and, while shapefiles have retained functionality in ArcGIS, coverages may require conversion if they are no longer supported. At this time there is no practical way to save GIS data in a software or platform-independent format.

Both uncorrected and corrected GPS data (e.g., .ssf and .cor files) will be archived in their native format in addition to the corresponding GIS files that are created.

11.3.2.3. Physical Objects and Records

The guidelines in this section apply to physical objects and records (e.g., draft and final reports, field notes, data collection forms, maps, photographs, audio and video recordings, natural and cultural history specimens) collected or produced by staff and cooperators.

The long term management of physical objects and records will require the close cooperation of the individual collectors (whether NPS personnel, contractors, or permitted researchers) and local park museum personnel. Much of the responsibility will rest with the collector who remains the sole source for all curated documentation and the principal authority for essential collection information.

DMP Appendix T – South Florida/Caribbean Network Archive and Storage Locations identifies repositories for paper documents, and other archival objects. Each item will be stored in a suitable physical location appropriate to the object or document, which will depend on where it is in its lifecycle (Chapter 3). Each location cited in DMP Appendix T is classified according to whether it can house temporary, permanent, or disposition suspended records or objects. A temporary record has value only for a specified period of time. A permanent record or object has enduring value and must be preserved forever. A disposition-suspended object or record should not be destroyed or transferred to the NARA. Depending on the classification, locations must meet certain physical and security conditions as described by the Records Management Handbook and Museum Handbook.

11.3.2.3.1. Documents

NPS Directors Order 19, Section 4.1.1 states that anything classified as a federal record must be printed and managed in paper form. Such records include certain emails, reports, publications, maps, or other documentary materials. It is important for Network staff to understand that the NPS does not currently have an approved system for archiving electronic records. At a practical level, this means that with only few exceptions (see above), permanent records must be printed and organized in paper files.

A formal process is needed for ensuring that federal hardcopy records needing permanent preservation are handled properly. This is part of the disposition process. These records cannot simply stay in the office of creation or use for two reasons: 1) there are mandatory preservation requirements that should be handled by professionals; and 2) federal records of enduring value must, by law, be available to the public for research use. The majority of collections derived from SFCN projects can be managed by network parks.

The Technical Information Center (TIC) in Denver, Colorado, is the principal repository for planning documents for the NPS. The TIC provides temperature and humidity-controlled facilities, a professional archival staff, and meets all museum standards set by NPS. This repository may be used for technical reports for which off-site storage is considered worthwhile.

For additional long-term data storage the network relies upon the NARA facility based in Atlanta For further details see WASO DMP Chapter 11

11.3.2.3.2. Natural History Specimens

The most explicit direction for the management of natural history collections is found in NPS Management Policies, Directive 4.2. It reads: "*Specimens that are not authorized for consumptive analysis remain federal property and will be labeled and cataloged into the NPS cataloging system (ANCS+, or its successor) in accordance with applicable regulations (36 CFR 2.5)."*

The Code of Federal Regulations (CFR 2001) further states that collected specimens "*placed in displays or collections will bear official National Park Service museum labels and their catalog numbers will be registered in the National Park Service National Catalog"* and that the specimens and any derived data be made available to the public.

Natural history specimens collected under the auspices of the SFCN will be transferred to the Network park in which they were collected for either inclusion in the parks' museum collections or for transferal to a repository approved by the park. In this latter case, the park will enter into a formal, documented relationship with the repository and the specimens will be considered to be "on loan" with clearly stated terms and responsibilities. All loans are subject to the approval of the park superintendent.

Ideally, park curators will be involved at an early stage in the permitting or agreements process; early cooperation between curators and collectors will facilitate compliance with the current NPS Management Policies. Park curators can provide the collector with a pre-formatted Excel spreadsheet or Access database template, the use of which will greatly simplify eventual importation of catalog data into the Automated National Catalog System (ANCS+). At a minimum, parks will need such data in comma-delimited format (.cvs) for automated uploading into ANCS+.

11.3.2.3.3. Photographs

While the SFCN is prepared to accept both digital and analog photographs, the particular photographic methods to be used by any given project will be developed jointly by the project leader and Network staff or cooperators. Early involvement of curatorial staff will insure that the specific preservation considerations of particular photographic methods are understood and considered.

For projects using analog methods, SFCN strongly encourages the use of Kodakchrome 35mm slide film which has the longest dark storage dye stability of any color film (Wilhelm and Brower 1993).

Slides should be labeled using indelible pigment, pH-neutral ink (e.g., Pigma Micron), or using laser-printed archival-quality slide labels. Labels must include the following information:

- Title – who or what is in the image
- Location – where the image was taken
- Date – when the image was taken
- Park Code

- Access Constraints – who may view the image
- Copyright information – restrictions on using the image
- Contact Information – who to contact for further information

Optional, but important information includes the geographic location with UTM NAD83 coordinates (SFCN mapping standard) and datum. All slides should be placed in archival, polypropylene slide sleeves and stored in the dark, preferably in an archival box.

Additionally, slides may be scanned and saved digitally in Tagged Image File Format (TIFF). If scans are used as the primary means of distributing or reproducing the images, the lifespan of the original slides will be greatly extended. Further recommendations regarding management of digital imagery can be found in Chapter 6 and DMP Appendix J.

If photographic *prints* are desired, staff and cooperators are strongly encouraged to use true black-and-white films (e.g., Ilford Delta, Kodak T-Max or Tri-X). Prints and negatives will be stored in individual polypropylene sleeves and within archival boxes. Each print will be labeled on the back, using archival-quality labels that are either laser-printed or hand-labeled in pencil with the same information elements required for slides. If a contractor is submitting photographs, corresponding TIFF files may also be submitted.

Every image, regardless of format, will be entered into the SFCN photo database (guidance documents in development) where attributes such as electronic file name, keywords, project, photo description, photographer, date, and location are cataloged. All photo files and the associated photo database are housed on the archive portion of the SFCN server.

11.4. References

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11.5. Credits

This chapter was taken largely from Cook and Lineback (2006).

Chapter 12. Project Tracking and Documentation

12.1. Objectives

Develop and implement a comprehensive and cohesive procedure for tracking I&M projects, including project status, data, and the products of analysis to support program coordination and annual reporting, and to improve accountability for South Florida/Caribbean Network natural resource inventory and monitoring efforts and products.

12.2. General Standards and Guidelines

12.2.1. Project Organization

All projects' electronic files should be well organized in a project directory (DMP Appendix E). The SFCN digital directory structure is organized at the project level, such that most or all digital files associated with a project are filed under a common root directory. Project file names will adhere to the naming conventions established for the Network (Chapter 11). Physical objects acquired as part of a project will be stored according to specification in Chapter 11 and its appendices.

12.2.2. Project Tracking

The SFCN I&M Project Tracking Database will be developed and will serve as the primary organizational tool for cataloging and searching information on I&M projects. Specifically, the purpose of this database is to:

- Maintain a list of projects – project managers and other users will be able to locate rapidly most project-related information (e.g., objectives, contact information, status, funding sources, and more) and to easily summarize this information for administrative reports.
- Track project deliverables – a comprehensive list of project deliverables will be maintained with information on permitting, contracting, content and formatting specifications, delivery schedules, disposition schedules, expected due dates, and storage location. This information is generally specified at project initiation and updated throughout the course of a project.
- Manage project codes – These are intelligent alphanumeric codes used to tie together digital information in various, minimally connected NPS project tracking systems (e.g., RPRS, PMIS), along with analog materials that cannot otherwise be linked to an integrated information system. These codes are also used to link to databases and GIS themes, especially where information from multiple sources is stored together. See DMP Appendix U for a list of Service-wide Project Tracking Systems.

The project tracking database will be hosted on a SFCN data server. Although primarily maintained by the SFCN Data Manager, the database will be available to project leaders and the Network Coordinator who will be able to update information as needed. The Data Manager will create custom query views and reports to help administrators manage projects, and to facilitate reporting on project status, accomplishments and delivered products.

12.2.3. Project Documentation

Project-specific protocol narratives and SOPs are the principle means by which I&M projects will be documented. Standards for these documents have been developed by the national I&M Program and are discussed for the SFCN in Mutch *et al*. (2006). These documents must always accompany the distribution of monitoring data.

12.2.3.1. Protocol and SOP Version Changes

Over time there will be instances when protocol narratives and SOPs need to be updated, and these updates may occur independently of each other. That is, a change in one SOP will not necessarily invoke changes in other SOPs; a narrative update may not require SOP modifications. The SFCN Project Tracking Database will track the project narrative and SOPs by version number. This information will be updated whenever any narrative or SOP document is modified. The protocol narrative and SOPs will not be distributed without a log of changes from the Project Tracking Database.

12.2.3.2. Additional Project Metadata

Long-term monitoring projects may require documentation beyond the scope of established FGDC standards and the South Florida/Caribbean Network Database Documentation Template (DMP Appendix 5A). Documentation should be provided for algorithms, output files, and analytical products which may reside in different systems and formats, and could potentially be overlooked when distributing or applying project data. Data use and data request histories, and information on secondary research or publications resulting from long-term monitoring projects, should also be maintained. The Project Tracking database potentially could be used to organize this information as well. Specific methods for documenting this information will be tested for ease of use and are likely to evolve over time as needs become apparent and new solutions are developed.

12.3. References

Cook, R. R. and P. Lineback. 2006. Sierra Nevada Network data management plan. Natural Resource Report NPS/PWR/SFCN/NRR—2006/000. National Park Service, Three Rivers, CA.

Mortenson, D. 2005. Data management plan for the Inventory and Monitoring Program, Southwest Alaska Network. U.S. Department of the Interior, National Park Service. Anchorage.

Mutch, L., M. Rose, A. Heard, R. R. Cook, and G. Entsminger. 2006. South Florida/Caribbean Network vital signs monitoring plan, draft phase III report, U.S. Department of the Interior, National Park Service Inventory & Monitoring Program. Three Rivers, CA.

12.4. Appendices

E) SFCN Directory Structure
F) South Florida/Caribbean Network Database Documentation Template
U) NPS Service-wide Project Tracking Systems

12.5. Credits

This chapter was taken largely from Cook and Lineback (2006) and from information provided by Mortenson (2005).

Chapter 13. Implementation

The data management plans for each of the 32 I&M Networks are the first comprehensive documents of their kind in the NPS and contain practices that may be new to staff and cooperators. However, almost every requirement stems from federal law, Executive Orders, Director's Orders, or national I&M Program guidance. The DMP helps put these requirements into context, and provides operational guidance for achieving them.

13.1. Education and Training

Implementation will require education and training in order to familiarize park staff and cooperators with the tools, procedures, and guidelines outlined in the plan. Formal (training sessions) and informal (one on one communication and assistance) methods will be used. These efforts will begin in 2008 and be led, at least initially, by I&M data management staff, with participation by interested parties at all parks actively encouraged.

13.2. Milestone Goals

Goals for the first 3 years should include:

- Acceptance and understanding by all staff of targeted programs and their cooperators of the fundamentals of data and information management, including
  - File management
  - Documentation
  - Quality assurance and quality control
  - Electronic storage
  - Archive storage
- Improvement of data management practices by implementing
  - accepted database design standards
  - thorough testing of databases, data collection methods, and their integration prior to field work
  - quality assurance and control procedures at every stage of project development
- Common SOPs and guidance documents for multiple protocols
- Inclusion of detailed specifications for data management consistent with the DMP in all protocols developed for the Vital Signs Monitoring Program
- Development of procedures and outlets for communication within and among Network parks and with the public as described in this plan

Beyond the first three years, goals should include the development and assessment of

- Methods for improving file management (e.g., a content management system), database administration and security (e.g., migration to SQL-Server), integration into the network of off-site users, and other needs identified in the DMP
- Procedures to facilitate the summarization and reporting of monitoring data to staff, cooperators, and the public in formats appropriate to each audience
- Framework and gateway for integration of monitoring data with other initiatives both within the NPS and with outside agencies

- Methods for improving information management (e.g., basic content management services including library services, search tools, and decentralized web administration), database administration and security (e.g., migration to SQL-Server), integration into the network of off-site users, and other needs identified in the DMP

Full implementation of this plan by the SFCN I&M Program is expected to be achieved by 2010.

13.3. Revisions

The next plan revision should be completed within three years of plan approval, or by October 1, 2011, and then every five years afterward. Plan appendices, including SOPs, detailed guidelines, reference manuals, policy statements, etc., will likely require more frequent updates to account for changes in technology or availability of better information. These updates should be completed as needed.

13.4. Credits

This chapter was taken largely from Cook and Lineback (2006).

APPENDIX A: ACRONYM LIST

ANCS+	Automated National Catalog System
BICY	Big Cypress National Preserve
BISC	Biscayne National Park
BUIS	Buck Island Reef National Monument
CESU	Cooperative Ecosystems Studies Unit
CSDGM	Concept Standards for Digital Geospatial Metadata
DMP	Data Management Plan
DRTO	Dry Tortugas National Park
EPA	U.S. Environmental Protection Agency
EPMT	Exotic Plant Management Team
ERD	Entity Relationship Diagram (for databases)
ESRI	Environmental Systems Research institute
EVER	Everglades National Park
FGDC	Federal Geographic Data Committee
FOIA	Freedom of Information Act
FTP	File Transfer Protocol
GIS	Geographic Information System
GPS	Geographic Positioning System
HTML	Hypertext Markup Language
I&M	Inventory & Monitoring (Program)
IMS	Internet Mapping Server
IT	Information Technology
ITIS	Integrated Taxonomic Information System
JPEG	Joint Photographic Experts Group
LAN	Local Area Network
LDM	Logical Data Model
LiDAR	Light Detection and Ranging
MS	Microsoft – change in text to Microsoft
NARA	National Archives and Records Administration
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
NRDT	Natural Resource Database Template
OMB	Office of Management and Budget
PC	Personal Computer
PDA	Portable Digital Assistant
PDF	Adobe Portable Document Format
QA/QC	Quality Assurance/Quality Control
RDMS/RDBMS	Relational Database Management System
SARI	Salt River Bay National Historical Park and Ecological Preserve
SDE	Spatial Database Engine
SFCN	South Florida/Caribbean Network
SMMS	Spatial Metadata Management System

SOP	Standard Operating Procedure
SQL	Structured Query Language
TIFF	Tagged Image File Format
USGS	U.S. Geological Survey
VIIS	Virgin Islands National Park
WAN	Wide Area Network
WASO	Washington Support Office
XML	Extensible Markup Language

APPENDIX B: GLOSSARY

ArcIMS, ArcSDE, (Arc Internet Map Server and Arc Spatial Database Engine) are ESRI GIS software applications that provide tools for managing large, complex datasets within a relational database management system – ArcSDE, and serving the data over the Internet - ArcIMS.

Best practices refers to the technique, methodology, or standard operating procedure that, through experience and research, has been proven to reliably lead to a desired result.

Biodiversity Data Store is a digital online repository of documents, GIS and other datasets that contribute to the knowledge of biodiversity in National Park units, including presense/absence, distribution and abundance of animal and plant species. Along with NatureBib and NPSpecies, comprises the NPS Biodiversity Information System.

Certified data and metadata are completed data and documentation for short-term projects, or one season of completed data for long-term monitoring projects. Certification is a confirmation by the project leader that data have passed all quality assurance requirements and are complete and ready for distribution. Metadata records include the detailed information about project data needed for proper use and interpretation.

Conceptual data model is a detailed model that shows the overall structure of organizational data, independent of any particular database management system or other implementation considerations. Conceptual data models are typically produced as the first step in system design, often presented as entity relationship diagrams, and frequently a precursor to the logical data model.

Data refers to observational information gathered directly (in the field) from a natural resource via specific protocols and organized for analysis, summary or reporting. Data may be either in analog or digital form (generally stored either on paper or a variety of computer-compatible media), though the latter is encouraged where ever feasible. Data may exist in several states (conditions) including ‘raw’, ‘validated’ and ‘analyzed’. ‘Analyzed’ data includes ‘reported’ or ‘summarized’ data and may represent ‘information’ as a final form of the data from which decisions or conclusions may be made. Ultimately, data are intended to contribute to the knowledge and decisions regarding the conditions, processes, and changes within the ecosystem.

Dataset can best be considered a convenient grouping of data, or individual observations, such that the summary of the information will be meaningful to prospective users.

Edit log is a means of tracking changes to certified data.

Document – Recorded information regardless of physical form or characteristics. Often used interchangeably with record (From DO19 glossary).

Ecological indicators are a subset of the physical, chemical, and biological elements and processes of natural systems selected to represent the overall health or condition of the system.

Entity relationship diagrams (ERDs) are high-level data models that are useful in developing conceptual designs for databases. Creation of an ER diagram, which is one of the first steps in designing a database, helps the designer(s) to understand and to specify the desired components of the database and the relationships among those components. An ER model is a diagram containing entities or "items", relationships among them, and attributes of the entities and the relationships.

Goal - The general ends toward which this data management plan is directed.

Inventories are “an extensive point-in-time effort to determine location or condition of a resource, including the presence, class, distribution, and status of plants, animals, and abiotic components such as water, soils, landforms, and climate. Inventories contribute to a statement of park natural resources, which is best described in relation to a standard condition such as the natural or unimpaired state. Inventories may involve both the compilation of existing information and the acquisition of new information. They may be relative either to a particular point in space (synoptic) or time (temporal).” (Source: http://www .nature.nps.gov/im/monitor/index.htm)

Legacy data existing data that has been acquired by a park unit and still has importance, but which is at risk of becoming obsolete because of software limitations or available metadata.

Local archives and digital library – Local storage of copies of data, metadata and other products generated by projects. Archives are for hard-copy items and off-line storage media, whereas the digital library is maintained live on a server.

Logical data model (LDM) is an abstract representation of a set of data entities and their relationships, usually including their key attributes. It may omit non-key attributes or use abstractions of actual types, and may include physical tables that are represented by relationships or as aggregates within a larger entity, depending on the notation used and the level of abstraction. The logical data model is intended to facilitate analysis of the function of the data design, and is not intended to be a full representation of the physical database. It is typically produced early in system design, and it is frequently a precursor to the physical data model that documents the actual implementation of the database.

Master database is the central repository for project data, used for viewing, summarizing, and analysis. Contains only data that have passed all quality assurance/quality control.

Metadata is information about data. A metadata document contains specific and detailed information about a dataset, including who, what, where, when, why and how the data were collected, analyzed, or manipulated.

NatureBib is the National Park Service bibliographic database. NatureBib is designed to work with NPS Focus to help staff identify, locate, and obtain NPS natural resources documents.

National databases and repositories are applications and repositories maintained at the national level, primarily for the purpose of integration among NPS units and for sharing information with cooperators and the public.

Natural Resource Database Template (NRDT) is a core set of database tables that serves as a foundation for building relational databases for the NPS Inventory and Monitoring Program.

Nonspatial data are data that do not include reference to geographic location and shape of, and relationships among, geographic features.

NPS Data Store an online graphical search interface that links dataset metadata to a searchable data server on which datasets are organized by NPS units, offices and programs.

NPS Focus is the National Park Service online digital library designed to provide a venue for researching and downloading natural resources documents and other digital imagery.

NPS Data Clearinghouse is the central repository for NPS GIS data available to the public; implemented through the NPS Focus gateway.

NPS Focus (Digital Library and Research Station) – a decentralized digital imagery and data management system, implemented through a central Internet portal sponsored by the NPS Office of the Chief Information Officer. NPS Focus includes to the NPS Data Clearinghouse.

NPSpecies is the master species biodiversity database for the NPS. The database lists the species that occur in or near each park, and the physical or written evidence for the occurrence of the species (e.g., references, vouchers, and observations). NPSpecies is implemented online through secure and public servers.

NPSTORET is the NPS version of the U.S. EPA STORET database, used for transferring water quality data collected by NPS programs to STORET.

Object is a physical items such as natural history specimens, cultural artifacts, photographs, audio, and video tapes.

Objective - Specific statements describing the results to be achieved.

Ortho-rectification is the process of correcting an image for distortions due to camera lens, sensor non-verticality, and terrain, a process collectively included in photogrammetry.

Orthophoto is a digital image in which the pixels have been corrected to an orthogonal projection, produced by removing errors due to tilt and relief displacement.

Physical data model is a representation of a data design which takes into account the facilities and constraints of a given database management system. In the lifecycle of a project it is typically derived from a logical data model, though it may be reverse-engineered from a given database implementation.

Protocol (or Monitoring Protocol) refers to the formal documents and sampling processes that describe how a vital sign will be monitored; composed of a narrative section, standard operating procedures and supplementary information (databases, reports, tools, hardcopy materials).

Raw Data are environmental measurements that have been recorded but not subjected to any quality assurance or control beyond those applied during field work. Raw data are typically recorded on field sheets or in handheld computers, but may also include the products of remote sensing (aerial photographs and spectrophotometry).

Relational Database Management System (RDMS/RDBMS) is a type of database management system (DBMS) that stores data in the form of related tables.

Sensitive data is any information, which through loss, unauthorized access, or modification could adversely affect the national interest, the conduct of federal programs, or the privacy of individuals.

Spatial data is information about the location and shape of, and relationships among, geographic features, usually stored as coordinates and topology. Spatial data can be stored in tabular or GIS file format.

Standard Operating Procedures (SOPs) are detailed step-by-step instructions that outline a formal set of procedures for performing specific tasks.

STORET is a database application maintained by the U.S. Environmental Protection Agency that contains raw biological, chemical and physical data on surface and ground water quality collected by federal, state and local agencies, Indian Tribes, volunteer groups, academics, and others.

Structured Query Language (SQL) is a language used to interrogate and process data in a relational database. Originally developed for mainframes, all database systems designed for client/server environments support SQL. SQL commands can be used to interactively work with a database or can be embedded within a programming language to interface to a database. Programming extensions to SQL have turned it into a full-blown database programming language, and all major database management systems (RDBMS s) support the language. There is an ANSI standardized SQL, but most database management systems (RDBMS s) have some proprietary enhancement, which if used, makes SQL non-standard.

Tabular Data is data organized into logical tables. Refers to the format of datasets rather than content. Tables usually contain information arranged in rows and columns.

Validated data are data that have been verified according to the standard operating procedure under which the data were gathered (typically the protocol for a given project) and are deemed ready for reporting and/or analysis.

Vital Signs are ecological elements or processes chosen to represent the overall health or condition of park ecosystems, known or hypothesized effects of environmental stressors, or

elements of value to humans, and are the subject of long-term monitoring by the NPS I&M Program.

Working database is a project-specific database for entering and processing data for the current season (or other logical period of time). May also constitute the master database for very short-term projects