National Park Service
U.S. Department of the Interior

Natural Resource Program Center

South Florida / Caribbean Network Vital Signs Monitoring Plan

Natural Resource Report NPS/SFCN/NRR—2008/063

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

ON THE COVER
Snowy egrets and mangroves in Everglades National Park, Grunts at Biscayne National Park,
Montastraea cavernosa coral at Dry Tortugas National Park, Alligators at Anhinga Trail in Everglades National Park
NPS Photos

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South Florida / Caribbean Network
Plan for Vital Signs Monitoring

Includes: Biscayne National Park, Big Cypress National Preserve, Buck Island Reef National Monument, Dry Tortugas National Park, Everglades National Park, Salt River Bay National Historical Park and Ecological Preserve, and Virgin Islands National Park.

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9-25-08
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Executive Summary

Knowing the condition of natural resources in national parks is fundamental to the National Park Service's (NPS) mission to manage park resources "*unimpaired for the enjoyment of future generations.*" Park managers are confronted with increasingly complex and challenging issues that require a broad-based understanding of the status and trends of park resources as a basis for making decisions and working with other agencies and the public for the long-term protection of park ecosystems. The National Park Service has initiated a long-term ecological monitoring program, known as "Vital Signs Monitoring", to provide the minimum infrastructure needed to track the overall condition of natural resources in parks and to provide early warning of situations that require intervention (see Figure A). The scientifically sound information obtained through this systems-based monitoring program will have multiple applications for management decision-making, park planning, research, education, and promoting public understanding of park resources.

To facilitate collaboration, information sharing, and economies of scale in inventory and monitoring, the NPS organized the more than 270 parks with significant natural resources into 32 ecoregional networks. The South Florida/ Caribbean Inventory and Monitoring Network (SFCN) is composed of seven parks in South Florida and the U. S. Virgin Islands: 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 Site and Ecological Preserve (SARI), and Virgin Islands National Park (VIIS). The network monitoring program is designed to complement, not replace, existing park and other agency

Endangered wood stork at Anhinga Trail, EVER. (Photo by I. Atkinson)

monitoring programs. Funding for the SFCN supports a core, professional staff who conduct the day-to-day activities of the network and who collaborate with staff from the seven parks and other programs and agencies to implement an integrated long-term program to monitor the highest-priority vital signs.

This vital signs monitoring plan is the foundation for a long-term, ecological monitoring program that has been designed to build upon existing information and understanding of park ecosystems and to make maximum use of leveraging and partnerships with other programs, agencies, and academia. The plan is the result of a multi-year investment in planning and design to ensure that monitoring will meet the most critical information needs and produce ecologically relevant and scientifically credible data that are accessible to park managers, planners, and other key users of the monitoring results. The first planning steps involved compiling and organizing relevant science information, conducting detailed park scoping to identify the most important resources and issues for each park, and determining what was already being monitored by

Goals of Vital Signs Monitoring

- Determine the status and trends in selected indicators 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.

Figure A. Goals of Vital Signs Monitoring.

others. Chapter 1 and associated appendixes summarize the results of these scoping efforts, and provide an overview of the ecological and geographical settings of the network parks. The policy and management context for the monitoring program, including the goals and broad objectives for the SFCN monitoring effort, are also summarized in Chapter 1.

A second important planning step was to develop conceptual ecological models of the predominant ecosystems associated with SFCN parks (Chapter 2). The models of key ecosystem drivers, stressors, and responses were used to identify and prioritize vital signs and to design monitoring protocols. Using the results of the early planning and design work, more than 100 participants evaluated and ranked potential vital signs, resulting in a high-priority list of 44 vital signs (Chapter 3) of which 34 will be monitored long-term by the SFCN, park staff, or collaborating programs and agencies (see Table A).

Chapter 4 provides an overview of general sampling design issues and describes how sampling locations will be chosen for each vital sign and how the sampling effort will be rotated through time among locations. Since many of the SFCN's Vital Signs are already being monitored by other programs, the SFCN's role in the sampling design is limited. Where possible, sampling for vital signs will be co-located in space and time to improve efficiency and depth of ecological understanding. SFCN will use existing programs and data wherever available and take advantage of regional applications for many vital signs to help put the data into context and to leverage the core SFCN funding and staff.

Over the next several years, network staff and collaborators will develop 12 monitoring protocols (Chapter 5) to address those vital signs for which SFCN staff will play a lead role in field data collection as well as analysis and reporting of the monitoring results. Monitoring protocols 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 a long-term monitoring program.

Data and information management is central to the SFCN I&M program, and a key to the network's success. The SFCN will follow procedures outlined in the Data Management Plan (Appendix Q) and summarized in Chapter 6 to assure and maintain data integrity. Data management quality assurance procedures include the acquisition, verification, validation, analysis, and dissemination of monitoring data. In addition, we describe storage, maintenance, and security issues that apply to all stages of the data flow.

Data analysis and reporting are key components in the development and implementation of the SFCN monitoring program. Network staff will play an important role in compiling, analyzing, synthesizing, and reporting monitoring results, including analysis and reporting of data collected by others to make the data more available and useful to park mangers, planners, and other key audiences. The specific proposed strategies for reporting each vital sign are outlined in Appendix P and Chapter 7 provides an overview of the procedures that the SFCN will use to analyze and report monitoring results, and examples of various products of the monitoring effort. The SFCN internet and intranet websites will be used as a clearinghouse to disseminate technical reports, briefing statements, monitoring protocols, and links to additional sources of data and information.

The network relies on two groups to provide program oversight and guidance, the Board of Directors and the SFCN Science and Technical Committee (Chapter 8), and is also accountable to the NPS Associate Director through the regional and national I&M program manager. The Board of Directors includes the superintendents of the network parks, as well as the Regional I&M Coordinator for the Southeast Region and the network coordinator. The Board makes decisions regarding the development and implementation of the network's monitoring strategy, including approval of annual budgets, work plans, and network staffing plans, and promotes overall accountability for the network monitoring program. The SFCN Science and Technical Committee, which includes the network coordinator, resource management chiefs for the seven parks, and the CESU coordinator for South Florida and the Caribbean, helps the network to develop the annual work plan, ensures that network activities dovetail with park activities, and provides input for issues that require Board of Directors approval. The network charter outlines these various roles and responsibilities.

Red hind on boulder star coral at Newfound Bay, St. John, USVI.

Table A. Vital signs for the South Florida/Caribbean I&M Network. Vitals signs for which the network will develop protocols and implement monitoring using funding from the vital signs or water quality monitoring programs are indicated by [+ symbol]. The remaining vital signs will be monitored by a network park, another NPS program, or by another federal or state agency using other funding [◊]. The network will collaborate with these other monitoring efforts

Vital Signs Category	Vital Sign	Example Measures	Parks where Implemented						
			BICY	BISC	BUIS	DRTO	EVER	SARI	VIIS
Air & Climate	Air quality-Deposition	Wet/dry deposition of anions, cations					◊		◊
	Air quality-Mercury	Mercury deposition					◊		
Geology & Soils	**Coastal Geomorphology**	Soil elevation change	+	+	+		+	+	+
Water	**Surface Water Hydrology**	Water stage, flow, timing, and duration, freshwater discharge to estuaries, rainfall	◊	◊	+	◊	◊	+	◊
	Estuarine salinity patterns	Conductivity patterns in bays		◊			◊		
	Water Chemistry	DO, pH, temperature, conductivity, organic carbon	◊	◊	◊	◊	◊	◊	◊
	Nutrient Dynamics	Nitrogen, Phosphorous	◊	◊	◊	◊	◊	◊	◊
	Periphyton (Freshwater)	Community composition and structure	+				◊		
	Phytoplankton (Marine)	Location, size, duration, type of algal bloom events		◊			◊		
Biological Integrity	**Invasive/Exotic Plants**	Species detected at common invasion points	+	+	+	+	+	◊	◊
	Invasive/Exotic Animals	Invasive fish species in canals and invasion points	+	◊	◊	◊	+	◊	◊
	Marine Benthic Communities	Coral % live cover, seagrass density, species diversity, community structure, disease incidence		+	+	+	◊	+	+
	Mangrove-Marsh Ecotone	Community composition and structure	+	+		+	+	+	+
	Wetland Ecotones and Community Structure	Wet prairie-forest ecotones change	◊	◊			◊		
	Forest Ecotones and Community Structure	Community composition & structure	+	+	+	+	+	+	+
	Marine Exploited Invertebrates	Lobster spatial/temporal distribution, abundance/density, size structure		+	+	+	+	+	+
	Aquatic invertebrates in wet prairies & marshes	Community composition, abundance (density,relative abundance), MBI	+						
	Marine Fish Communities	Fish community composition, abundance, diversity		+	+	+	◊	+	+
	Focal Fish Species	Goliath Grouper, Sharks, Spotted Sea trout, Snook relative abundance, distribution, size structure		◊	◊	◊	◊	◊	◊
	Freshwater fish and large macro-invertebrates	Community composition, abundance (density and relative abundance), size structure	+				◊		
	American Alligator	Density, sex and age ratio	◊				◊		
	Amphibians	distribution, community composition	+				+		+
	Colonial Nesting Birds	Location, size of colonies by species, fledging success	◊	+	◊	◊	◊	◊	◊
	Marine Invertebrates-Rare Threatened, Endangered	Species dependent (*Acropora* sp., *Diadema*, *Antipathes* sp.)		+	+	+		+	+
	Sea Turtles	Nest counts and distribution, egg counts/nest, hatching success		◊	◊	◊	◊		◊
	American Crocodile	Abundance, nests/region, size		◊			◊		
	Protected Marine mammals	Distribution, abundance, size, condition (manatees, dolphins)	◊	◊			◊		
	Florida panther	Abundance, distribution, recruitment, mortality	◊				◊		
	Sawfish	Distribution, relative abundance, recruitment		◊			◊		
Human use	Visitor Use	Distribution and abundance of visitors	◊	◊	◊	◊	◊	◊	◊
Landscapes (Ecosystem Pattern and Processes)	Fire Return Interval	Fire location, size, time since last burn	◊				◊		
	Vegetation Communities Extent & Distribution	Extent, distribution, shape, orientation of vegetation community types using remote sensing	+	+	+	+	◊	+	+
	Benthic Communities Extent & Distribution	Extent and distribution of benthic community types using remote sensing.		+	+	+	+	+	+
	Land Use Change	Land use change, permitting/zoning changes	+	+			+	+	+

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Chapter 1: Introduction and Background

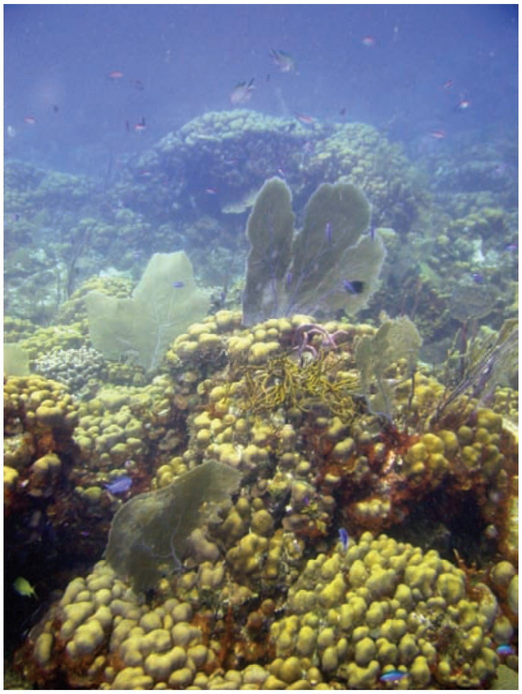
1.1 Purpose of a Monitoring Program

Knowing the condition and trends of natural resources in national parks is fundamental to the National Park Service's ability to manage park resources "*unimpaired for the enjoyment of future generations.*" National Park managers across the country are confronted with increasingly complex and challenging issues that require a broad-based understanding of the status and trends of park resources as a basis for making decisions, and for working with other agencies and the public for the benefit of park resources.

Monitoring is a central component of natural resource stewardship in the National Park Service (NPS). Natural resource monitoring offers park-specific information needed to understand and identify change in complex, variable, and imperfectly understood natural systems and to determine whether observed changes are within natural levels of variability or may be indicators of unwanted human influences. Thus, monitoring provides a basis for understanding and identifying meaningful change in natural systems (Roman and Barrett 1999).

The *South Florida/Caribbean Network Vital Signs Monitoring Plan* describes the process for selection of and the plan for monitoring "vital signs" of the natural resources in the following parks:

- 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)
- Virgin Islands National Park (VIIS)



Tektite reef at Virgin Islands National Park, St. John, U.S. Virgin Islands (2003).

"Vital signs," as defined by the NPS, are a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources or elements that have important human values. The elements and processes that are monitored are a subset 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 those resources. The broad based, scientifically sound information obtained through natural resource monitoring will have multiple applications for management decision-making, research, education, and promoting public understanding of park resources.

1.1.1 Service-wide Monitoring Goals

The overall goal of natural resource monitoring in parks is to develop

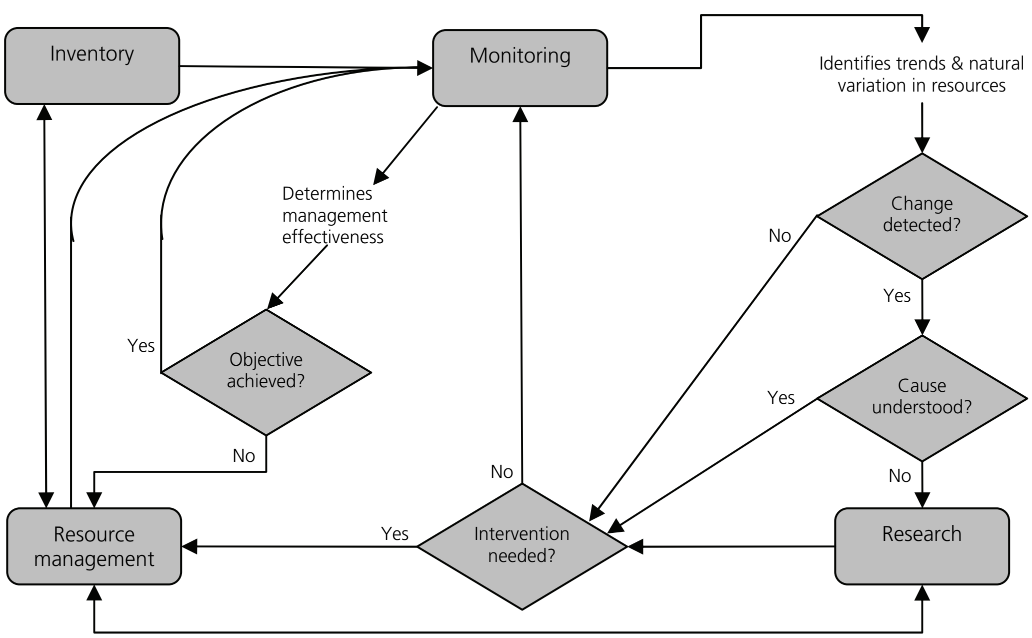
Table 1-A. Five NPS service-wide Vital Signs monitoring goals.

1) Determine the status and trends in selected indicators 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.
2) Provide early warning of abnormal conditions of selected resources to help develop effective mitigation measures and reduce costs of management.
3) Provide data to better understand the dynamic nature and condition of park ecosystems and to provide reference points for comparisons with other, altered environments.
4) Provide data to meet certain legal and congressional mandates related to natural resource protection and visitor enjoyment.
5) Provide a means of measuring progress towards performance goals.

scientifically sound information on the current status and long-term trends in the composition, structure, and function of park ecosystems, and to determine how well current management practices are sustaining those ecosystems. The five NPS service-wide Vital Signs monitoring goals are listed in Table 1-A.

Inventories, monitoring, and research all generate information for effective, science-based managerial decision-making, resource protection and for communicating park concerns to government officials, agencies, and the public (see Figure 1-A). Natural resource inventories are extensive point-in-time efforts to determine the 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. Such inventories typically provide important information for the development of monitoring programs. Monitoring differs from inventories by adding the dimension of time; the general purpose of monitoring is to detect changes or trends in a resource. Elzinga *et al.* (1998) defined monitoring as, "*the collection and analysis of repeated observations or measurements to evaluate changes in condition and progress toward meeting a management objective.*" Detection of a change or trend may trigger a management action, or it may generate a new line of inquiry. Research is generally defined as the systematic collection of data that produces new knowledge or relationships and usually involves an

Figure 1-A. Stewardship of natural resources in national parks involves the interconnected activities of inventories, monitoring, research, and resource management (modified from Jenkins *et al.* 2002).



experimental approach, in which a hypothesis concerning the probable cause of an observation is tested in situations with and without the specified cause. A research design is usually required to determine the cause of changes observed by monitoring. The development of monitoring protocols also involves a research component to determine the appropriate spatial and temporal scale for monitoring.

Better-informed management decisions require an effective monitoring program (White and Bratton 1980, Croze 1982, Jones 1986, Davis 1989, Quinn and van Riper 1990). By monitoring data over long periods, correlations between different attributes become apparent, and resource managers, park researchers and the public in general gain a better general understanding of the ecosystem. Additionally, monitoring information can be used to convince others to make decisions benefiting national parks (Johnson and Bratton 1978, Croze 1982). Monitoring sensitive species, invasive species, culturally significant species, or entire communities can provide park managers, stakeholders, and the public with an early warning of the effects of human activities before they are noticed elsewhere (Wiersma 1984, Davis 1989), and hopefully before the impacts have permanently damaged the resource.

1.1.2 Legislation, Policy, and Guidance for Natural Resource Monitoring

In establishing the first national park in 1872, Congress *"dedicated and set apart (nearly 1,000,000 acres of land) as a ... pleasuring ground for the benefit and enjoyment of the people"* (16 U.S.C. 1 § 21). By 1900, a total of five national parks had been established, along with additional historic sites, scenic rivers, recreation areas, monuments, and other designated units. Each unit was to be administered according to its individual enabling legislation, but had been created with a common purpose of preserving the "precious" resources for people's benefit. Sixteen years later, the passage of the National Park Service Organic Act of 1916 (16 U.S.C. 1 § 1) established and defined the mission of the National Park Service, and through it, Congress implied the need to monitor natural resources and guarantee unimpaired park services:

> *"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 purpose of the said parks, monuments, and reservations, which purpose is to conserve the scenery and the natural and historic objects and the wild life 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*."

Congress reaffirmed the declaration of the Organic Act vis-à-vis the General Authorities Act of 1970 (16 U.S.C. 1a-1a8) and effectively ensured that all park units be united into the 'National Park System' by a common purpose of preservation, regardless of title or designation. In 1978, the National Park Service's protective function was further strengthened when Congress again amended the Organic Act to state "*...the protection, management, and administration of these areas shall be conducted in light of the high public value and integrity of the National Park System and shall not be exercised in derogation of the values and purposes for which these various areas have been established...*" thus, further endorsing natural resource goals of each park. A decade later, park service management policy again reiterated the importance of this protective function of the NPS to *"understand, maintain, restore, and protect the inherent integrity of the natural resources,"* (NPS 2001).

More recent and specific requirements for a program of inventory and monitoring park resources are found in the National Parks Omnibus Management Act of 1998 (P.L. 105- 391). The intent of the Act is to create an inventory and monitoring program that may be used *"to establish baseline information and to provide information on the long-term trends in the condition of National Park System resources."* Subsequently, in 2001, NPS management updated previous policy and specifically directed the Service to inventory and monitor natural systems in efforts to inform park management decisions:

> *"Natural systems in the national park system, and the human influences upon them, will be monitored to detect change. The Service will use the results of monitoring and research to understand the detected change and to develop appropriate management actions"* (NPS 2001).

In addition to the legislation directing the formation and function of the National Park System, there are several other pieces of legislation intended to not only protect the natural resources within national parks and other federal lands, but to address concerns over the environmental quality of life in the United States generally. Many of these federal laws also require natural resource monitoring within national park units. As NPS units are among some of the most secure areas for numerous threatened, endangered or otherwise compromised natural resources in the country, the particular guidance offered by federal environmental legislation and policy is an important component to the development and administration of a natural resource inventory and monitoring system in the National Parks. Relevant federal legislation, executive orders, and NPS policies and guidance are summarized in Appendix C.

1.1.3 SFCN Monitoring Plan and Performance Management Goals

The Government Performance and Results Act (GPRA), passed by Congress in 1993, directs federal agencies to ensure that daily actions and expenditures of resources are guided by long- and short-term goal setting in pursuit of accomplishing an organization's primary mission, followed by performance measurement and evaluation. GPRA requires federal agencies to develop and use three primary documents in conducting business: a Strategic Plan, an Annual Performance Plan, and an Annual Performance Report.

The creation of the South Florida/Caribbean Network (SFCN) Inventory and Monitoring Program is a significant step towards fulfilling GPRA Goal Category I (Preserve Park Resources) for network parks. The service-wide goal pertaining to Natural Resource Inventories specifically identifies the strategic objective of inventorying the resources of the parks as an initial step in protecting and preserving park resources (GPRA Goal Ib1). The service-wide long-term goal is to *"acquire or develop 87% of the outstanding datasets identified in 1999 of basic natural resource inventories for all parks"* based on the I&M (Inventory & Monitoring) program's 12 basic datasets:

- Natural resource bibliography
- Base cartographic data
- Air quality data
- Air quality related values
- Climate inventory
- Geology resources inventory
- Soil resources inventory
- Water body location and classification
- Baseline water quality data
- Vegetation inventory
- Species lists
- Species occurrence and distribution

GPRA goal Ib1 tracks the basic natural resources information that is available to parks and performance is measured by what datasets are obtained. The SFCN Inventory Study Plan (Sasso and Patterson 2000) delineated what information exists for the network, its format and condition, and what information is missing.

The SFCN Vital Signs Monitoring Plan identifies the monitoring indicators or "vital signs" of the network and presents a strategy for long-term monitoring to detect trends in resource condition. The long-term monitoring results will help network parks report to the Department of the Interior's Land Health Goals for each park where data is available.

1.1.4 SFCN Park Unit Enabling Legislation

The SFCN includes four National Parks, one National Preserve, one National Monument, and one National Historical Park and Ecological Preserve. In 1970, Congress elaborated on the 1916 NPS Organic Act, clearly stating that all of these designations have equal legal standing in the National Park System. The enabling legislation of an individual park provides insight into the natural and cultural resources and resource values for which it was created to preserve. Along with national legislation, policy and guidance, a park's enabling legislation provides justification and, in some cases, specific guidance for the direction and emphasis of resource management programs, including inventory and monitoring. See Table 1-B for summaries of SFCN park enabling legislation.

Table 1-B. Enabling Legislation.

Park	Summary Content
Big Cypress National Preserve (Est. 1974; Expanded 1988)	*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 (Est. 1980)	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 (Est. 1961; Expanded 2001)	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- 4§3). Impressed by the caliber and scientific importance of the coral reefs of Buck Island, had urged their prompt protection to prevent further despoliation; 2001 Buck Island was expanded by Presidential Proclamation adding 18,035 acres of submerged lands.
Dry Tortugas National Park (Est. 1992)	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 (Est. 1947; Expanded 1989)	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 (Est. 1992)	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 (Est. 1956; Expanded 1962)	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''.

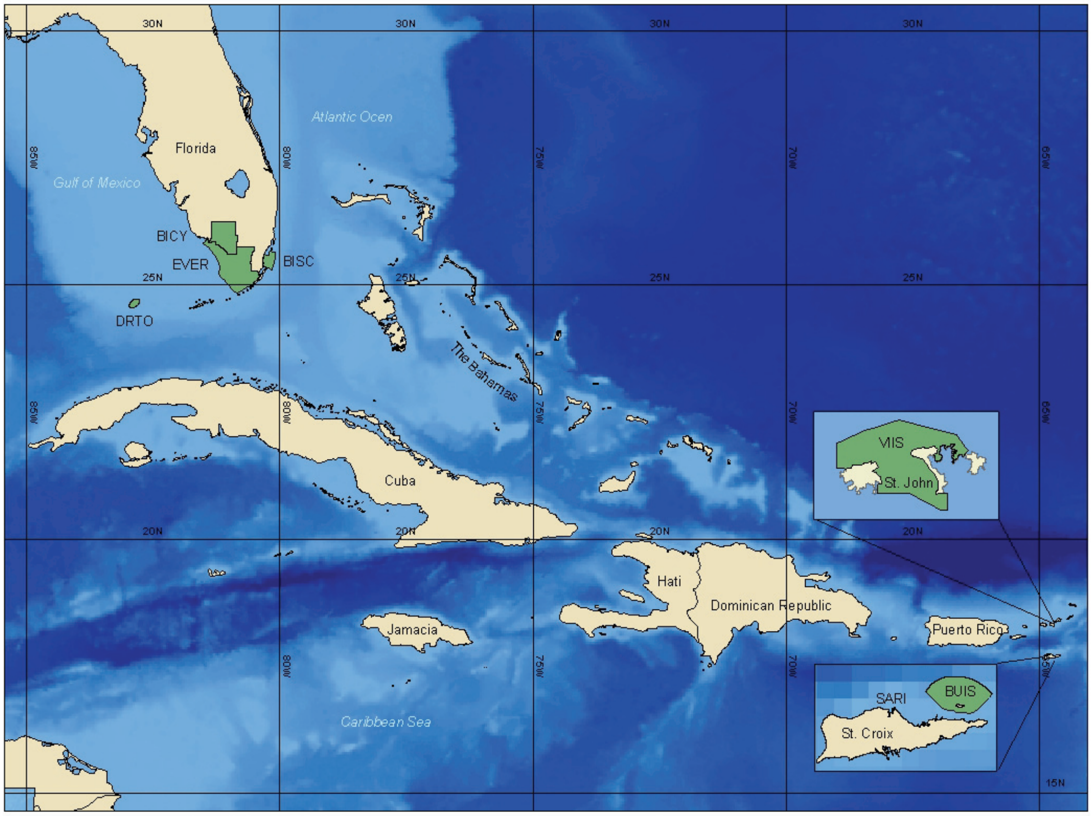


Figure 1-B. Map of South Florida/ Caribbean Network and associated NPS units.

1.2 Overview of the South Florida/ Caribbean Network (SFCN)

The following sections describe the range of environmental conditions and anthropogenic influences prevalent in the South Florida/Caribbean Network including regional climate, geology, and hydrology, as well as descriptions of the individual parks within the SFCN network. See Appendix D for regional maps highlighting park boundaries and partner conservation areas bordering or near our network of parks.

The South Florida/Caribbean Network is one of 32 networks in the National Park Service Inventory & Monitoring Program. It is comprised of four National Park Service units located in South Florida and three in the U.S. Virgin Islands (see Figure 1-B). SFCN parks vary in size from 978 acres to more than 1,508,500 acres and total over 2,500,600 acres across the network. More than 1,296,600 of these acres are designated as wilderness. The majority of the SFCN park units were designated to protect natural resources, although several were also designated to protect the associated cultural resources.

South Florida is characterized by flat marshlands and wet prairies interspersed with tree islands; cypress swamps; pinelands; hardwood hammocks; broad mangrove forests; and coastal prairies. Relatively slight differences in elevation and landform have important consequences for vegetation and the diversity of habitat types. Despite portions of this region being protected as parks, conservation areas and refuges, most of the region has undergone extensive hydrological and biological alteration.

The U.S. Virgin Islands parks are composed of tropical dry forest islands where vegetation is mostly drought deciduous. Cacti, thorny legumes, grasses, and short trees with flattened crowns are common.

Both South Florida and U.S. Virgin Islands are undergoing rapid urbanization. Coastal areas across the country are receiving new residents in large numbers. This may be best illustrated in South Florida, where Miami-Dade County has increased in population by 19% since 1990 (Beacon Council 2006) to nearly 2.3 million residents. Both South Florida and the U.S. Virgin Islands are under heavy developmental pressure as land is converted to urban and agricultural uses, resulting in increased demand placed on a limited water supply and increased stresses on the natural system. Additionally, the Virgin Islands are experiencing increased visitation pressure as they have become the primary tropical tourist destination for Americans and Europeans under current political world climate and travel restrictions. These pressures add to the already complicated task of managing these natural systems with growing anthropogenic pressures pushing from every direction.

1.2.1 Climate

Appendix I.2 provides a weather and climate inventory for the South Florida/Caribbean Network of Parks. Below is a brief synopsis for South Florida and the U.S. Virgin Islands climate.

1.2.1a South Florida

The climate of South Florida is tempered somewhat by its proximity to water. Most of the state has a humid subtropical climate with the extreme tip of Florida and the Florida Keys bordering on a true tropical climate. The seasons in Florida are determined by precipitation more than by temperature with warm, relatively dry autumns and winters (the dry season) and hot, wet springs and summers (the wet season). The Gulf Stream has a moderating effect on Florida climate, although it is common for much of Florida to experience high summer temperatures over 90° Fahrenheit. Mean high temperatures for late July are primarily in the low 90s. Mean low temperatures for late January range in the mid-50s in South Florida. South Florida averages about 58 inches of rainfall each year.

In the continental U.S., Florida has the highest average precipitation of any state, due in large part to afternoon thunderstorms which are common throughout most of the state from late spring until the early autumn. Hail is not an uncommon occurrence in some of the more severe thunderstorms. Snow is a rare occurrence in Florida. The most widespread snowfall in Florida history happened in January 1977 with snow flurries falling over much of the state extending as far south as Homestead. Snow flurries fell on Miami Beach for the only time in recorded history.

Hurricanes pose a threat during the summer and fall. In 2004, Florida was hit by a record four hurricanes. Hurricanes Charley (August 13), Frances (September 4-5), Ivan (September 16), and Jeanne (September 25-26) cumulatively cost forty-two billion dollars in damages to the state. The 2005 hurricane season included 28 named storms, 15 hurricanes, and 7 major hurricanes, of which 6 struck the United States. Hurricanes Dennis (July 10), Katrina (August 25), and Wilma (October 24) struck Florida (Rita on September 20 just missed).

Florida was also the site of the second most costly single weather disaster in U.S. history, Hurricane Andrew, which caused more than twenty-five billion dollars in damage when it struck on August 24, 1992 (Blake *et al.* 2005). Biscayne National Park was devastated during this storm and Everglades National Park was substantially impacted as well.

1.2.1b U.S. Virgin Islands

The islands are hot and humid throughout the year, with most rain falling between August and November. Daily temperatures range from lows around 73°F in the winter and 77°F in the summer, with daily highs ranging between 84 to 89°F. Annual precipitation averages 35-55 inches with a wet season from August to November and a secondary wet season during May. A dry season stretches from January to April.

Infrequent extreme events such as hurricanes occur mostly in late summer (August to October). St. John has two intermittent streams, and several guts have permanent pools, some of which contain small populations of shrimp and fish.

In St. Croix, a wet season occurs from August to November and a secondary wet season during May. In 1989, after a 30 year period of calm, the Virgin Islands were hit by Hurricane Hugo, one of the most devastating hurricanes of the century. It destroyed over 80 percent of the structures on the island of St. Croix. Since 1989 there have been major storms in 1995 (H. Humberto, H. Marilyn, T.S. Sebastien), 1998 (H. Georges, T.S. Bonnie), and 1999 (H. Irene, H. Jose, H. Lenny (www.nhc.noaa.gov). Elevated seawater temperatures in 1998 and 2005 stressed coral reef communities, initiating coral bleaching on many reefs. In 2005, over 90% of stony corals bleached at SFCN monitoring sites, and subsequent coral disease added additional impact creating a severe coral mortality event with some reefs experiencing over 60% of their live stony coral killed (Miller *et al.*, submitted manuscript).

1.2.2 Geologic Resources

The South Florida/Caribbean Network underwent Geologic Evaluations during 2004 and 2005 to identify geologic resource issues and mapping needs. For detailed information regarding the geology of SFCN parks, please reference Appendix E. Common geologic resource issues across the network include migrating shorelines, subsidence of coastal berms, groundwater movement into and around the South Florida parks, impacts from off-road vehicle use, and coral reef accretion, bioerosion, and sedimentation across the coral reef parks.

1.2.2a South Florida

South Florida lies at the lower end of the Floridian peninsula on a bedrock of limestone, which has high permeability, and is the cause for numerous small lakes and sinkholes which dot the state. South Florida is characterized by low elevation and topographic relief and has several physiographic units that lie within the SFCN parks including the Everglades province, the Atlantic Coastal Ridge, the Coastal Marshes and Mangrove Swamp province, and the Big Cypress Swamp. The Everglades province is 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 to the north"* (Thornberry-Ehrlich, 2005c). The Atlantic Coastal Ridge ranges in elevation from 5-20 feet, dips south into EVER where it contains the rare pine rocklands community, and historically was cut by transverse glades which dumped into Biscayne Bay but have since been replaced by canals. The Big Cypress Swamp is underlain by the Pliocene Tamiami Formation and is slightly higher in elevation than the Everglades basin.

The keys of BISC and DRTO are part of the Florida Keys. Keys in BISC consist of islands on coral rock and transitional islands that contain features of both hard rock coral keys and sand barrier islands (Thornberry-Ehrlich, 2005a). DRTO consists of sand islands that form an atoll-like rim (Thornberry-Ehrlich, 2005b).

1.2.2b U.S. Virgin Islands

St. John is volcanic in origin. Folding, faulting and uplifting have created the mountainous topography. Eighty percent of the slopes on the island are greater than 30% (CH2M HILL 1979) and there is little flat land. Coastal lowlands are occasionally large enough to form salt ponds that may be breached during storm events from the ocean, and catchment areas during heavy rain events. Major geologic resource issues for the island include sedimentation from the island along clear cut hillsides which smother the seagrass beds and coral reefs nearshore. Landslides and rockslides occur along road cuts and slope failures occur during heavy rain events as well.

The rocks of Buck Island Reef National Monument, St. Croix are sedimentary in origin and the island itself is very steep, with 90% of slopes steeper than 30% (CH2M HILL 1979). The majority of Buck Island is formed primarily from Caledonia formation during the Cretaceous period, mostly of mudstone. Buck Island is undeveloped, with only one trail traversing the island. The west end of the island is comprised of a 360m sandy beach, used heavily by visitors. Four species of sea turtle nest on the island primarily during June-Nov., but less than 30% of nesting occurs on the major recreational beach area. This coral sand beach area changes seasonally with winter storms and summer swells, as well as occasional tropical storms and hurricanes. Coral reefs – the barrier reef, patch and fringing reefs, and the unique haystack formations on the northeast corner of the barrier reef – are all geologic formations developed through biological processes with much of the reef still actively accreting.

The elkhorn coral barrier reef put the 'reef' in Buck Island Reef National Monument. The present day barrier reef formation has existed for over 8000 years (Hubbard 1991) and has survived hurricanes, massive die-off and bleaching events. Elkhorn coral, *Acropora palmata*, has been the primary architect of this formation. A branching coral, it is one of the fastest reef building corals in the Caribbean; it has been devastated throughout its range and was listed as a threatened species on May 2006 under the U. S. Endangered Species Act, 1973. Up until 2005 Buck Island Reef was one of the few places where *A. palmata* was experiencing a re-growth and re-colonization but as a result of the 2005 bleaching event 36-66% of *A. palmata* colonies at Buck Island were lost (Lundgren and Hillis-Starr, 2008).

1.2.3 Water Resources

1.2.3a South Florida

Water management is the critical issue for the Greater Everglades Ecosystem, whose

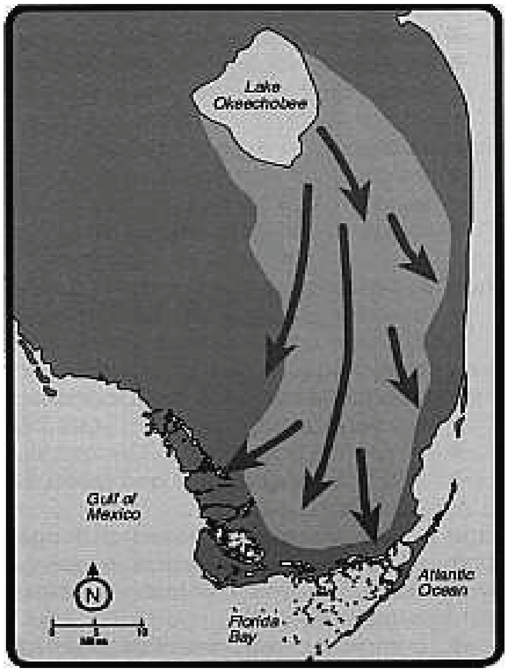


Figure 1-C. Historical pattern of water flow from Lake Okeechobee through Everglades to Florida Bay and Gulf of Mexico.

watershed begins in central Florida's Kissimmee River basin. Rainfall (which may total 40 to 65 inches (100 to 165 cm yr^{-1})) on the Kissimmee River basin and southward, is the source of South Florida's surface water. Evaporation, transpiration, and runoff consume four-fifths of the rainfall. Slow and rain-driven, the natural cycle of freshwater circulation historically built up in shallow Lake Okeechobee, one of the largest freshwater lakes wholly within the U.S. (average depth 12 ft (3.7 m) and area 730 mi^2 (1890 km^2)). From that build-up flowed the wide, shallow "River of Grass." Fifty miles (80 km) wide in places, one to three feet (0.3 to 0.9 m) deep in the slough's center but only 6 inches (15 cm) deep elsewhere, it flowed south 100 feet (30 meters) per day across Everglades sawgrass toward mangrove estuaries of Florida Bay and the Gulf of Mexico (Figure 1-C). This sheet-flow connected to the eastern coastal areas and bays via transverse glades, natural geologic depressions or cuts through the relict rock ridge along the eastern areas of southern Broward and Miami-Dade Counties.

During the dry season (December to April), water levels gradually drop. Fish migrate to deeper pools. Birds, alligators, and other predators concentrate around the pools to feed on a varied menu of fish, amphibians, and reptiles. This abundant food source is vital to many wading birds that are nesting during the dry season. In May, spring thunderstorms signal the beginning of the wet season. A winter landscape dotted with pools of water yields to a summer landscape almost completely covered with water. Wildlife disperses throughout the park. Insects, fish, and alligators repopulate the Everglades, thus replenishing the food chain. Marine parks are the recipients of this runoff, which supplies Florida and Biscayne Bays with freshwater during the rainy season and reverting to a more marine system during the winter and spring. Oceanic processes drive the marine system with currents and tides dominating, and winds affecting smaller water bodies. Elaborate water controls now disrupt the natural flow. Incorrect quality, quantity, distribution, and timing of freshwater to the Everglades and the bays have severely degraded the ecosystem.

Outstanding Florida Waters (OFWs)

Several areas in SFCN parks have been designated to receive special protection. Outstanding Florida Waters (OFW's) are waters that are found to have exceptional recreational or ecological significance (Chapter 62-302.700(1) Florida Administrative Code). OFW's include 41 of Florida's 1,700 rivers, plus several lakes and lake chains, several estuarine areas, and the Florida Keys. Outstanding Florida Waters are waters designated by the State Legislature and reviewed by the Environmental Regulation Commission as worthy of special protection because of their natural attributes. OFWs generally include surface waters in National Parks, Preserves, Wildlife Refuges, Seashores, Marine Sanctuaries, Estuarine Research Reserves, certain National Monuments, certain waters in National Forests, as well as waters in the State Park system, Wilderness Areas, waters in the Environmental Endangered Lands Bond Program (EEL), Conservation and Recreation Lands Program (CARL), Land Acquisition Trust Fund Program (LATF), Save Our Coast Program (SOC), Wild and Scenic Rivers, and State Aquatic Preserves.

Biscayne Bay viewed from BISC headquarters. Biscayne Bay has been designated as Outstanding Florida Waters.

In 1978 Biscayne Bay was designated as an Outstanding Florida Water (OFW). Existing anti-degradation standards associated with the OFW designation are principally narrative rather than numeric and are therefore generally not enforceable. In addition, the state of Florida water quality standards for Biscayne Bay as a Class III waterbody, have narrative standards for nutrients. The enforceability of both the OFW and Class III (F.A.C. 62-400) designation is extremely important to the preservation of BISC.

Everglades National Park has been listed as a Florida Outstanding Natural Resource Water (ONRW). The Florida Administrative Code (F.A.C.) describes the surface water quality standards for Outstanding Natural Resource Waters in Chapter 62-302.700. Special Protection, Outstanding Florida Waters, Outstanding National Resource Waters. This chapter lists the existing designated water-bodies and describes both of these designations (OFW and ONRW), rulemaking procedures, permitting exceptions and requirements. Both OFW and ONRW do not allow "permitted" degradation of water quality other than what is described in Rule 64-4.242(2) and (3), F.A.C. respectively, notwithstanding any other FDEP rules that allow water quality lowering. The standards for OFW is based on the year of designation- for EVER it is March 1, 1979 (62-302.700(8)) except Northeast Shark Slough which is August 8, 1994 (62-302.700(9)(a)3).

There is further description of Outstanding National Resource Waters in Florida State Statute 62-302.700(10). According to the rule, the Commission (Florida Environmental Regulation Commission) designated EVER as an Outstanding Natural Resource Water on June 15, 1989. However, park staff believe that the Florida legislature has never authorized it as an ONRW. (M. Zimmerman, personal communication)

Impaired Waters

Several areas in both South Florida and USVI parks have been designated as impaired. Section 303(d) of the Clean Water Act (CWA) requires states to submit lists of surface waters that do not meet applicable water quality standards (impaired waters) after implementation of technology-based effluent limitations, and establish Total Maximum Daily Loads (TMDLs) for these waters on a prioritized schedule. TMDLs establish the maximum amount of a pollutant that a water body can assimilate without exceeding water quality standards. As such, development of TMDLs is an important step toward restoring waters to their designated uses. In order to achieve the water quality benefits intended by the CWA, it is critical that TMDLs, once developed, be implemented as soon as possible.

Chapter 99-223, Laws of Florida, sets forth the process by which the 303(d) list is refined through more detailed water quality assessments. It also establishes the means for adopting TMDLs, allocating pollutant loadings among contributing sources, and implementing pollution reduction strategies. Implementation of TMDLs refers to any combination of regulatory, non-regulatory, or incentive-based actions that attain the necessary reduction in pollutant loading.

Low dissolved oxygen, mercury and nutrients were the most common impairments on the verified list of 303(d) water bodies within the South Florida parks (see Table 1-C).

1.2.3b U.S. Virgin Islands

The Virgin Islands Rules and Regulations (VIRR) Title 12, Chapter 7, Section 186 provides provisions for Water Quality Standards for Coastal Waters of the Virgin Islands and defines (among other things) numerical and narrative standards for water quality within differential classifications of waterbodies, e.g., Class A, B, & C. Of particular interest to SFCN, this section defines best usage of Class A waters as:

> *"Preservation of natural phenomena requiring special conditions, such as the Natural Barrier Reef at Buck Islands, St. Croix and the Under Water Trail at Trunk Bay, St. John."*

Title 12, Ch 7, § 186-11(a) 1 and 2 defines the legal limits of Class A waters to be:

> *"Within 0.5 miles of the boundaries of Buck Island's Natural Barrier Reef, St. Croix"* and *"Trunk Bay, St. John."*

The narrative water quality criteria standards within the Class A waters are defined:

> *"Existing natural conditions shall not be changed."*

These two areas defined by the VIRR are located within the Virgin Islands National Park, and Buck Island Reef National Monument, and are included within existing water quality monitoring programs (see below). Note: USVI Division of Environmental Protection (VIDPNR) Aaron Hutchins, Director,

Table 1-C. 303(d) List of impaired water resources within South Florida / Caribbean Network parks. The 303(d) lists are based primarily on the state and territories' 1996 305(b) Water Quality Assessment Report ("305(b) report"). Here is reported the 303(d) list 2002 update. This list was complied 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. 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), plus direct contact with appropriate state and territorial environmental departments.

Park	Water Body Name	Water Body type	Parameters	Priority
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
	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
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 is listed and moves water to the park via canals	Stream	Lead, Cadmium, Copper-- Heavy metals potentially from Homestead Air Force Base. Suggested by DEP-Tallahassee	Low
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

stated – "All Class A waters in the VI are now totally within Federal waters."

Title 12, Ch 7, § 186-3 defines the best use of Class B waters to be *"for propagation of desirable species of marine life and for primary contact recreation (swimming, water skiing, etc.)."* This section includes numeric and narrative water quality criteria as given in Appendix F.

Class C waters are defined to be best used *"…for the propagation of desirable species and marine life and secondary contact recreation (boating, fishing and wading, etc.)."* Class C waters are located [VIRR T12, Ch 7, § 186-11(c) (1) (A-C)] in St. Thomas industrial sections and [VIRR T12, Ch 7, § 186-11(c) (2) (A-D)] St. Croix industrial harbors. VIRR defines Class B waters as all those that are not Class A or Class C. Therefore, the majority of waters within the VIIS and BUIS are defined by the Territory to be Class B waters.

Low dissolved oxygen and turbidity were the most common impairments on the verified list of 303(d) water bodies within the Virgin Island parks (see Table 1-C).

1.2.4 Park Descriptions

1.2.4a Big Cypress National Preserve (BICY)

Big Cypress National Preserve, the first National Preserve in the National Park System, was established in 1974 with an additional 146,000 acres added in 1988. Currently the park has 720,567 acres and receives approximately 425,000 visitors annually, who come to hike, canoe, camp, bird-watch, hunt, fish, and use off road vehicle (ORV) trails (see Figure 1-D). Oil, gas, and mineral extraction occur. The Preserve also has a rich cultural history and remains home to the Miccosukee Tribe of Indians of Florida and the Seminole Tribe of Florida and sustains resources important to their culture.

The Preserve contains a large remnant of natural wetland mosaic including cypress strands and domes, pines, wet prairies,

Alligator in cypress forest in Big Cypress National Preserve during the dry season.

marshes, sloughs, mangrove forests, and hardwood hammocks. These habitats support a diverse array of flora and fauna unique to South Florida's climate, including 91 federal and state listed plant species and 31 listed animal species such as the Florida panther, black bear, and red-cockaded woodpecker. The preserve also contains the largest stands of dwarf cypress known, as well as rare orchids, bromeliads and unusual ferns. The name "Big Cypress" refers to the vast expanse of cypress rather than to the size of the trees. The larger "bald cypress" trees were logged during the past two centuries. The few remaining giants are extremely old; some hundreds of years old with trunks over 6 feet wide.

The primary management concerns today relate to restoration of the human altered regional hydrology to a more natural flow pattern, improving water quality entering the park, managing invasive species, balancing recreational and extractive uses with long-term sustainability of the system, managing impacts from urban development outside and in-holdings within the park, and protecting and preserving rare species.

1.2.4b Biscayne National Park (BISC)

Biscayne National Park was established first as a monument in 1968, and then as a National Park in 1980. Ninety-five percent of Biscayne National Park's 173,000 acres are submerged marine environments. Four major ecosystems are protected within the park. They are composed of a narrow fringe of mangrove forest along the mainland shoreline of Biscayne Bay; the clear shallow waters of Biscayne Bay itself; the northernmost islands of the Florida Keys; and the beginning of the world's third-longest coral reef tract (see Figure 1-E). The mangrove fringe along the western boundary helps reduce the runoff from

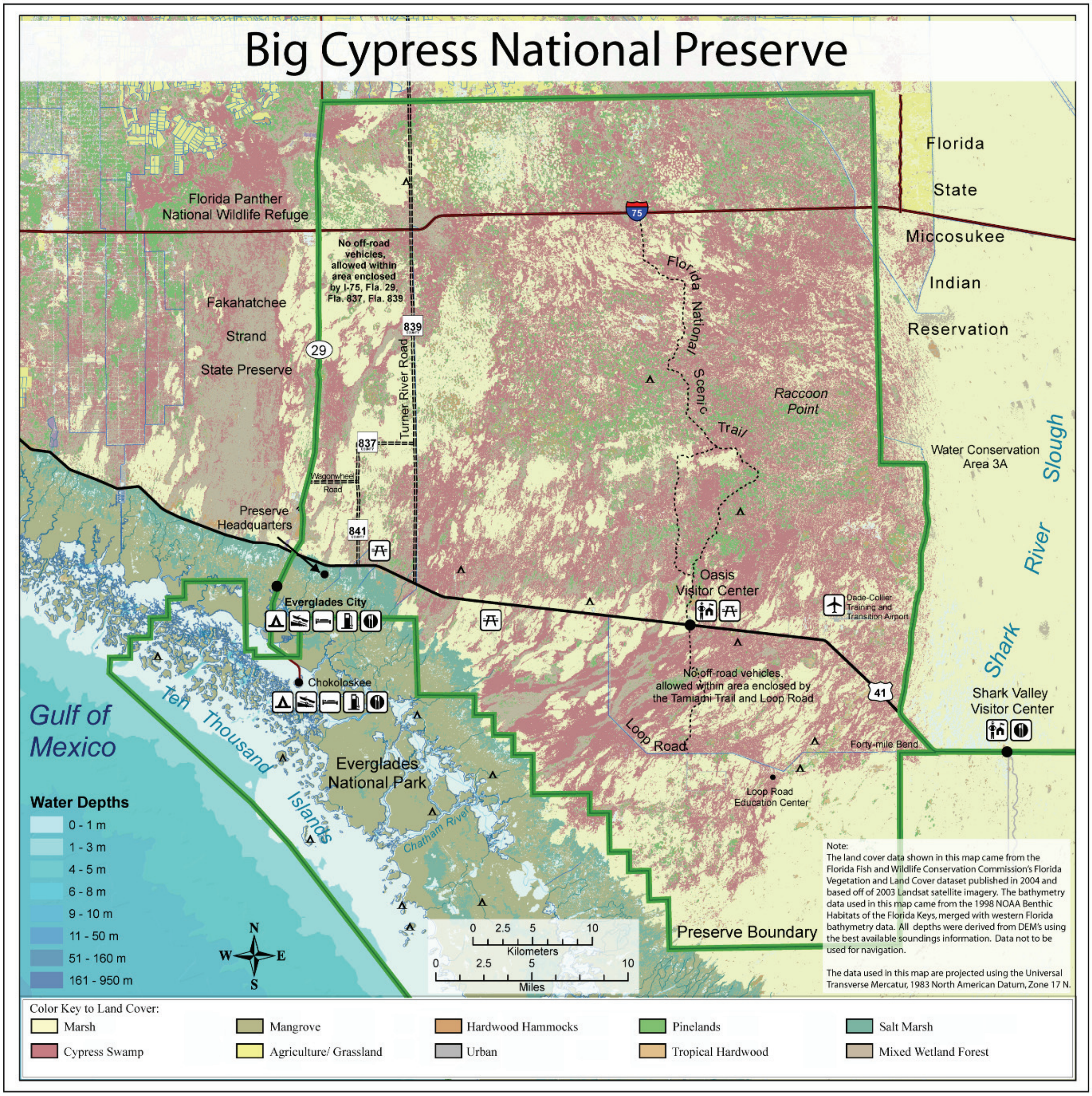


Figure 1-D. Big Cypress National Preserve.

the urban sprawl south of Miami into the bay. This area, once prime habitat for wading birds, juvenile fish, and crustaceans, has been modified from natural tidal creeks mixing freshwater with marine during the wet season to areas dominated by canal discharges, which pass freshwater into the bay year-round, by water management dictated pulses. Biscayne Bay supports lush seagrass meadows and hard-bottom communities (at a 2m average depth). There are 42 islands that make up the northernmost Florida Keys protected within the park boundary, most of which are in the same state as when the park was established decades earlier. Elliott Key is the largest island at roughly 7 miles long, and in places nearly a mile wide. Many of these keys are currently impacted by exotic invasive plant and animal species. Although treatment is ongoing, many

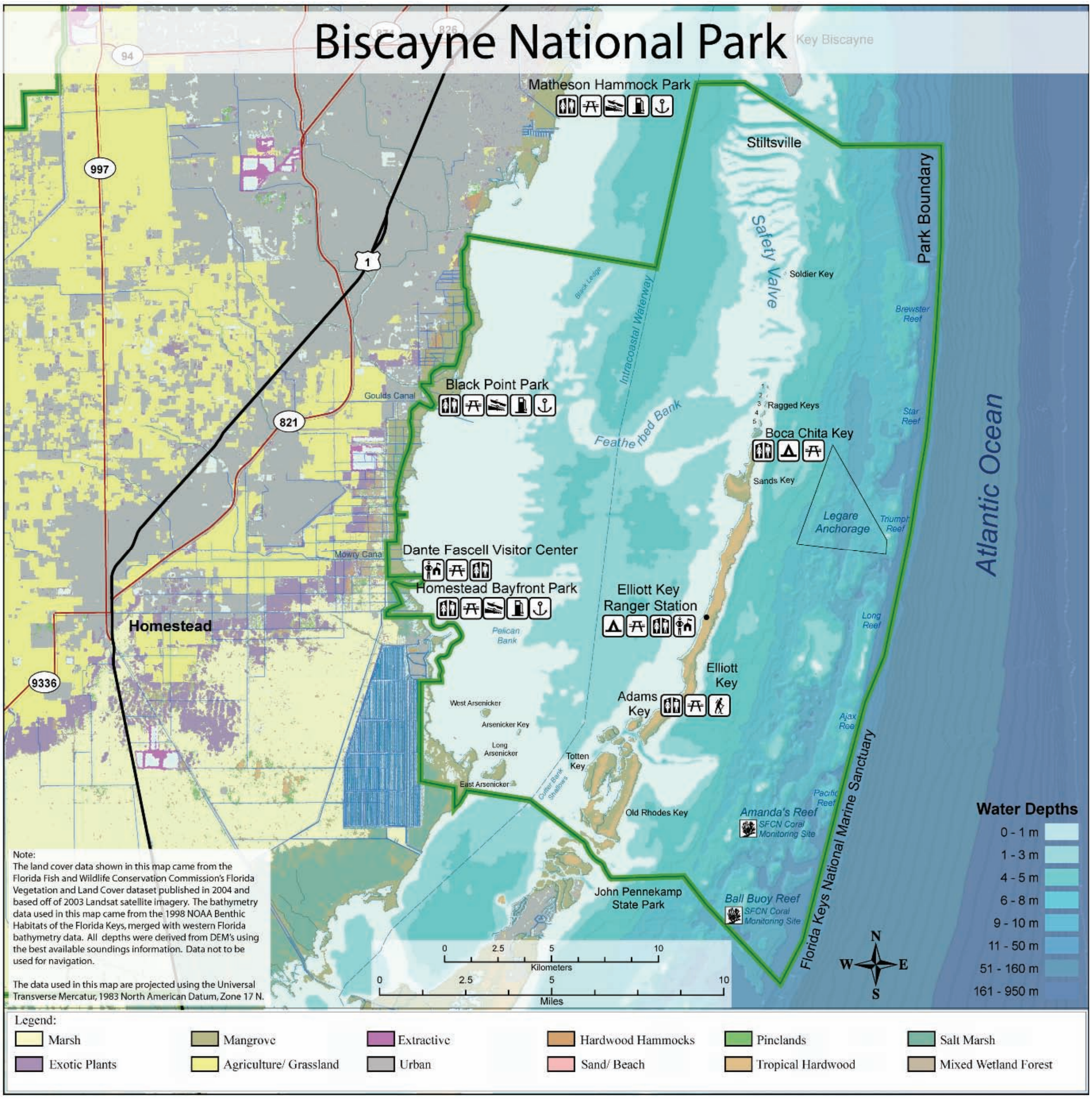


Figure 1-E. Biscayne National Park.

invasive plant species are reintroduced through birds, or drift in with the tides. The offshore marine environment of Biscayne National Park is approximately 5 miles wide and 21 miles long. It is an area densely populated with coral patch reefs, with some estimates indicating more than 3,000 of these patch reefs occur in this area. The eastern edge of the park is defined as the 60 ft contour line, east of which the shelf edge drops hundreds of feet deep. Biscayne National Park receives approximately a half million visitors each year, many of which come to boat, fish, snorkel and dive within the park.

1.2.4c Buck Island Reef National Monument (BUIS)

Buck Island Reef National Monument was established by Presidential proclamation in 1961. On January 17, 2001, under the U.S. Coral Reef Initiative, the monument was expanded by Presidential

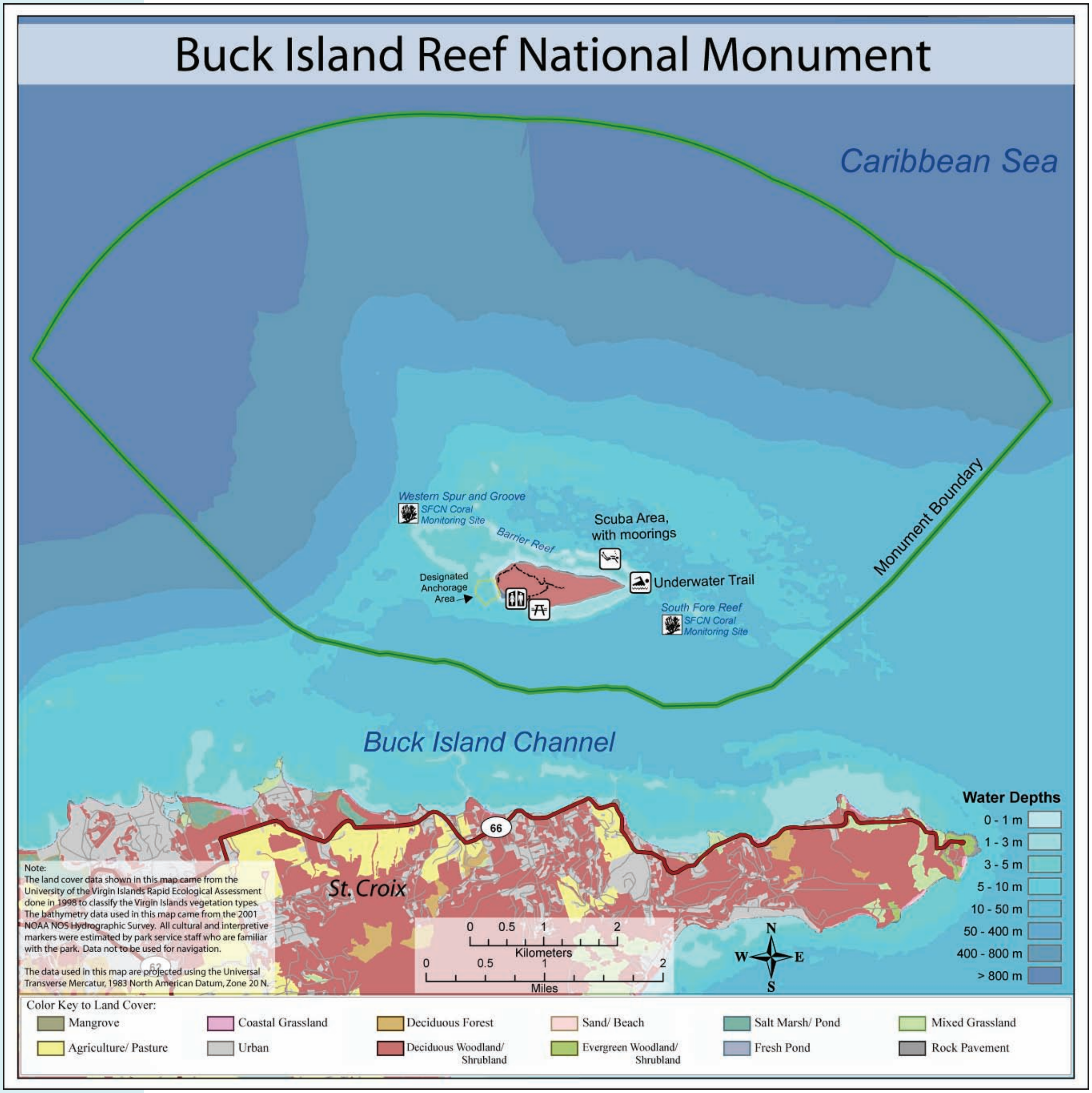
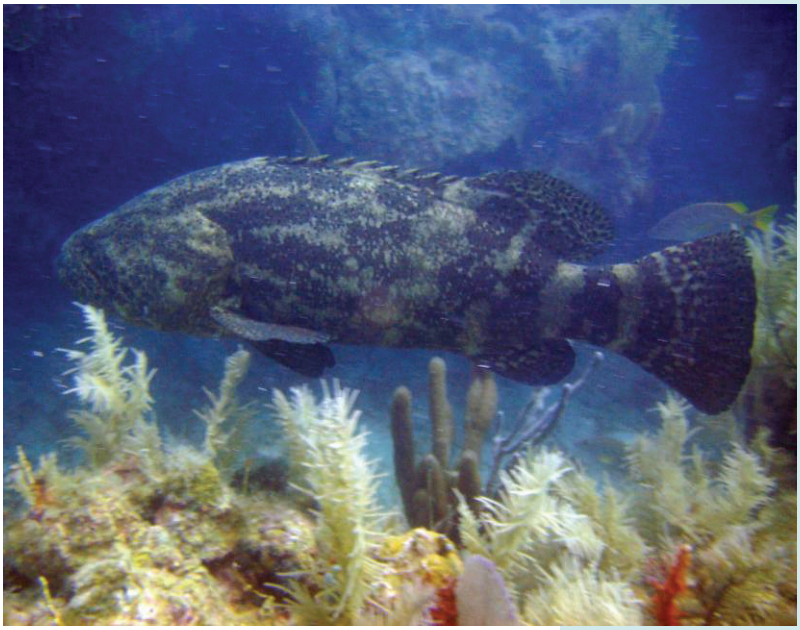


Figure 1-F. Buck Island Reef National Monument.

Proclamation from 880 to 19,015 acres, adding extensive marine resources to the monument. This addition also increased the protection of the resources by making the entire monument a "no take" marine reserve. The expanded monument may contain some of the deepest marine environments within the National Park Service (approximately 5000 ft) (see Figure 1-F).

The coral barrier surrounding two-thirds of the island is over 7000 years old and contains extraordinary coral formations, deep grottoes, abundant reef fishes, sea fans and gorgonians with the eastern most point of the reef containing the famous "Underwater Trail". The 176-acre island has an overland nature trail and white coral sand beaches. The monument supports a large variety of native flora and fauna, including several threatened and endangered species including leatherback, hawksbill, loggerhead, and green sea turtles, elkhorn and staghorn coral, brown pelicans, and endemic beetles. Buck Island Reef National Monument has been subjected to several major hurricanes (Hurricane Hugo in 1989, Marilyn/Luis in 1995, George in 1998, and Lenny in 1999) and constant pressure from exotic predators like the tree rat (*Rattus rattus*) and mongoose (*Herpestes javanicus*). Buck Island began exotic predator control in the 1980s removing all mongoose by 1986. In 1999 the park began an island-wide rat eradication program which successfully controlled the tree rat population. The only non-native predator that remains is the European house mouse, *Mus musculus* which is being monitored bi-annually. In 2003, in collaboration with the NPS Florida and Caribbean Exotic Plant Management Program, BUIS has undertaken an island-wide non-native plant control program targeting 10 invasive species. The control of these exotic species will affect the entire terrestrial ecosystem and is essential to preserve the island's present biodiversity.



Goliath grouper at Dry Tortugas National Park.

1.2.4d Dry Tortugas National Park (DRTO)

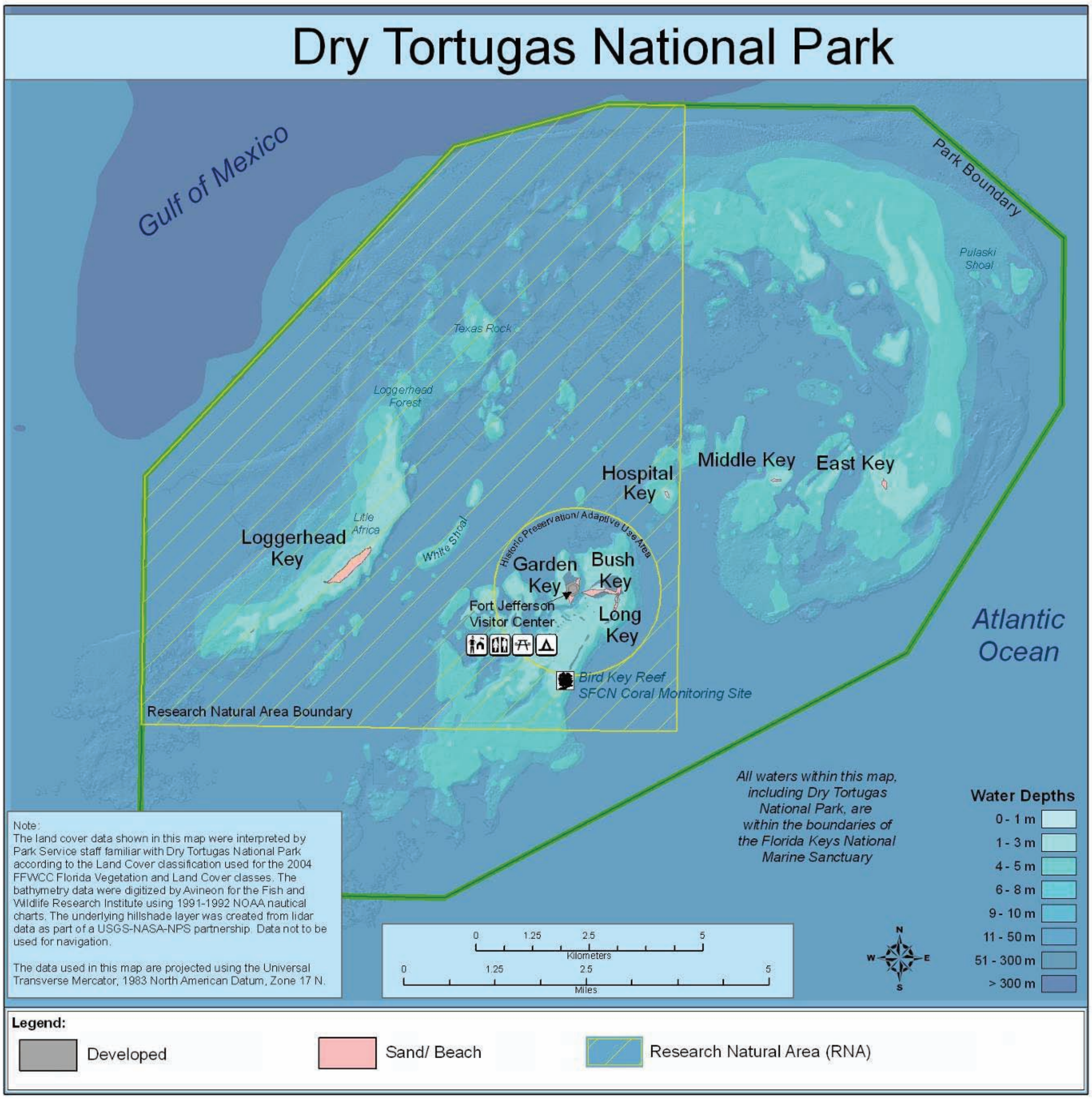
Dry Tortugas National Park, established in 1992, is one of the most unique areas of our National Park System. First visited by Ponce De Leon in 1513, the park comprises the westernmost part of the Florida Keys and is located 70 miles west of Key West, Florida, in the Straits of Florida.

The 64,657 acre park encompasses a cluster of seven coral reef and sand islands, surrounded by shoals and submerged resources such as coral reefs and seagrass beds. Totaling 104 acres, the islands in the park are situated on the edge of the main shipping channel between the Gulf of Mexico, the western Caribbean, and the Atlantic Ocean. The islands and reefs pose a serious navigation hazard to ships passing through the 75-mile wide straits and have been the site of hundreds of shipwrecks, which still occasionally occur in the area. The shipwrecks on the reefs comprise one of the nation's principal ship graveyards. The tropical coral reef of the Tortugas are among the best developed on the continent and possesses a full range of Caribbean coral species, some of which are listed endangered and/or threatened (see Figure 1-G).

Fort Jefferson, on Garden Key, is the park's central cultural feature and is the largest 19th century American coastal fort, as well as "the biggest brick building in the western hemisphere." Construction began on the structure in 1846, but the fort was never completed. Originally built to protect shipping access to the Gulf, the fort was used as a military prison during the Civil War, housing Union deserters and four Lincoln assassination conspirators. Today the fort is the primary destination for people visiting the park. Loggerhead Key is the largest key and contains a brick tower lighthouse built in 1857 that is still operated. Also on this key are the ruins of the first marine biological laboratory in the Western Hemisphere—the Carnegie Institution of Washington, D.C. Marine Biological Laboratory.

In 2007 a no-fishing Research Natural Area covering 46% of DRTO was established to protect the park's biodiversity and resource integrity.

Figure 1-G. Dry Tortugas National Park.



1.2.4e Everglades National Park (EVER)

When Everglades National Park was established in 1947, the park's original boundaries contained 460,000 acres. Subsequent additions have increased its size to 1,509,000 acres, and include most of Florida Bay and the most recent addition of the Northeast Shark River Slough (see Figure 1-H). The park is the second largest national park in the lower 48 states behind Yellowstone National Park in Wyoming. It holds the largest expanse of wilderness east of the Rocky Mountains. Congress designated 1,296,500 acres of this vast park as the Marjorie Stoneman Douglas Wilderness Area in 1978.

The park is located at the interface of temperate and subtropical environments and has a great diversity of resources. These include over 400 species of birds, 800 species of land and water vertebrates, 1600 species of vascular plants, 125

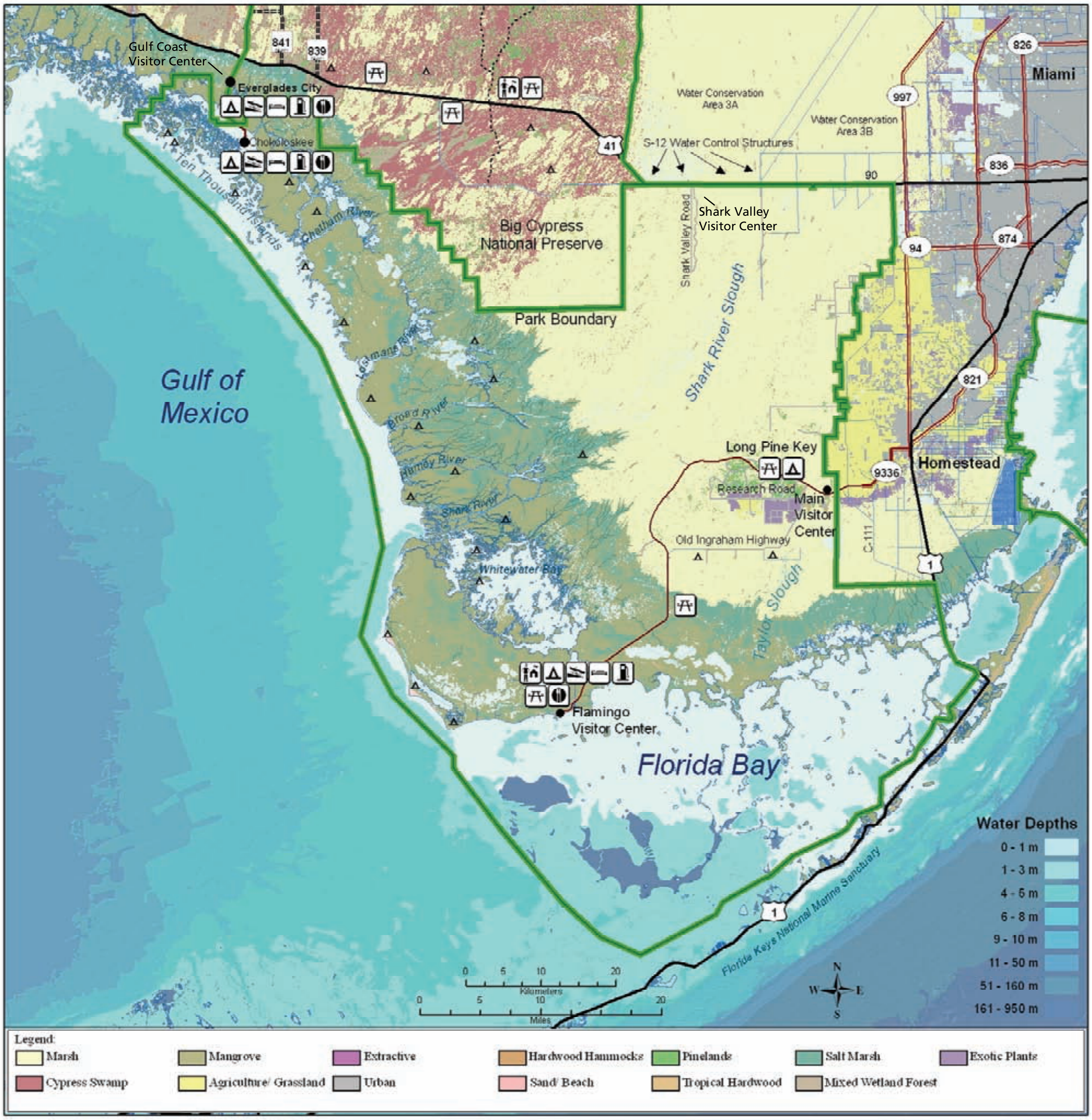
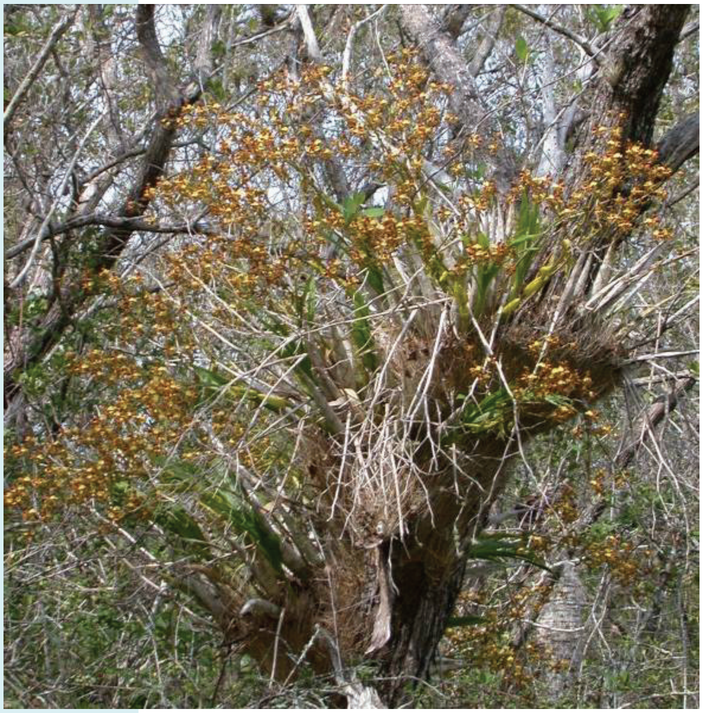


Figure 1-H. Everglades National Park.



Above: Five foot long clump of orchids in EVER.

species of fish and 24 varieties of orchids. The park is home to 202 federal or state listed species. Over 1 million visitors experience the park each year. Popular activities include canoeing, camping, boating, wildlife observation and fishing.

Everglades has been named an International Biosphere Reserve, World Heritage Site and a Wetland of International Importance. The international community has agreed the Everglades are unique and superlative. The existence of Everglades is threatened by several internal and external factors including altered hydrology and fire regimes, water quality, and development. Adaptive management strategies are needed to monitor, protect, preserve, and restore the Everglades to the bountiful ecosystem of the past.

The greater Everglades survival is linked to the Comprehensive Everglades Restoration Plan (CERP http://www.evergladesplan.org/) efforts to restore portions of the greater Everglades ecosystem as well as its original functions and to lay the basis for a sustainable future for the region.

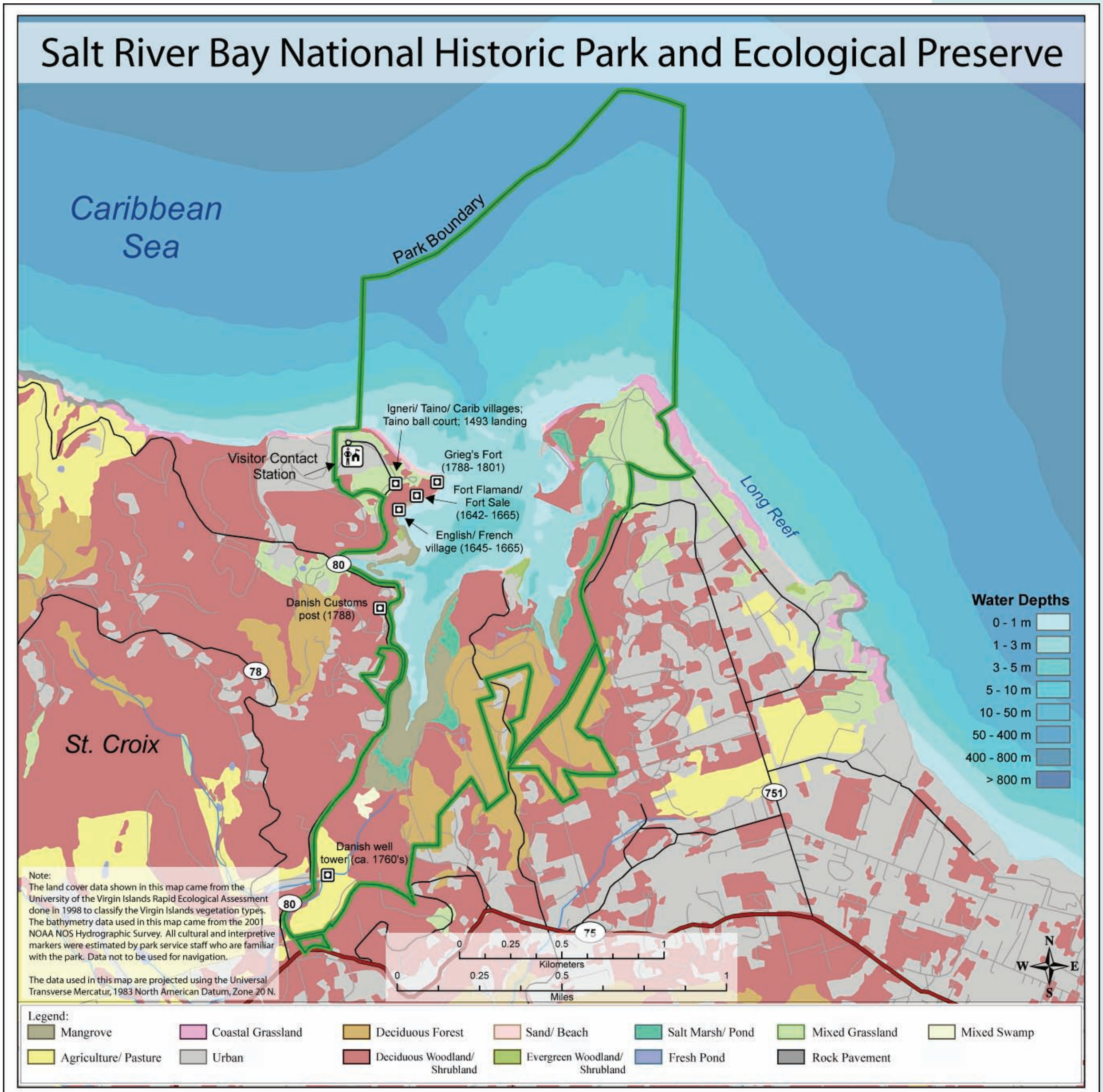
1.2.4f Salt River Bay National Historical Park and Ecological Preserve (SARI)

The 1,015-acre Salt River Bay National Historical Park and Ecological Preserve

Right: Rainstorm in SARI.

was created by Congress in 1992. The water acreage of the park was designated as a National Natural Landmark in 1980 and is home to 27 species that have been listed as rare, threatened, or endangered. Salt River Bay is located in the Salt River watershed on the north side of St. Croix is a large and diverse environment encompassing 4,164 acres (see Figure 1-I). The terrestrial communities surrounding and draining into Salt River Bay are dominated by 1,750 acres of shrubland or 42% of the total area. This shrubland can be classified as gallery shrubland of natural drainage guts, thicket scrub, mixed dry shrubland, sclerophyllous evergreen shrubland and coastal hedge found in a heterogeneous pattern as a result of natural effects and human influences. Developed areas of a residential or commercial nature comprise 847 acres (20 % of total area) and are scattered around Salt River Bay on the east, west and south boundaries.

Figure 1-I. Salt River Bay National Historical Park and Ecological Preserve.



Pasture and grassland habitat cover 644 acres or 15% of the area. Much of this is dominated by the exotic species, *Urochloa maximum*, or Guinea grass. The less common habitat types of significant ecological value are coastal woodlands, mangrove forests, and semi-deciduous dry forest, each occupying almost 10% of the area. Wetlands are particularly rare in this area and cover only 74 acres, a mere 1.8%. The diversity and complex pattern of the terrestrial and near shore marine habitats in this watershed, the geological history of the valley and the close linkage of these features make the Salt River watershed a valuable and critical natural resource. The Salt River estuary opens into the Caribbean Sea through a break in the fringing reef. Outside the reef the benthic community is dominated with rubble and small patch reefs. The Salt River Canyon starts not far from the break in the reef, and splits the shelf as it plunges into the abyss. The walls of the canyon provide large areas for stony corals to grow, and the canyon serves as

Figure 1-J. Virgin Islands National Park.

an aggregation area for many pelagic fish species.

1.2.4g Virgin Islands National Park (VIIS)

Virgin Islands National Park was established on St. John, U. S. Virgin Islands in 1956 (16 U.S.C. Sec. 398). After a number of additions the total park area is now 15,276 acres. 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. Virgin Islands National Park contains examples of most tropical Atlantic terrestrial, coastal and marine ecosystems (see Figure 1-J). These include various types of tropical dry to moist forest, salt ponds, beaches, mangroves, seagrass beds, coral reefs and algal plains. Large portions of St. John's original forests were cleared in the late 1700s and early 1800s, making most of the present forest late secondary growth. Dominant terrestrial vegetation types include moist forest (17%) and dry evergreen forest (63%) with the rest of the island split between mangroves, salt flats, pasture, dry thicket, thorn and cactus, disturbed vegetation, and coastal hedge.

VIIS contains some of the last remnants of intact Caribbean dry tropical forests and is significant wintering habitat for Neotropical migratory birds (Askins et. al. 1989). Interpretation of recent aerial photographs (1999) shows VIIS marine environment consisting of 34% coral reef and colonized hard-bottom, 20% submerged aquatic vegetation, 17% sand, and 28% unknown (areas deeper than 20 m) (NOAA 2001). Sixteen federally listed endangered and threatened species have been observed at VIIS, including six species of marine mammals, three birds, three reptiles (all sea turtles), two marine invertebrates and two plants. Other faunal species include bats (9), birds (170), reptiles (14), insects (1000s), fish (300+) and many marine invertebrates.

1.3 Park Natural Resources and Management Priorities

Park Natural Resources and Management priorities have been compiled from a number of sources including discussions with resource managers, scientists, and park superintendents; network surveys; network meetings; reviews of management plans; reviews of state and territorial conservation strategies; reviews of South Florida restoration efforts; discussions with stakeholders; and direct observation. The following section provides a summary of those methods which have helped the SFCN with Vital Signs planning and ecological model development.

1.3.1 Issues Identified in Network Scoping

Important management issues for SFCN parks were identified through a variety of methods, including an initial issue/stressor survey during the January 9, 2002 network meeting. The SFCN worked with Resource Management staff to develop a list of 27 management issues. During the next year, the network identified other issues and needs the parks were requesting and sent out a more robust survey including management issues, network staffing needs, office space availability, and various technical needs. Each of the parks was sent the survey for park level ranking. The parks returned the survey and the results were shared during the network meeting held in Homestead, Florida on November 4-6, 2003. The high priority management issues identified included the effects of "No-take" zones in the marine environment; recently expanded areas of network parks in which there was little knowledge of natural resources; impacts to fisheries and benthic resources including coral reefs and seagrass beds; declining coral reef resources and how to manage for these declines; exotic plant and animal impacts; impacts of the Comprehensive Everglades Restoration Program; managing recreational use; and regional development. Summary results are provided in Appendix G. Many of the network parks are met with continued questions regarding how these issues are being managed, and many times the questions are not well answered. This is primarily due to the inability to communicate large issues from many disparate data sets. An additional benefit of this exercise was to focus park staff on resource-management and monitoring issues, as well as discuss where network staffing could help parks, which parks had available office space, and determine what types of shared network equipment, training, and technical needs existed across the network. An expanded survey format was developed to help ensure all management issues were addressed, however, the results from the initial and the expanded surveys revealed the same overarching issues. These survey results helped the network define short term needs like better vegetation and habitat maps, as well as the need to identify space to grow the program.

1.3.2 General Management Plans

The South Florida/Caribbean Network parks are all going through the General Management Plan (GMP) process, with the exception of Dry Tortugas National Park, which finished its plan in 2001. This process takes 3-5 years if not longer to define how the park will be managed for the following 15-20 year timeframe. Each park describes its desired future conditions, and then looks towards proper zoning to balance visitor use with resource protection through a variety of alternatives. Public comment and scoping helps ensure the park's vision is consistent with the park user's vision, and through an iterative process, the general management plan is developed.

This planning process occurring during development of the Vital Signs monitoring plan helps the park managers look into the future at what might be occurring in their parks two decades away, and think long-term at how resources within the park may be affected over time. Such forward-thinking and planning should assist the Vital Signs planning process and better enable the resulting monitoring program to help park managers determine not only the ecosystem 'health' of their parks, but also track how the park is managing towards those desired future conditions stated within these GMPs.

1.3.3 State and Territorial Comprehensive Wildlife Conservation Strategy

As the number of species listed under the Endangered Species Act has steadily increased along with the costs involved with saving imperiled species, it has become clear that a more comprehensive approach needs to be taken for wildlife conservation. The U.S. Congress helped to address this need by creating the State Wildlife Grants Program in 2002. This is a national effort with all U.S. states and territories participating with each creating a long-range strategy for managing all fish and wildlife, to be submitted to the U.S. Fish and Wildlife Service by October 1, 2005. The objectives of the strategy are to identify species (and their habitats) of greatest conservation need and to develop and implement high-priority conservation actions to abate problems for those species and habitats. These prudent steps will save millions of tax dollars by preventing declines before species become imperiled. Through the matching requirement, the State Wildlife Grants Program encourages partnerships and cooperation.

The State of Florida and U.S. Virgin Islands territorial government are both participating in the program. The Florida Fish and Wildlife Conservation Commission (FWC) has created Florida's Wildlife Legacy Initiative in order to develop a strategic vision for conserving all of Florida's wildlife (see http://floridaconservation.org/wildlifelegacy). Within the U. S. Virgin Islands (USVI) the Government of the Virgin Islands' Department of Planning and Natural Resources, Division of Fish and Wildlife recently completed its conservation strategy in June 2005 (see http://www.vifishandwildlife.com/Wildlife/05F01WildlifePlan/Part%201%20Introduction/table%20of%20contents.htm).

The National Park Service and the South Florida/Caribbean Network participated in the development of these strategies and used materials from the strategy documents in developing SFCN's conceptual models. SFCN hopes to collaborate with these efforts in the future so that regional trends may be better evaluated in the future.

1.3.4 South Florida Restoration Efforts

The Comprehensive Everglades Restoration Plan and the Modified Water Delivery Plan are two very substantial projects which will have long lasting effects on how water passes through the South Florida Parks. The Modified Water Deliveries to Everglades National Park (aka Mod Waters) project is being conducted by the U.S. Army Corp of Engineers to help alleviate some of the hydrologic bottlenecks created by the Central and Southern Project by the Corp in the 1950s when many of the canals were dug throughout South Florida to assist with flood control and water supply. The project will hopefully increase the amount of freshwater capacity to the park by breaching the westernmost canal along the Southeast boundary of Everglades National Park; increase the amount of water from the Water Conservation Areas north of the park into the headwaters of Shark River Slough; and mitigate for flooding along the eastern boundary of the park, specifically around the 8.5 square mile area, where homes repeatedly are flooded during heavy rain events (see http://www.saj.usace.army.mil/dp/mwdenp-c111). The Comprehensive Everglades Restoration Plan follows Mod Waters as a major construction project with 68 components all hoping to get the quantity, quality, timing and distribution of freshwater more aligned to how the natural system operated 60 or more years ago (see http://www.evergladesplan.org). This project is a partnership between the U.S. Army Corp of Engineers and the South Florida Water Management District. This federal state partnership will directly affect how water will be released to Everglades National Park, Big Cypress National Preserve, and Biscayne National Park. Both projects have major impacts to the resources, and are working on how best to monitor those effects over time.

1.4 Designing an Integrated Monitoring Program for the SFCN

Should vital signs monitoring focus on the effects of known threats to park resources or on general properties of ecosystem status? Woodley *et al.* (1993), Woodward *et al.* (1999), Jenkins *et al.* (2002) and others have described some of the advantages and disadvantages of various monitoring approaches, including a strictly threats-based monitoring program, or alternate taxonomic, integrative, reductionist, or hypothesis-testing monitoring designs (Woodley *et al*., 1993, Woodward *et al*. 1999). The approach adopted by SFCN agrees with the assertion that the best way to meet the challenges of monitoring in national parks and other protected areas is to achieve a balance among different monitoring approaches (termed the "hybrid approach" by Noon 2003), while recognizing that the program will not succeed without also considering political issues. This system segregates indicators into one or more of four broad categories.

1) Physical system drivers that fundamentally affect park ecosystems
2) Anthropogenic stressors and their ecological effects
3) Focal resources of parks
4) Key properties and processes of ecosystem integrity

When a good understanding of relationships between potential threats and responses by park resources (known effects) exists, monitoring of system drivers, stressors, and affected park resources is conducted. A set of focal resources (including ecological processes) will be monitored to address both known and unknown effects of system drivers and stressors on park resources. Key properties and processes of ecosystem status and integrity will be monitored to improve long-term understanding and potential early warning of undesirable changes in park resources. Natural physical system drivers are major external driving forces such as climate, fire, and hydrology that have large-scale influences on natural systems. Trends in system drivers that will have corresponding effects on ecosystem components may provide early warning of presently unforeseen changes to ecosystems. Anthropogenic stressors are physical, chemical, or biological perturbations to a system that are foreign to that system. Stressors cause significant changes in the ecological components, patterns, and processes in natural systems. Examples include water withdrawal, nutrient enrichment, toxic contaminants, historic timber harvest, poor fishing methods, vessel groundings, off-road vehicle use, poaching, land-use change, and air pollution. It should be noted that anthropogenic stressors may have negative impacts on some species while having positive impacts on others. And even natural system drivers can sometimes push a system out of its equilibrium given the large reductions in natural areas that would otherwise buffer against extremes. Monitoring of stressors and their effects, where known, will ensure short-term relevance of the monitoring program and provide information useful to management of current issues. Focal resources, 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 communities such as coral reefs or hardwood hammocks, or they may be a species that is harvested, endemic, alien, or has protected status. Some examples of key properties and processes of ecosystem integrity include the presence and distribution of top predators, the composition and distribution of seagrass beds, ephemeral ponds which are maintained by alligators as "alligator holes" used by multiple species, or the structure and composition of marsh fish and invertebrate communities which support much of the food web. Collectively, these basic strategies for choosing monitoring indicators achieve the diverse monitoring goals of the National Park Service.

1.4.1 SFCN Approach to Vital Signs Identification

Each network is required to design an integrated monitoring program that addresses the monitoring goals listed in section 1.1.1 and is tailored to the high-priority monitoring needs and partnership opportunities for the parks in that network. Although there will be considerable variability among networks in the final design, the basic approach to designing a monitoring program should follow five basic steps:

1) Define the purpose and scope of the monitoring program
2) Compile and summarize existing data and understanding of park ecosystems and resource management issues
3) Develop conceptual models of relevant ecosystem components
4) Select indicators and specific monitoring objectives for each
5) Determine the appropriate sampling design and sampling protocols

These steps are incorporated into a 3-phase planning and design process that has been established for the monitoring program. Phase 1 of the process involved defining goals and objectives; beginning the process of identifying, evaluating and synthesizing existing data; developing draft conceptual models; and completing other background work as a prelude to the selection of ecological indicators. Much of this background information is documented in this chapter and appendix reports. Conceptual models are discussed in Chapter 2 and Appendix J. Phase 2 of the planning and design effort involved prioritizing and selecting vital signs and developing specific monitoring objectives for each vital sign that will be included in the network's initial monitoring program. The process is documented in Chapter 3 and Appendix O. Phase 3 entailed the detailed design work needed to implement monitoring including: outline of strategies for vital signs implementation and relationships with existing programs (Appendix P); outline of sampling design issues (Chapter 4); development of sampling protocols (Chapter 5 and Appendix Q); a plan for data management (Chapter 6 and Appendix R); details on the type of analyses and content of various products of the monitoring effort such as reports and websites (Chapter 7); and the administrative structure (Chapter 8). Chapter 9 outlines the anticipated schedule of protocol development and monitoring activities planned for the 5 years following plan approval and the budget is given in Chapter 10.

1.4.2 Monitoring Questions and Objectives

The SFCN monitoring program is designed around the five broad, service-wide goals (see section 1.1.1 Service-wide Monitoring Goals). These goals were converted to general monitoring questions for each of SFCN's 44 vital signs (see Table 1-D) and then even more specific monitoring objectives for the 12 protocols SFCN will be developing (see Chapter 5, Table 5-B). Both the monitoring questions and monitoring objectives should be much more specific but link clearly to the overarching service-wide goals. These then lead to the monitoring variables and exact scope of the monitoring. The specific monitoring objectives should be articulated as clearly as possible, leading directly to how data will be collected, interpreted and put to practical use. The clearer these objectives, the easier it will be to design the rest of the monitoring program (MacDonald and Smart, 1993; Olsen *et al.*, 1999; Yoccoz *et al.* 2001). These monitoring objectives will be refined as protocol development progresses.

1.5 Summary of Current Monitoring Within and Surrounding the Network

The South Florida/Caribbean Network (SFCN) may be one of the more fortunate networks within the Inventory and Monitoring Program because of the amount of historic and ongoing monitoring occurring within and around the parks. Appendix H provides a table of ongoing monitoring activities by park and as part of the CERP RECOVER Monitoring and Assessment Plan (MAP). NOAA's National Marine Fisheries program has been monitoring commercially exploited fish species for the past 26 years, with many samples collected within South Florida network parks. USGS has been monitoring freshwater fish in South Florida for decades. Park Resource Management has been monitoring birds since the 1950s,

NPS employee Jeff Miller applying prototype coral monitoring protocol at Dry Tortugas National Park.

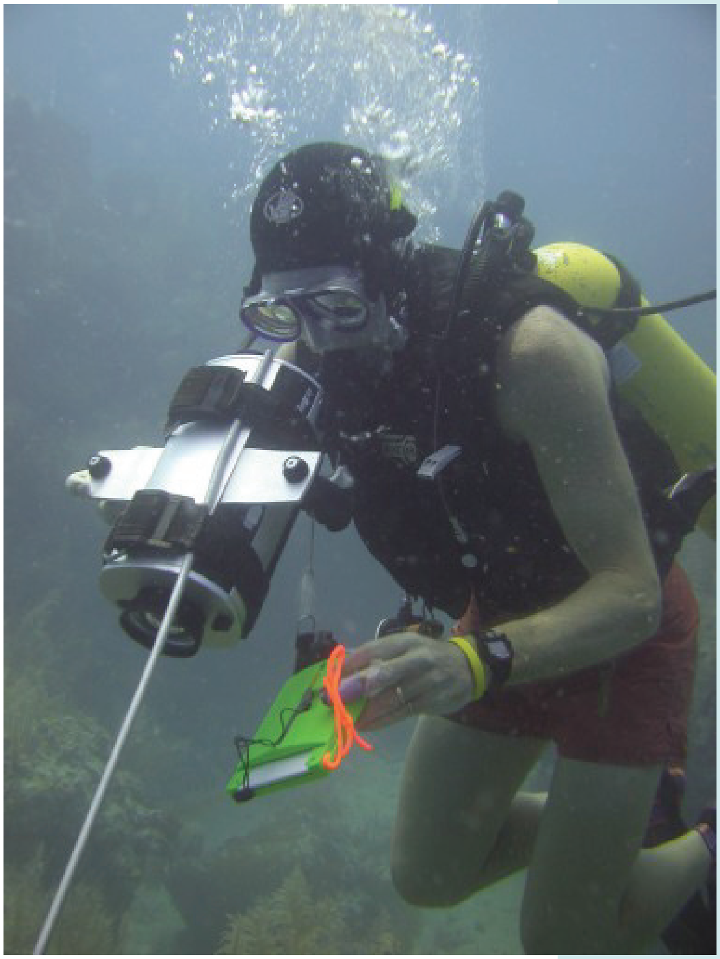


Table 1-D. Vital Signs and general monitoring questions. Deferred vital signs marked with "*".

Vital Sign	General Monitoring Questions
Air Quality-Deposition	What are the status, trends, and episodic events in air quality in SFCN parks, as measured by wet and dry deposition?
Air Quality-Mercury	What are the status and trends in mercury deposition?
American Alligator	What are the status and trends in the alligator distribution, abundance, body condition, hole occupancy, nesting, and demographic structure of alligators, esp. in relation to water levels and CERP/MOD Waters Everglades restoration in EVER and BICY?
American crocodile	What are the status and trends in crocodile distribution, abundance, nesting, body condition, demographic structure, growth and survival esp. in relation to water levels, salinities and CERP/MOD Waters Everglades restoration in EVER and BISC?
Amphibians	What are the status and trends in amphibian distribution, abundance (occupancy), community composition, pig frog demographic structure, and mercury levels, esp. in relation to water levels and CERP/MOD Waters Everglades restoration?
Aquatic invertebrates in wet prairies & marshes	What are the status and trends in aquatic invertebrate community composition and structure, esp. in relation to hydrological patterns and water quality in the wet prairies and marshes?
Bats-USVI*	What are the status and trends in bat species abundance and bat roosting locations esp. the red fruit bat and the fisherman bat?
Benthic Communities Extent & Distribution	What is the extent and distribution of marine benthic communities and how are they changing?
Butterflies*	What are the status and trends in abundance and distribution of butterflies?
Coastal Geomor-phology	What are the status and trends in soil dynamics (accretion, subsidence and erosion) in mangroves, mud-banks, and salt ponds, esp. in relation to changes in hydrology sea-level, storms/hurricanes, and upland erosion? Where do Florida Bay berms, embankments & mudbanks change in location?
Colonial Nesting Birds	What are the status and trends in colony size, distribution, and nesting status of colonial nesting birds (e.g., egrets, ibis, wood storks, spoonbills, sooty terns, brown pelicans)?
Contaminants*	What are the distribution, range, variability and concentrations of contaminants, including Emerging Pollutants of Concern (EPOCS), in the water column, organisms, and sediments?
Estuarine salinity patterns	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?
Fire Return Interval Departure	What is the extent and distribution of areas across the landscape where a departure from native fire regimes exists?
Florida Box Turtle*	What are the status and trends in the abundance and distribution of Florida Box Turtles?
Florida panther	What are the status and trends in Florida panther abundance, distribution, mortality, and recruitment?
Focal Fish Species	What are the status, trends, and variability of focal fish species within and near parks, specifically Goliath grouper, Nassau Grouper, Red hind, Sharks (Bonnethead, Lemon, Bull, and Nurse sharks), Spotted sea trout, and Snook?

Table 1-D. Vital Signs and general monitoring questions (cont.).

Vital Sign	General Monitoring Questions
Forest Ecotones and Community Structure	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?
Freshwater fish and large macro-invertebrates	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?
Imperiled & Rare Plants*	What are the status and trends in the number of populations, distribution, and population sizes of rare plants?
Invasive/ Exotic Animals	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?
Invasive/ Exotic Plants	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?
Island Insects*	What are the status and trends in the composition and distribution of major insect groups (e.g., beetles, pollinators)?
Land Use Change	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?
Landbirds*	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?
Mangrove-Marsh Ecotone	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?
Marine Benthic Communities	What are the status and trends of 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, incl. 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?
Marine Exploited Invertebrates	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)?
Marine Fish Communities	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?

Table 1-D. Vital Signs and general monitoring questions (cont.).

Vital Sign	General Monitoring Questions
Marine Infaunal Community*	What are the status and trends in distribution and abundance of important indicators and keystone organisms, esp. with respect to salinity and nutrient gradients?
Marine Invertebrates-Rare Threatened, Endangered	What are the status and trends in relative abundance & distribibion of rare, threatened, and endangered species (*Acropora spp*., *Antipathes spp*., and *Diadema antillarum*)?
Nutrient Dynamics	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?
Periphyton (Freshwater)	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)?
Phytoplankton (Marine)	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?
Protected Marine mammals	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?
Reptiles-USVI*	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?
Sawfish	What are the status and trends in distribution, relative abundance, number of active nursery areas, and demographics (sex ratios, adult/juvenile ratios)
Sea Turtles	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)?
Surface Water Hydrology	What are the spatial and temporal patterns (quantity, timing, duration, flow) of freshwater input (surface water, and to a point groundwater) into estuaries/bays and of 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?
Vegetation Communities Extent & Distribution	What are the status and changes in the extent and distribution of vegetation communities? 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?
Visitor Use	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?
Water Chemistry	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?
Wetland Ecotones and Community Structure	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?
Wetland substrate*	What are the status and trends in the extent and distribution of substrate types at landscape scales over time, especially in relation to hydrology, water quality, fire, and other processes?

Florida panthers, deer, and alligators since the 1980's, and more recently fish, aquatic invertebrates, and plants. The Florida Coastal Everglades Long Term Ecological Research (LTER) group has many studies that continue to analyze the effects of phosphorus on the freshwater system and how it mixes when it meets the oceanic system as it flows through the Shark and Taylor Sloughs of Everglades National Park. More information about the LTER can be accessed at: http://fcelter.fiu.edu/. Dry Tortugas National Park, Buck Island Reef National Monument and Virgin Islands National Park were selected to be part of the NPS Prototype Inventory and Monitoring Program for coral reef ecosystems in the mid 1990s. That program researched, developed, and implemented monitoring protocols for several key resource areas including coral reefs, sea turtles, reef fishes, and water quality. These historic and ongoing data sets are providing invaluable information toward the vital signs program. The SFCN works closely with NOAA's NCCOS CCMA Biogeography Team coordinating efforts on production of benthic habitat map products for the network parks, and evaluating the coral reef and fisheries of the U.S. Virgin Islands. The Biogeography Program can be accessed at: http://biogeo.nos.noaa.gov/. The U.S. Geological Survey (USGS) and the SFCN collaborate on many projects including benthic mapping, coral reef research especially diseases and bleaching response, plant and animal inventories, water quality monitoring and soil elevation dynamics. The USGS provides resources and support during the Vital Signs Monitoring planning process and beyond. The State of Florida Fish and Wildlife Conservation Commission (FWC), the state of Florida's Department of Environmental Protection (FDEP), and the Government of the Virgin Islands Department of Planning Natural Resources (VIDPNR) all work in and around the network parks monitoring water quality, game species, and state-listed species in addition to other ongoing projects. The South Florida Water Management District (SFWMD) conducts a significant amount of water quality monitoring across the South Florida, as well as coordinates the state efforts for the Comprehensive Everglades Restoration monitoring activities. County Resource Management agencies like the Miami-Dade County Department of Environmental Management conduct seagrass monitoring, water quality monitoring, and exotic plant and animal management in and around network parks.

1.5.1 Climate Monitoring

Climate Monitoring has been addressed by almost all of the networks as a key data set needed to help determine trends of other key Vital Sign indicators (i.e. an environmental co-variate). The Western Regional Climate Center (WRCC) developed a network weather and climate inventory for the SFCN (see Appendix I.2, Davey *et al*. 2007). The inventory describes broad-scale climatic factors and zones important to network parks, an inventory of weather and climate station locations in and near network parks, results of an inventory of metadata on each weather station, and an initial evaluation of the adequacy of coverage for existing weather stations and recommendations for improvements in monitoring weather and climate.

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 Florida Automated Weather Network (FAWN) and Remote Automated Weather Station Network (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 Hammock Overlooks.

1.5.2 Air Quality Monitoring

Air pollution ambient monitoring and effects information, as well as recommendations for additional air quality-related monitoring, has been prepared for the South Florida/Caribbean Network. The summary report and associated tables and appendixes are provided in Appendix I.1.

The National Atmospheric Deposition Program/National Trends Network (NADP/NTN) is a nationwide network of precipitation monitoring sites. Both Everglades National Park and Virgin Islands National Park support NADP/NTN monitoring stations. 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. Everglades National Park monitors for mercury deposition with this system.

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. Everglades National Park installed a monitoring station in 2000. Virgin Islands National Park ran a monitoring station from 1993 until 2004 when it was removed.

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.

A number of research projects have been conducted within SFCN parks looking at air quality parameters; some of which are detailed within the Air Quality summary report from the NPS Air Resource Division (Appendix I). Updated estimates of air quality parameters can be found in the future at the NPS Air Resource Division Air Atlas site http://www.nature.nps.gov/air/maps/AirAtlas/index.cfm.

1.5.3 Physical Science and Water Quality Monitoring

Water Quality monitoring currently occurs within all network parks. In South Florida, federal and state agencies have been monitoring hydrology and other resources for many years in order to determine how best to manage the hydrology as part of the Comprehensive Everglades Restoration Program (CERP). Monitoring in South Florida parks is being conducted by NPS staff, the U.S. Geological Survey (USGS), the South Florida Water Management District (SFWMD), Florida International University Southeast Environmental Research Center (FIU-SERC), Miami-Dade County Department of Environmental Resources Management (DERM) and Florida Department of Environmental Protection (FDEP). Less extensive monitoring in the U.S. Virgin Islands is being conducted by NPS staff, the U.S. Virgin Island Territorial Government, and National Oceanic and Atmospheric Administration (NOAA) National Buoy Data Center in conjunction with the Florida Institute of Oceanography. Due to the complexities of this extensive monitoring across the network, the SFCN role is more of a consolidation and regional disperser of hydrology products (See Appendix F).

Measurements during juvenile hawksbill sea turtle monitoring program at Buck Island Reef National Monument.

1.5.4 Biological monitoring

Biological monitoring activities occurring in the network parks are summarized in Appendix H. Some of the longer running programs at various parks (although often sharply limited in geographic scope) include creel surveys, fire effects monitoring, reef fish surveys, coral community monitoring, coral disease monitoring, bird and sea turtle migration, recruitment, and seasonal nesting and monitoring of other federally listed species (e.g., panthers, manatees, sooty terns, brown pelicans). CERP has several programs in either pilot phase or recently initiated long-term monitoring.

1.5.5 The South Florida Natural Resources Center

The South Florida Natural Resources Center (SFNRC), a division of Everglades National Park provides scientific information and environmental assessments to the NPS units of South Florida and to the Department of the Interior. Established in 1978, the center was given the unprecedented mandate to address the impacts of activities taking place outside park boundaries. This unique charter requires that center scientists conduct scientific inquires into the ecology of the region as a whole, evaluating the impacts that land-use and water resources management actions have on the freshwater, estuarine, and coastal ecosystems of south Florida. The SFNRC is organized around four major categories of activities: Natural Resources Management, Inventory and Monitoring, Restoration Assessments, and Applied Science. The center has four offices in South Florida: in Loxahatchee National Wildlife Refuge, the South Florida Ecosystem Office in Homestead, The Daniel Beard Center in EVER, and the Florida Bay Interagency Science Center in Key Largo. More information about the center can be obtained at their website at: http://www.nps.gov/ever/naturescience/sfnrc.htm.

1.5.6 The South Florida/Caribbean Prototype Monitoring Program

The South Florida/Caribbean Network merged with the South Florida/Caribbean Prototype Monitoring Program in 2004. The merger of the two programs has allowed the coral reef monitoring protocol developed in 1997 in the U.S. Virgin Islands parks to be expanded into both Biscayne National Park and Dry Tortugas National Park, providing a consistent monitoring effort across network parks and allowing the network parks to talk about trends in coral reef resources in a more consistent manner. Coral monitoring at reef sites using the Aquamap™ Underwater navigation system and underwater video collection provides these parks with trend information regarding live percent cover values of the reef's basic functional groups and stony coral species, as well as continuous reef water temperature, occurrence of coral disease, and presence of the long-spined urchin (*Diadema antillarum*). The prototype monitoring program has also developed protocols for sea turtle monitoring, seagrass monitoring, and water quality monitoring in conjunction with BUIS and VIIS. The merger also provided funding to hire a network quantitative ecologist to help optimize sampling efficiency, and assist with data analysis of historical data sets.

Squirrelfish over boulder star coral, Tektite Reef, VIIS. Picture taken before massive coral dieoff in 2005.

Chapter 2: Conceptual Models

2.1 Introduction

In this section we describe the purposes and characteristics of management-oriented conceptual models along with summaries of the SFCN ecological zones conceptual models. Full details about the SFCN conceptual models are given in Appendix J.

2.1.1 Why use conceptual models

The NPS Inventory and Monitoring Program requires the development of conceptual models as a prelude to identifying the vital signs to be monitored. Conceptual models assist with designing monitoring programs in an adaptive management context (National Research Council 1990; Margoluis *et al*. 1998; CALFED Bay-Delta Program 2000a, 2000b; Elzinga *et al*. 2001; Stevens and Gold 2003; Noon 2003, Ogden *et al*. 2003; Atkinson *et al*. 2004; RECOVER 2004). Programs that do not use conceptual models frequently experience difficulty in prioritizing among vital signs, choosing monitoring protocols, and developing appropriate sampling designs. Conceptual models are qualitative or quantitative models used to clearly describe a system and help program designers:

- summarize existing knowledge and hypotheses about a system,
- select and prioritize important components of the system to monitor,
- identify and prioritize critical uncertainties for research,
- communicate understanding of the system to all program participants and encourage interdisciplinary dialog,
- facilitate review of the program by outside experts by summarizing system complexities in a digestible form (Atkinson *et al*. 2004).

There are many different types of conceptual models. Sometimes confusion results because the term "conceptual model" means different things to different people (e.g., food web diagrams, detailed species life-history descriptions, management-oriented "control" models). Form and details of models differ depending on the purpose, scales of focus, and system complexity. ***The purpose of the conceptual models in this report is to assist the program with identifying and prioritizing "vital signs" in an adaptive management context.*** These models do not contain all possible details or relationships in the system. Instead, the level of detail and format chosen for these models is designed to facilitate vital signs selection.

2.1.2 Development of Conceptual Models

SFCN used an adaptive management-oriented framework in designing its conceptual models. This framework ***links causes of change (physical drivers and anthropogenic stressors) to the state of the environment and to management activities*** as well as identifying areas of uncertainty that could affect decision-making (see Figure 2-A). Similar management-oriented approaches have been applied in other ecosystem management programs, although the terminology varies (New Zealand Ministry for the Environment, 1997; Gibbs *et al*., 1999; Bertram and Stadler-Salt, 2000; Atkinson *et al*., 2002; California Resources Agency, 2002; Noon, 2003; MHCP, 2003; CVMSHCP, 2004 draft; RECOVER, 2004; Atkinson *et al*. 2004).

To facilitate the identification and prioritization of vital signs, SFCN divided the ecosystems in the South Florida and Caribbean parks into six ecological zones and developed conceptual models for each plus one extensive sub-model that relates to two of the marine zones:

- Freshwater wet prairies and marshes
- Forested wetlands and uplands
- Island interiors
- Coastal wetlands
- Florida and Biscayne Bays
- Coastal shelf and deep oceanic
- Marine Benthic Communities Sub-model

The biological communities in these ecological zones are assumed to be affected by similar physical drivers and the same general set of stressors. These ecological zone conceptual models were reviewed and used to focus discussion and identification of indicators at the SFCN Vital Signs Indicator Identification Workshops in January – March 2006 described in Chapter 3.

The conceptual models draw strongly from the available literature plus consultation with park management. The reader is especially referred to the following references for more details:

- *Comprehensive Everglades Restoration Program conceptual models* (Ogden 2004; Davis 2004; Deuver 2004; Browder *et al.* 2004; Rudnick 2004)
- *The State of Coral Reef Ecosystems of the United States and Pacific Freely Associated States: 2005* (Waddell 2005)
- *Comprehensive Wildlife Conservation Strategy for the U. S. Virgin Islands* (U.S. Virgin Islands Division of Fish and Wildlife 2005)
- *The Everglades Handbook: Understanding the Ecosystem, 2nd Edition* (Lodge 2005)
- *The Big Cypress National Preserve* (Deuver *et al.* 1979)
- *South Florida Multi-species Recovery Plan* (USFWS 1999)

A brief summary of each zone conceptual model is provided below. Each of these models is given in more detail in Appendix J with various sub-models including vegetation-process models (e.g., vegetation-fire-hydrology) and food web model diagrams from the literature where appropriate to help explain complex topics. The relationships among these various models are shown in Figures 2-B and 2-C. Park-specific public-friendly conceptual model diagrams were also created summarizing issues for each park (see Appendix J.10). Appendix K lists all federal and state listed species. Appendix M lists invasive plant species (but not all exotics) and Appendix N lists all known exotic animals in SFCN parks.

Table 2-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

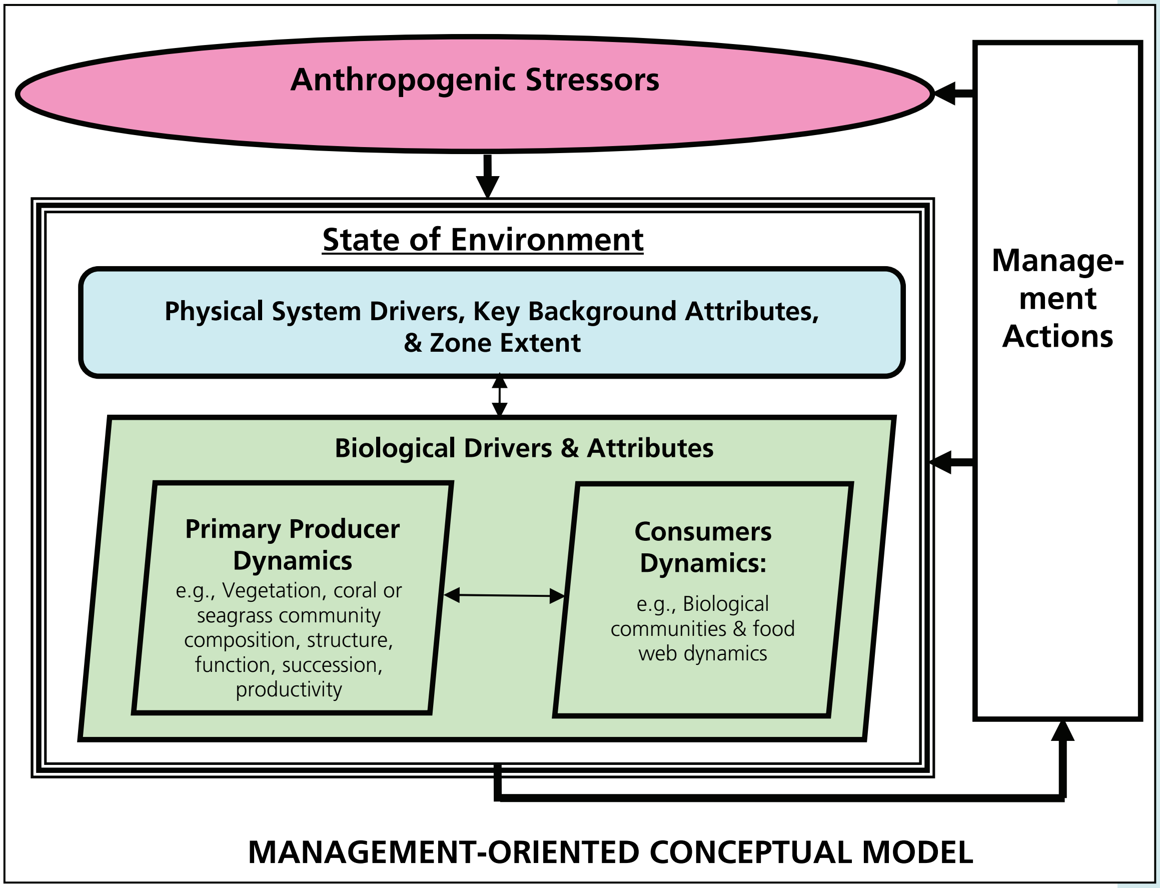


Figure 2-A. Key components of management-Figure 2-A. Key components of management-oriented conceptual models. Conceptual models facilitate adaptive management by showing how system drivers, stressors and management actions are hypothesized to affect key components of the environment and their interactions. 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.**

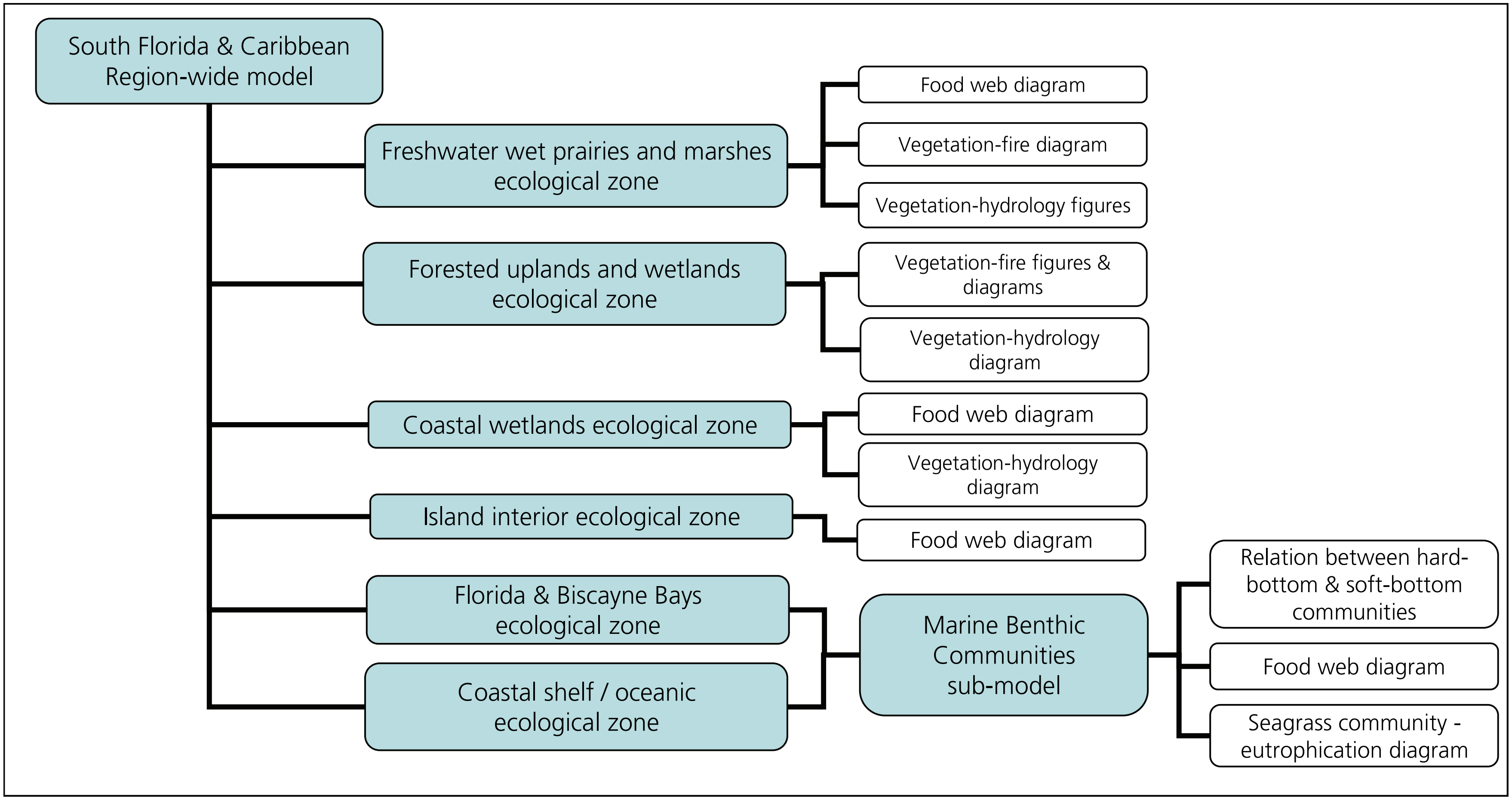


Figure 2-B. Inter-relationships among south Florida and Caribbean Network conceptual models and sub-models.
Figures in blue [blue box] represent the models developed in detail in this report. [white box] represent sub-model figures included in the larger models.

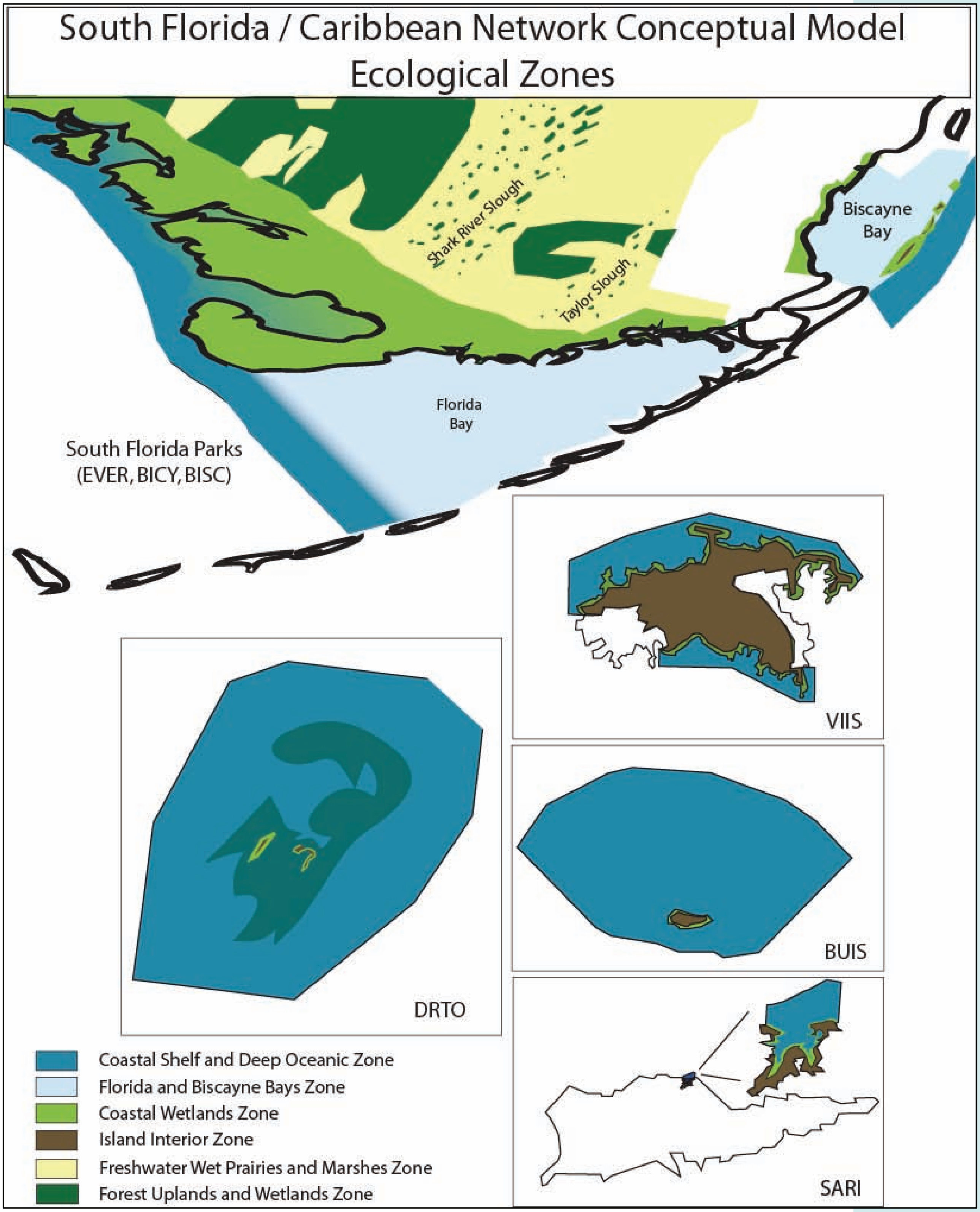


Figure 2-C. South Florida / Caribbean Network Ecological Zones.

2.2 Freshwater Wet Prairies and Marshes Ecological Zone

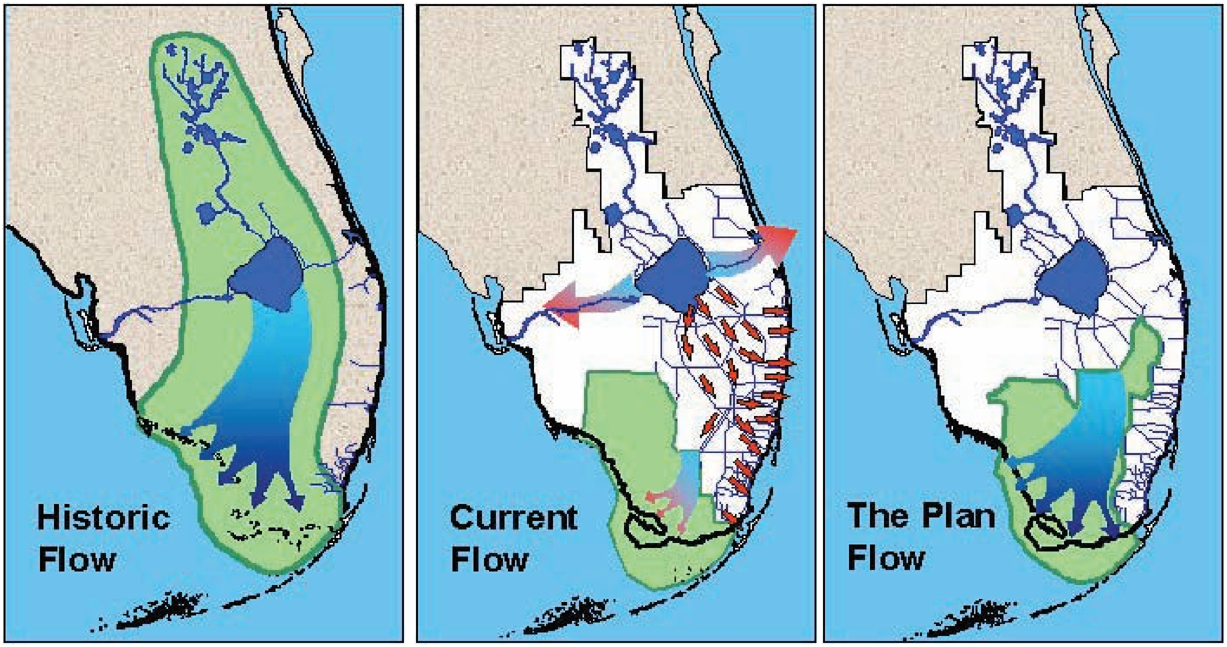
The Freshwater Wet Prairies and Marshes Ecological Zone is a vast, shallow, clear-water, oligotrophic (low nutrients) system that includes the deeper regions of Shark River Slough, Taylor Slough, Lostmans Slough, and Mullet Slough plus large expanses of wet prairies. This zone expands northwards outside the EVER and BICY into the state-managed Water Conservation Areas and the hydrology of the Everglades is highly dependent on water management in these areas.

Top: Sawgrass marsh with periphyton on water surface at Shark River Slough in EVER.

Bottom: Muhly grass wet prairie in glade near Long Pine Key in EVER during dry season.

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. 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 and alligator holes, 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.) (Rutchey *et al.*, 2005). These areas concentrate larger aquatic species during dry-down periods, becoming popular wildlife viewing areas (e.g., Anhinga Trail).



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. Wet prairies include marl prairies, short-sawgrass prairie, muhly prairie, mixed grass/sedge prairies and rocky glades prairies and typically include vegetation dominated by muhly grass (*Muhlenbergia filipes*), little bluestem (*Schizachyrium scoparium*), Gulfdune paspalum (*Paspalum monostachyum*), black sedge *(Schoenus nigricans)*, sparse sawgrass species (< 1.5 m tall), bluejoint panicgrass (*Panicum tenerum*), sparse beakrush (*Rhynchospora* sp.), and/or cordgrass (*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.

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; and as a watershed for Florida Bay and the Ten Thousand Islands.

A diagram showing the key drivers and stressors affecting vegetation community and consumer community dynamics is given in Figure 2-D. Issues are briefly summarized below with more details provided in Appendix J.3.

Some of the most important drivers impacting the wet prairies and marshes vegetation community dynamics include hydrology, major weather events (hurricanes, droughts), fire, water quality, sea level rise and the underlying geology, topography, and soils. The main physical driver in this system is the surface water hydrology coupled with the flat topography. 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

Great egret at Anhinga Trail, EVER.

Florida Bay. Wetland vegetation community composition and structure changes in response along ecotones from long-hydroperiod marshes and sloughs, especially in the Water Conservation Areas (WCAs), Shark River Slough and Taylor Slough, to short-hydroperiod wet prairies. Within the WCAs, Shark River Slough and Taylor slough there is a patterning of ridge and slough formation interspersed with tree islands which play important roles for the fauna in the park. Other key drivers are major weather events such as droughts, which sharply impact this wetland system, and hurricanes, which can carry salt water far inland, nutrient dynamics (historically this is a low nutrient system), water chemistry (e.g., pH, dissolved oxygen), the periphyton mat which is an important base of the food web and is responsive to changes in flood duration and water quality, and fire size, severity, and return interval. Pesticides and phosphorous enrichment from agricultural areas north and east of EVER and BICY are also a concern. Phosphorous enrichment allows abnormal expansion of cattails into wet prairies and sloughs, alters vegetation composition and structure, and shifts periphyton composition into less digestible forms for other organisms. Sea level rise is expected to cause shifts in the mangrove-marsh ecotone as mangroves and other coastal wetlands move into the wet prairies and marshes zone. Fire suppression can allow the marsh-forest ecotone to shift as shrubs and trees (including mangroves) gradually invade the wet prairies and marshes. Unseasonal human-initiated fires not only affect vegetation composition and structure but potentially topography as dry-season fires burn the peat substrate. Off-road vehicles have created discernable trails in BICY.

A freshwater marshes and prairies food web is provided in Figure 2-E. The major driver affecting food web community dynamics is changes in hydrology (amount, timing, duration, and quality). When the fish and large macro-invertebrates of this vast "river of grass" are concentrated along drying fronts, they have historically supported large numbers of wading birds (e.g., white ibis [Eudocumus albus], snowy egrets [*Egretta thula*], great egrets [*Ardea albus*], wood storks [*Mycteria americana*], little blue herons [*Egretta caerulea*], tricolor herons [*Egretta tricolor*]), alligators (*Alligator mississippiensis*), and other wildlife. The major anthropogenic stressors are the water diversions, canals, levees, and water level reversals that have severely altered the system surface water hydrology, (i.e., flood duration, depth, seasonality, and effects of droughts). This in turn has impacted the entire food web with reductions in the biomass of fish, amphibian, and invertebrates produced in the vast wetland and consequent declines in wading bird communities and shifts in locations of supercolonies. Alligators likewise move out of the drying wet prairies into deeper sloughs, borrow pits, and canals. Alligators are important biological drivers which, in addition to being an important top predator, maintain and enhance alligator holes which can provide important refugia during the dry season. The major toxic contaminant problem is mercury which is aerially deposited, becomes methylated and bioaccumulates in mid- and top-level predators (e.g., wading birds, large fish, pig frogs [*Rana grylio*], and panthers [*Puma concolor coryi*]). Pesticides from agriculture outside the park can also affect aquatic invertebrates, fish and amphibians and may also bioaccumulate up the food chain.

Other stressors include land use change, invasive species and visitor use. Land use change is resulting in the reduction in habitat outside parks that affects regional species such as wading birds as well as increasing edge effects and human-initiated fires. Invasive plants and animals are a major problem with new predators being established (e.g., constrictors and pythons [*Boa constrictor*, *Python spp*.], Cuban tree frogs [*Osteopilus septentrionalis*], and Mayan cyclids [*Cichlasoma urophthalmus*)). Other invasive species such as apple snails (*Pomacea "canaliculata group*") and brown hoplo (*Hoplosternum littorale*) are rising concerns (see Appendix N for a complete list). The primary visitor use disturbances include roadkill along Tamiami Trail and park roads killing animals such as alligators, turtles, and otters, plus off-road vehicle use in BICY which is a stressor in the dry season. Airboats used to be a stressor but are now restricted within Everglades National Park.

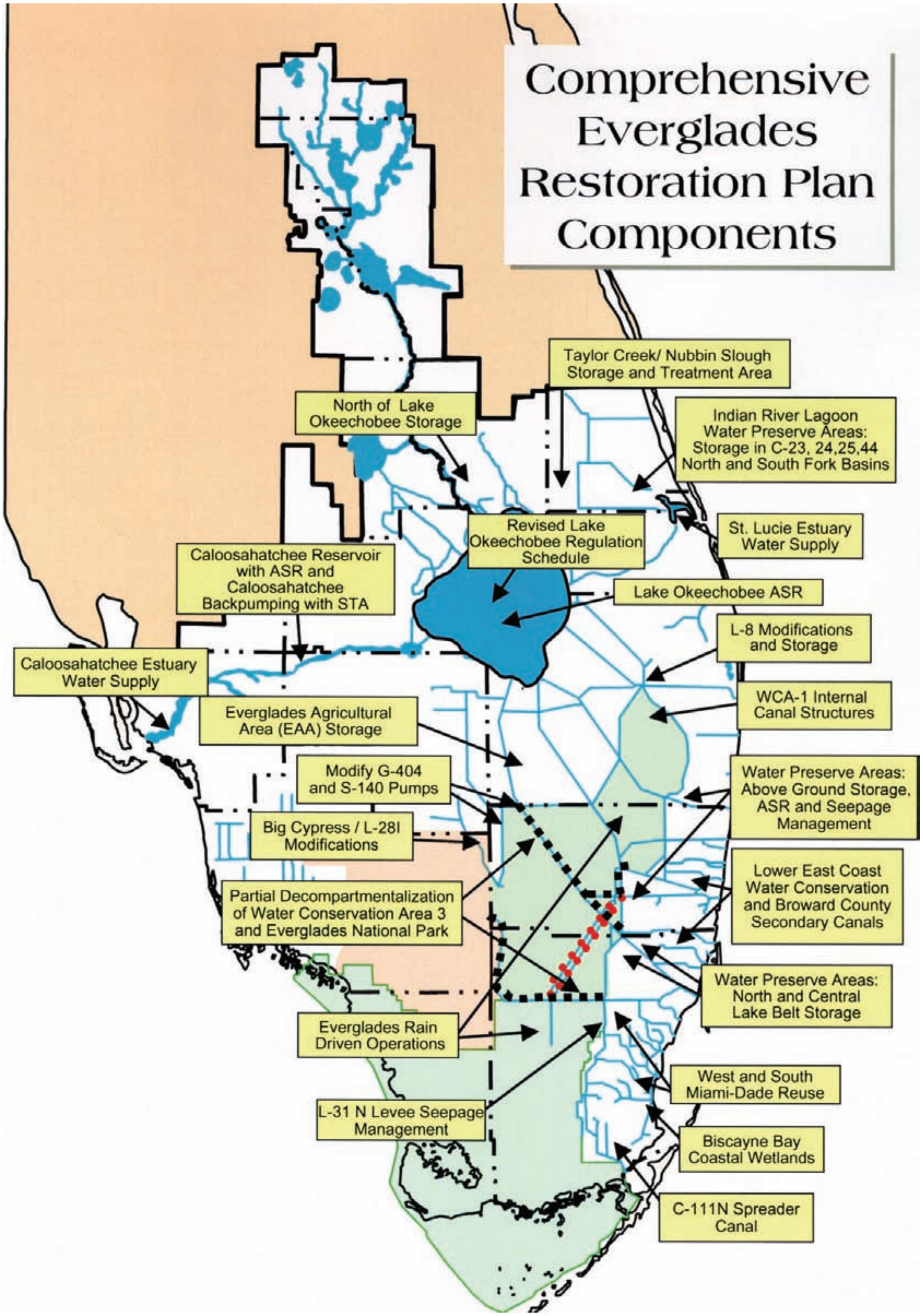
The key management issues in the Freshwater wet prairies and marshes Ecological Zone include rehabilitation of system hydrology, fire management, controlling and preventing the introduction of invasive plants and animals, reductions in phosphorous loading from outside the park, determining methods to reduce or mitigate mercury bioaccumulation, managing recreational impacts, and protection and management of rare plants and animals and their habitats.

The vital signs that relate to the Freshwater Wet Prairies and Marshes Zone conceptual model include:

- Air Quality-Deposition
- Air Quality-Mercury
- American Alligator
- Amphibians
- Aquatic Invertebrates in Wet Prairies & Marshes
- Colonial Nesting Birds
- Contaminants
- Fire Return Interval Departure
- Florida Box Turtle
- Freshwater fish and large macro-invertebrates
- Invasive/Exotic Animals
- Invasive/Exotic Plants
- Land Use Change
- Landbirds
- Nutrient Dynamics
- Periphyton (Freshwater)
- Surface Water Hydrology
- Vegetation Communities Extent & Distribution
- Visitor Use
- Water Chemistry
- Wetland Ecotones and Community Structure
- Wetland Substrate

Alligator at Anhinga Trail, EVER. The permanently flooded borrow pits at Anhinga Trail in EVER have become a popular wildlife viewing area.

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)



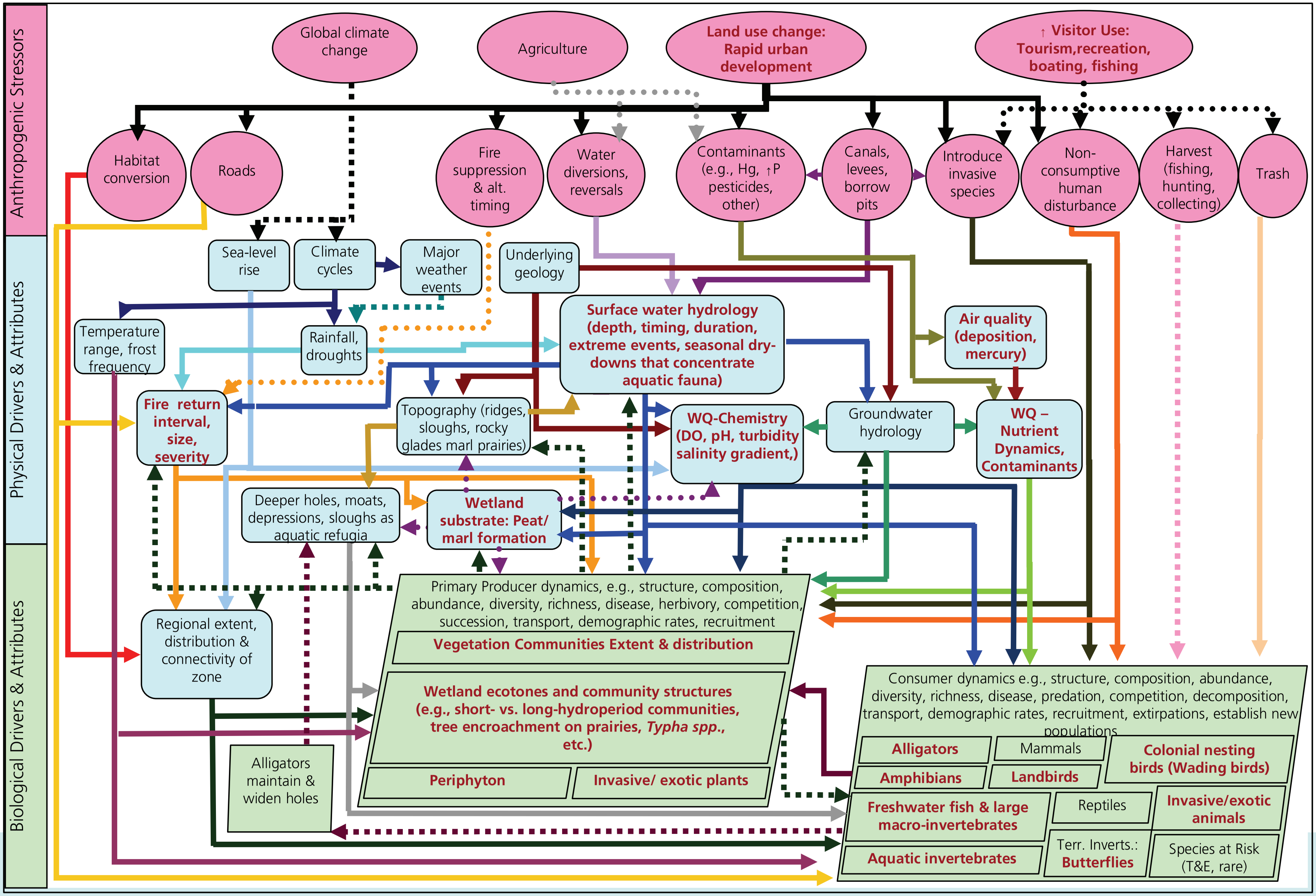


Figure 2-D. South Florida wet prairies and marshes ecological zone conceptual model diagram. Solid and dotted lines show assumed effects of anthropogenic stressors, physical and biological drivers and attributes. Boxes with red print directly relate to a Vital Sign. (Use of dotted lines is used to clarify and does not indicate lesser importance).

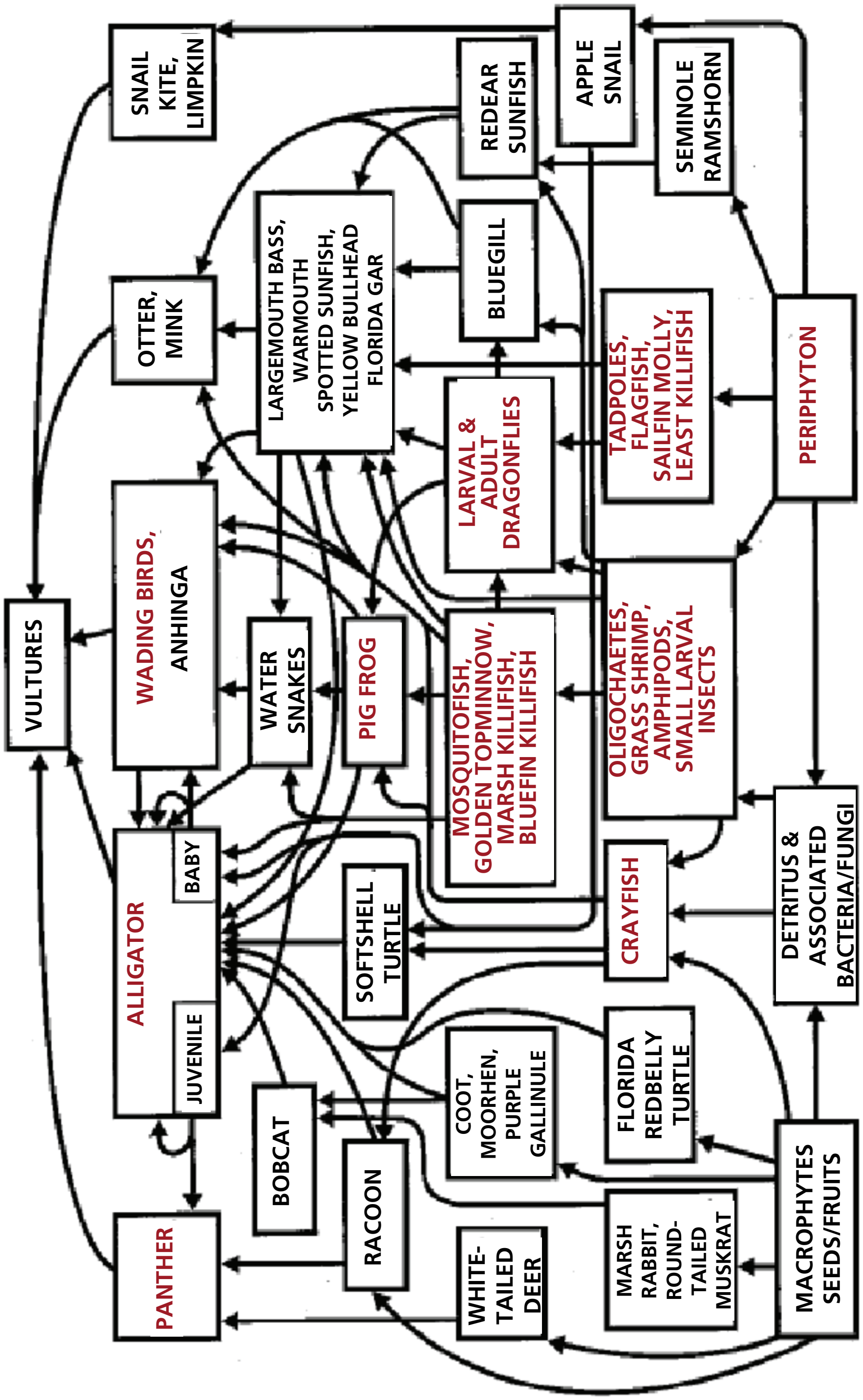


Figure 2-E. Wet prairies and marshes food web. Boxes with red print relate to proposed vital signs [Figure modified from Lodge 2005; used with permission].

2.3 Forest Uplands and Wetlands Zone

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. 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 (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).

From top to bottom: Pine rocklands in EVER, hardwood hammock in EVER, and cypress forest strand during dry season 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 flood, frost, and fire frequency and along with fire severity. 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 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.

Fire in BICY. Fire is a major driver in Everglades and Big Cypress.

Cypress Forest: Pond Cypress (*Taxodium ascendens*) and Bald Cypress (*T. distichum*) are deciduous conifers that thrive in ponded water and slow seepage swamps. 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.

The Forest Uplands and Wetlands Ecological Zone is valued for its rare vegetation communities, rare and endangered plants and animals, hiking, wildlife viewing, canoeing, and additionally in BICY for recreational fishing, hunting of deer and pigs, off-road vehicle (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 stands 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 six 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 which provide important nesting habitat for species in the wet prairies and marshes zone such as alligators, red-bellied turtles and wading birds. This zone also contains many cultural sites used by the Miccosukee Indian Tribe.

A diagram showing the key drivers and stressors affecting vegetation community and consumer community dynamics is given in Figure 2-F. Issues are briefly summarized below with more details provided in Appendix J.4.

Some of the most important drivers impacting forest vegetation community dynamics include hydrology, climate (temperature range, frost frequency, rainfall), major weather events (hurricanes, droughts), fire, water quality, dispersal agents, and the underlying geology, topography, and soils. Similar to the wet prairies and marshes, much of the surface water hydrology in this zone is dependent on influx of water from areas north of EVER and BICY. Minor differences in elevation cause differences in flood duration which in turn affect forest community composition and structure along hydrological gradients. Most forest tree species in this zone tolerate varying degrees of flood duration resulting in ecotonal differences in overstory and even larger ecotonal differences in understory forest species composition structure. 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. The limestone geology of south Florida is highly porous causing a strong inter-relationship between groundwater and surface water levels. Thus changes in surface water hydrology also affect groundwater levels in the slightly elevated drier hammocks and pine "uplands".

Other non-hydrological drivers are important as well to forest community composition and structure. Fire size, severity and return interval is a major driver in the system that restricts hardwood species expansion into pinelands and cypress, forest expansion into the wet prairies and marshes, and tree island size and expansion. Unfortunately, human-initiated, dry season fires and droughts can allow fires deeper access into moist hammock and

Alligator with large non-native python in its jaws.
(Photo by Everglades National Park staff).

cypress dome interiors than would occur in the wet season causing greater damage to some rare communities. Much of these forests are in succession stages from logging and agriculture that occurred in the early 1900's. Habitat loss has also impacted some of the rarer plant species reducing them to a few populations within park boundaries. Rising urbanization could also increase aerial deposition of nitrogen and sulfur in the system as well as pollutants which may especially impact some rare plants. Nutrient enrichment due to agricultural runoff (EVER, BICY), fish camps and inholdings (BICY), especially phosphorous, is a concern and may affect forest community structure. Wading bird nesting colonies may also cause localized impacts on nutrient enrichment. Frost frequency determines the northward and coastal-to-inland expansion of sub-tropical species including rare plant species and may change with global climate change. Major weather events such as hurricanes can cause direct physical destruction to forests and resulting canopy openings are rapidly exploited by invasive plant species. Invasive plants and animals remain one of the greatest threats to this zone with invasive trees (e.g., Australian pine [*Casuarinas* spp.], Melaleuca [*Melaleuca* spp.]), invasive shrubs (e.g., Brazilian pepper [*Schinus terebinthifolius*]) and vines (e.g., Lygodium, (*Lygodium* spp.]) causing major structural changes in forest communities, changing hydrology and fire dynamics, and reducing habitat quality for rare plants and animals (see Appendixes M and N for complete lists).

The food web is similar to the wet prairies and marshes zone given in Figure 2-E, except that periphyton is largely missing under the tree canopy and detritus, insects, and influx from marsh areas presumably play a larger role. Many of the drivers and stressors affecting the food web are similar to the wet prairies and marshes zone including changes in surface water hydrology (timing, depth, duration, and quality), mercury contamination, and invasive animal species. However, other drivers and stressors are different, including land use changes, global climate change, additional contaminant concerns, and visitor use. Historic logging coupled with the large-scale loss of forested lands to development, especially the rare pine rocklands community, and fragmentation of remaining areas, has impacted many of the species dependent on these communities including cavity-nesting landbirds such as bluebirds (*Sialia sialis*) and red-cockaded woodpeckers (*Picoides borealis*), rare butterflies such as the Schaus swallowtail *(Papilio aristodemus ponceanus)*, old-growth species such as the presumed extinct ivory-billed woodpecker (*Campephilus principalis*), and land-bound species such as the Florida panther, snakes, and the Florida box turtle (*Terrapene carolina bauri*). Historic hunting and collecting has also impacted some species. Climate change may cause further changes by influencing the timing of migration and nesting of species such as neotropical migratory landbirds. Mosquito spraying within EVER is a concern, especially regarding some of the rare butterfly species. Oil drilling activities have the potential for spills and contamination in BICY. The primary visitor use disturbance is roadkill (both parks), ORV use (BICY), hunting (BICY), fishing (BICY), and illegal collection (both parks). Some additional disturbance occurs around campgrounds and trails. Although wading birds primarily feed in the wet prairies and marshes zone and coastal wetlands zone, they also feed in the forested wetlands and their nesting colonies frequently occur in the forests and tree islands and need to be free from invasive predatory species and disturbance.

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.

The vital signs that relate to the Forest Uplands and Wetlands Zone conceptual model include:

- Air Quality-Deposition
- Air Quality-Mercury
- American Alligator
- Amphibians
- Butterflies
- Colonial Nesting Birds
- Contaminants
- Fire Return Interval Departure
- Florida Box Turtle
- Florida panther
- Forest Ecotones and Community Structure
- Freshwater fish and large macro-invertebrates
- Imperiled & Rare Plants
- Invasive/Exotic Animals
- Invasive/Exotic Plants
- Land Use Change
- Landbirds
- Nutrient Dynamics
- Surface Water Hydrology
- Vegetation Communities Extent & Distribution
- Visitor Use
- Water Chemistry
- Wetland Substrate

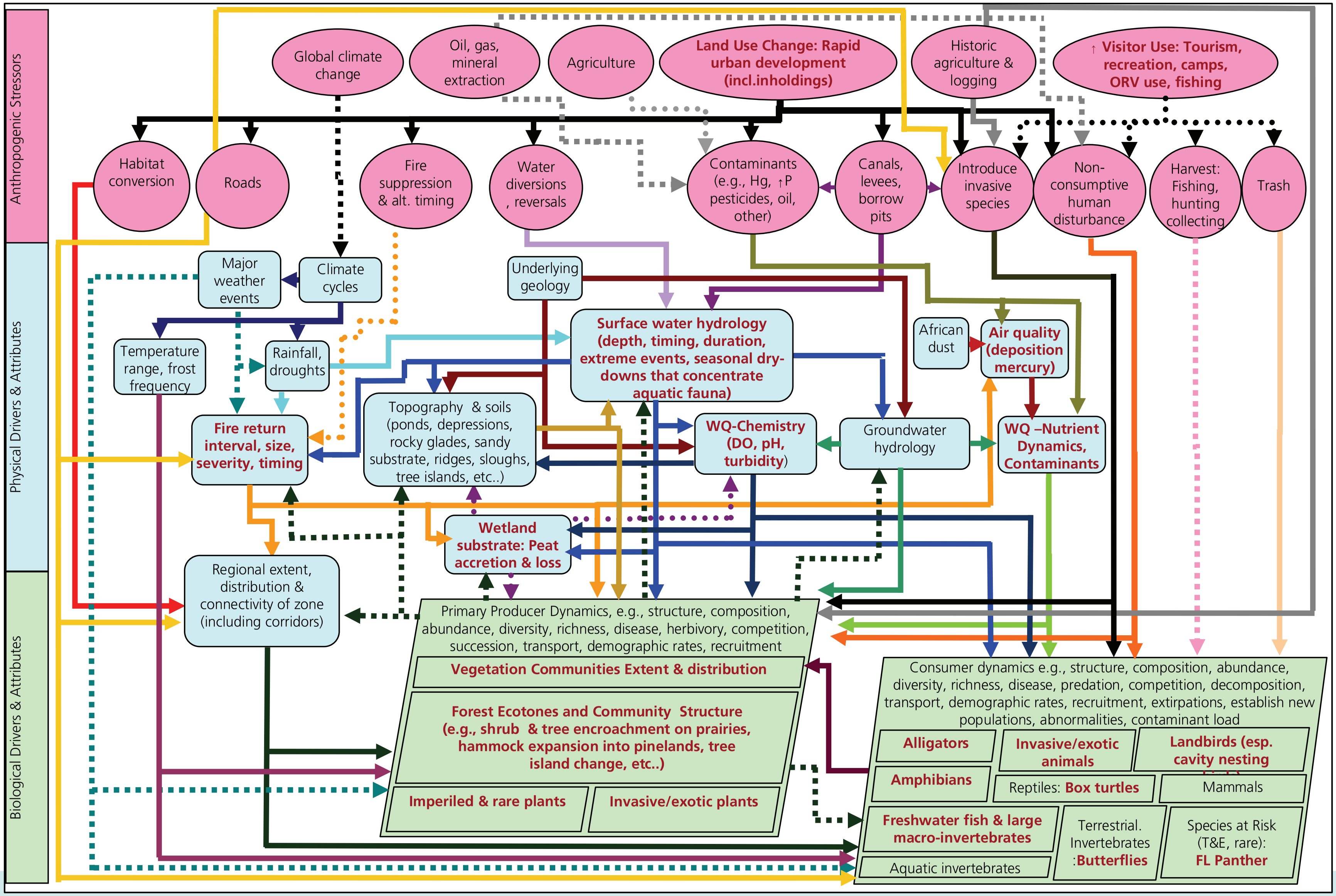


Figure 2-F. Florida Forested uplands and wetlands ecological zone conceptual model diagram. Solid and dotted lines show assumed effects of anthropogenic stressors, physical and biological drivers and attributes. Boxes with red print directly relate to a selected Vital Sign. (Use of dotted lines is to clarify and does not indicate lesser importance).

2.4 Island Interior Ecological Zone

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 the Coastal Wetlands Zone conceptual model (Section 2.5). The Island Interior Ecological Zone is found in VIIS on St. John, BUIS on Buck Island, inland areas of SARI, the keys in BISC, DRTO, and possibly a few islands in EVER in the Ten Thousand Islands and Florida Bay.

Vegetation primarily consists of tropical dry shrublands, tropical dry forests, 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. Grasslands in the US Virgin Islands are typically an early successional stage from other land uses. Island interior vegetation communities are described more completely in USVI Division of Fish and Wildlife (2005) and Rutchey *et al.* (2005).

Top: Dry shrubland vegetation at BUIS.

Bottom: "Spite Highway" through coastal hardwood hammock on Elliot Key, BISC.

This community assemblage is valued for its unique and rare plants and fauna (see Appendix K), its dry tropical and sub-tropical vegetation, as stopover habitat for migrating and over-wintering landbirds, and its hiking and recreational communities. Smaller islands are valued as predator free nesting areas for some colonial nesting seabirds, shorebirds and wading birds and sea turtles.

A diagram showing the key drivers and stressors affecting vegetation community and consumer community dynamics is given in Figure 2-G. Issues are briefly summarized below with more details provided in Appendix J.5.

The vegetation communities in this zone are strongly affected by climate, topography, tropical storms, sea level rise, rapid urbanization, invasive species, contaminants, historic and current land use, and possibly air quality. The hot climate coupled with little available standing freshwater leads to dry tropical and sub-tropical vegetation community composition that is adapted to such conditions. Freshwater exists in karst (BISC) or gut (VIIS, BUIS) formations and in ephemeral streams (VIIS, SARI). The steep elevation of USVI parks results in orographic effects and landslides that influence vegetation succession, composition and structure. The shallow elevation of islands in BISC, DRTO, and EVER makes them susceptible to complete inundation during storm surge events. Hurricanes cause physical damage to vegetation, resetting plant succession processes. Sea level rise may gradually cause shrinking of these island interior areas and in the case of South Florida parks, may result in their eventual loss over the next century if deposition processes cannot keep pace. Rapid urbanization on St. John and St. Croix is reducing and fragmenting habitat outside and within (inholdings) VIIS and SARI, increasing related stressors such as construction impacts, increased hydraulic loading on septic systems, increased solid waste, introduction of new invasive species, increased contaminants in the ephemeral streams on the islands, and possibly increased freshwater runoff from lawns into dry natural areas which alter plant and invertebrate communities. Much of the vegetation on these islands is in succession from historic land uses including agriculture, logging, and residential. 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. Air quality is periodically reduced by African dust (all parks), volcanism (USVI parks), and urbanization effects which may impact soil nutrient levels.

Island food webs (see Figure 2-H) are strongly affected by island size, invasive species, and urbanization impacts. Island isolation coupled with island size, limited freshwater and founder effects has strongly impacted the foodwebs that have developed on each island. The dominant native organisms are birds, reptiles, amphibians (except BUIS and DRTO), bats and island insects. Large predators and herbivores were absent from DRTO and the USVI parks. Thus introduced species such as rats (*Rattus rattus and R. norvegicus*), mice (*Mus musculus*), goats (*Capra hircus*), deer (*Odocoileus virginianus*), mongoose (*Herpestes javanicus*) (VIIS, SARI only), and Cuban tree frogs, pythons (EVER, BISC) have had devastating effects on island food-webs (see Appendix N for complete list). Introduced plant species are a problem, reducing habitat quality for native species (see Appendix M for invasive plant species). 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 urban-adapted native predators such as raccoons (*Procyon lotor*) when they historically were not present in large numbers on the islands. On St. Croix and St. John urbanization has had impacts on inland freshwater quality. Sedimentation from construction

Introduced goats in vegetation on St. John, USVI

Construction occurring just outside SARI and right to the edge of the mangroves. Coral communities are just off-shore (2005).

is filling in guts and impacting water quality which may in turn affect aquatic invertebrates, freshwater fish and amphibians (as well as coral reefs offshore). Nutrient enrichment is also a concern upstream of SARI. Other urbanization impacts include a rapid reduction in available habitat for species on these already small islands, increased roadkill and urban edge effects such as disturbance and introduction of new invasive species. Some visitor use disturbance occurs along trails and campgrounds.

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.

The vital signs that relate to the Island Interior Zone conceptual model include:

Air Quality-Deposition
Air Quality-Mercury
Amphibians
Bats-USVI
Butterflies
Coastal Geomorphology
Colonial Nesting Birds
Contaminants
Forest Ecotones and Community Structure
Freshwater fish and large macro-invertebrates
Imperiled & Rare Plants
Invasive/Exotic Animals
Invasive/Exotic Plants
Island Insects
Land Use Change
Landbirds
Nutrient Dynamics
Reptiles-USVI
Surface Water Hydrology
Vegetation Communities Extent & Distribution
Visitor Use
Water Chemistry

Dry tropical forest on Buck Island, BUIS.

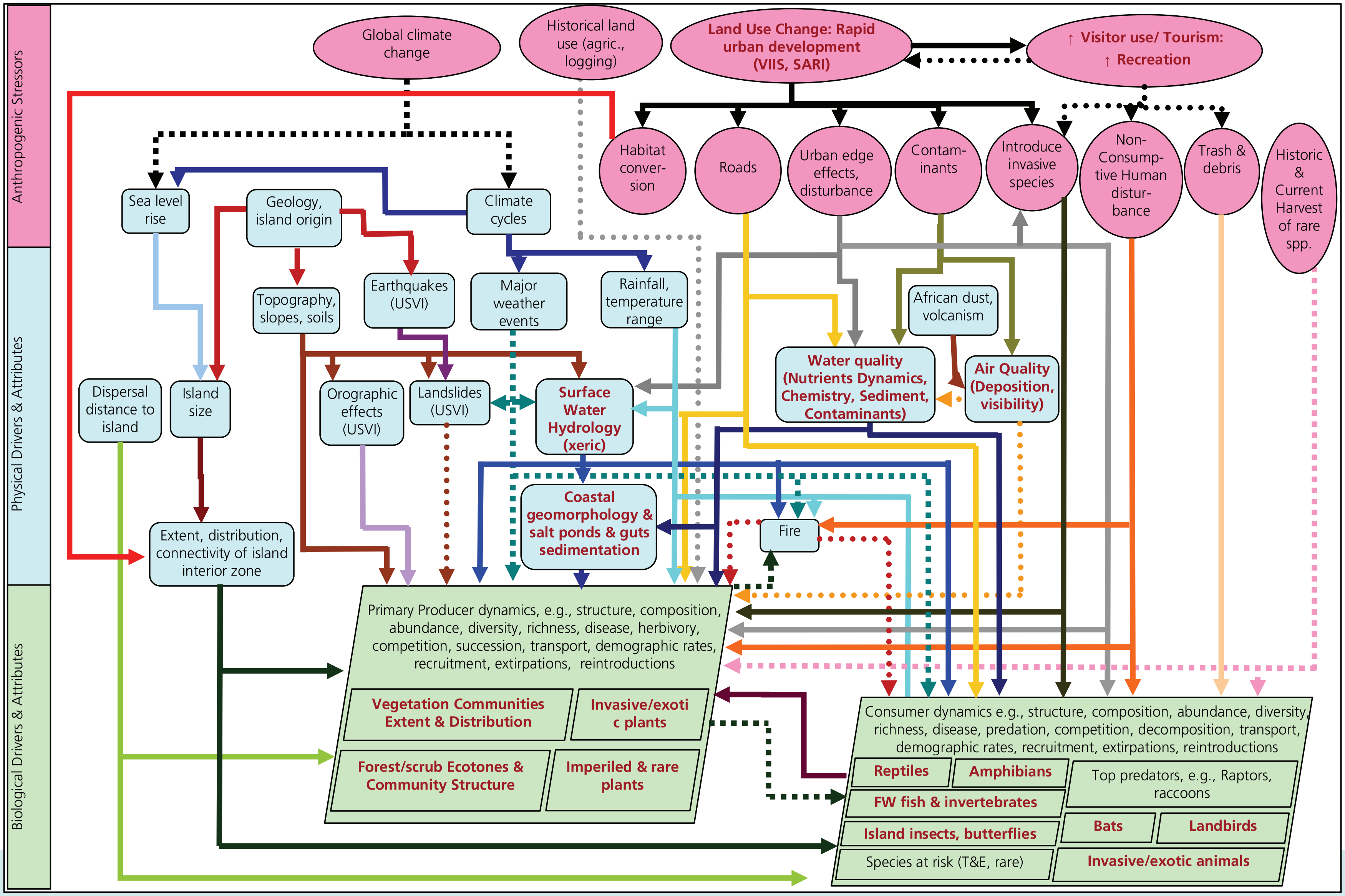


Figure 2-G. Island interior ecological zone conceptual model diagram. Solid and dotted lines show assumed effects of anthropogenic stressors, physical and biological drivers and attributes. Boxes with red print directly relate to a selected Vital Sign. (Use of dotted lines is to clarify and does not indicate lesser importance.)

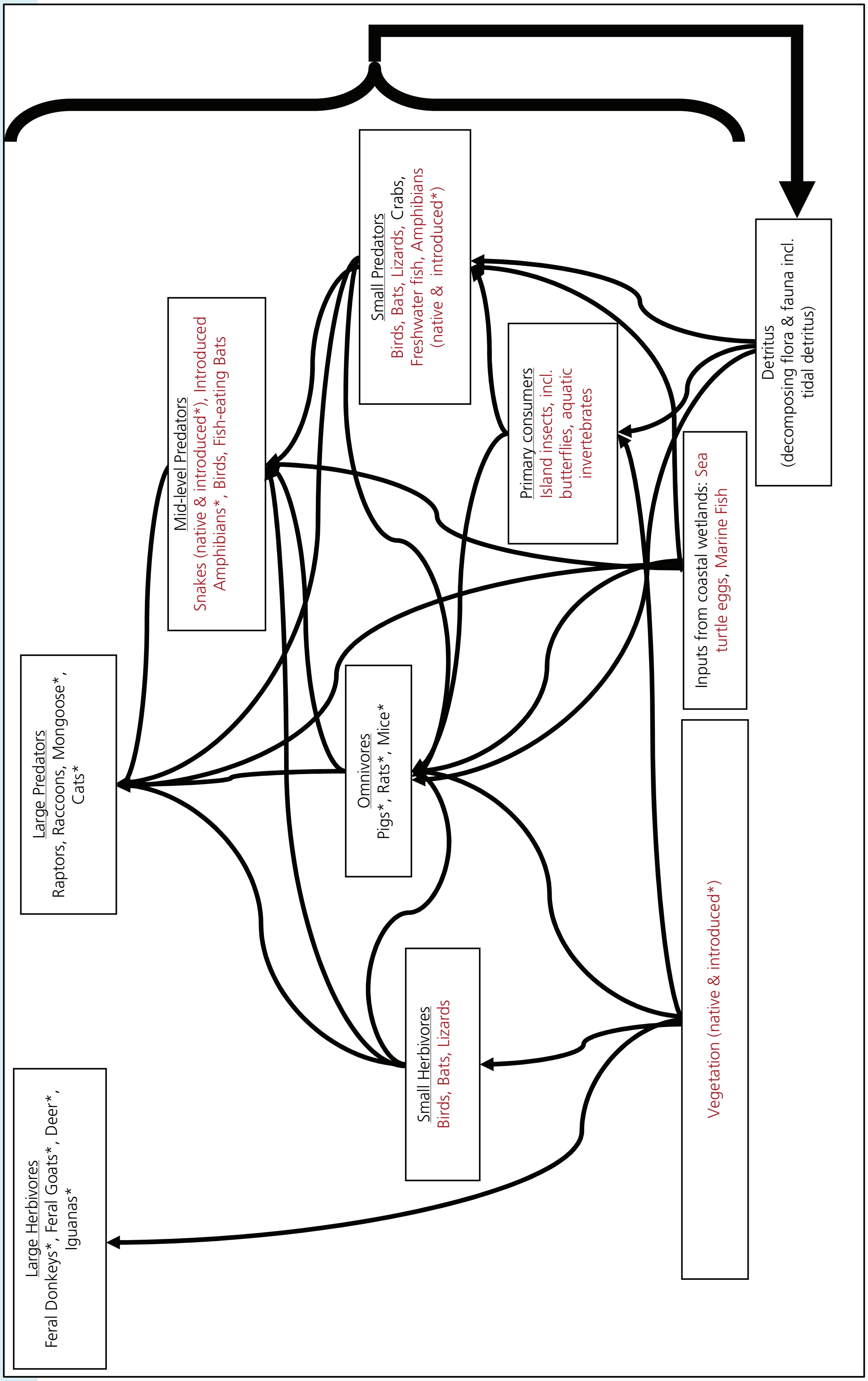


Figure 2-H. Island interior food web. Introduced species have had a major impact and are indicated by a "*". Red items are directly related to a selected Vital Sign.

2.5 Coastal Wetlands Zone

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.

Mangroves: Mangrove forests are found along shorelines and in the coastal channels and winding rivers in south and central Florida and the Caribbean. 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 as 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., Shark River in EVER). 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. Typical

Top: Red mangroves along western edge of Biscayne Bay, BISC.

Bottom: Salicornia marsh with dead black mangrove remnants from hurricane damage in EVER. Buttonwoods are in background on the left.

Top: Salt pond in VIIS.

Bottom: Sandy beach on Buck Island, BUIS

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 VIIS, BUIS, and SARI inside the mangroves that are maintained through tidal seepage or periodic breaching of the coastal berm. 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 (*Fulica Americana*), scaup (*Aythya affinis*), widgeon (*Anas americana*) and pintail (*Anas acuta*)(Davis 2004b).

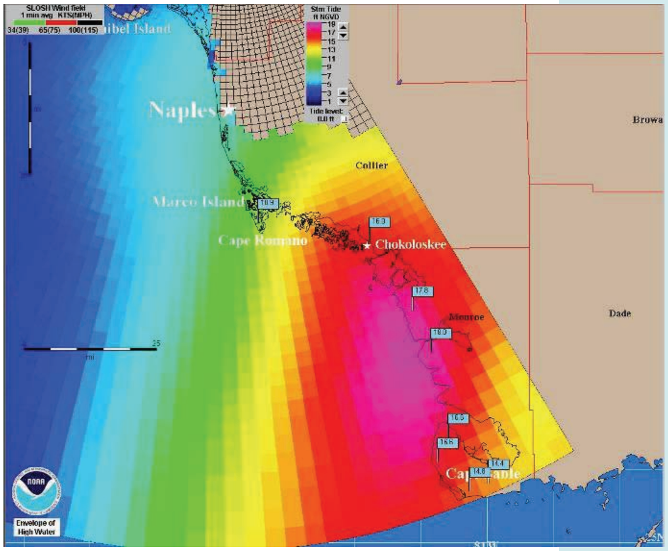
Tidal flats: Tidal flats in Florida Bay and other coastal areas vary from calcareous, carbonate muds to sandy areas exposed during low tides and are popular feeding grounds for shorebirds and wading birds.

Beaches: Beaches in the SFCN vary from narrow beaches fringed by mangroves, to some areas of wider sandy beaches in BUIS, DRTO and EVER, and include calcareous mud/sand beaches, coralline beaches, and gravel beaches.

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 (*Farfantepenaeus duorarum)*, 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 and smaller mangrove islands 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.

A diagram showing the key drivers and stressors affecting vegetation community and consumer community dynamics is given in Figure 2-I. Issues are briefly summarized below with more details provided in Appendix J.6.

The coastal wetlands zone is highly dynamic zone influenced by freshwater inputs, currents and tides, sea level rise, major weather events, coastal geomorphology, and water quality. The mixture of freshwater inputs, currents and tides influences the salinity regime and coastal geomorphology which in turn strongly influence the vegetation community that establishes there. Mangrove estuaries are considered among the most productive in the world and are the climax community for this zone. Mangroves themselves contribute detritus, and mangrove roots provide substrate for algal growth – both of which greatly add to the estuarine and coastal productivity. This is an environment of extremes and vegetation must tolerate wide swings in inundation, and water chemistry (e.g., salinity, temperature, dissolved oxygen and pH). 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. As sea level rises, the mangroves wetlands may either be able to remain in place due to soil accretion or may be pushed inland into freshwater marshes and forests or up against an urban edge. This will partially be offset by freshwater inputs in EVER, BICY and BISC which if restored from their currently low levels may help slow these ecotonal changes. Hurricanes and tropical storms, in addition to creating general vegetation destruction, can alter coastal geomorphology by causing breaks in berms, reconnecting/disconnecting salt ponds and lagoons to/from the sea, moving large amounts of sediment, and creating new berms. Storms can also cause sudden changes in inland movement of coastal wetlands by carrying salt water and propagules inland. These alterations are difficult to predict.



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).

The vegetation in this zone is affected by other drivers and stressors as well. Sediment runoff from coastal development into coastal wetlands is a problem in VIIS with some salt ponds filling up and more depositing in the mangroves and some washing out to the coastal reefs. Nutrient enrichment could also lead to algal blooms which can then cause local dissolved oxygen problems for fish and aquatic invertebrates. Invasive plant species, such as Brazilian pepper (*Schinus terebinthifolius*), lather leaf (*Colubrina asiatica*), and Australian pine (*Casuarina equisetifolia*) are displacing native vegetation. Dredging outside the parks could bring contaminants into the park. Other sources of change are more localized such as boat groundings, illegal collection, herbicide use, and tree-trimming by uninformed land-owners. However, if unmanaged, these smaller stressors can also have a large cumulative negative impact on the resources.

The highly productive mangrove estuaries in turn provide productive nursery grounds for juvenile fish and invertebrates such as sea trout (*Cynoscion nebulosus*), common snook (*Centropomus undecimalis*), pink shrimp, bivalves and conch, and sawfish (*Pristis pectinata*). A

Entangled dead frigate bird on Buck Island, BUIS.

simplified food web model showing the relationship between mangrove wetlands and reef fish communities is given in Figure 2-J. 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. 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 (*Ajaia ajaja*), least terns (*Sterna antillarum*), roseate terns (*Sterna dougailii*), sooty terns (*Onychoprion fuscatus fuscatus*), brown pelicans (*Pelecanus occidentalis*), brown boobies (*Sula leucogaster*), masked boobies (*Sula dactylatra*), magnificent frigatebirds (*Fregata magnificens*), and others.

Baby sea turtles scramble to sea on Buck Island, BUIS.

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 meets the Gulf of Mexico. Similarly, changes in the salinity gradient affect productivity in the bays. Decreases in freshwater inputs to Everglades National Park over the past 50 years have resulted in increased salinity levels in Florida Bay and 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 and abundance of crocodiles (*Crocodylus acutus*). Adult crocodiles are able to tolerate higher salinities than alligators, but 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).

Some additional drivers and stressors affecting coastal wetland food webs include crocodilians, invasive species, contaminants, excessive trash, and visitor use. Crocodiles may play an important role in keeping some tidal channels open. Invasive estuarine species are a major concern in all parks with the Mayan cichlid already severely altering estuarine fish communities in Florida Bay (Davis 2004b). Other introduced cichlids are listed in Appendix N. Aquariums, ship bilge water and boat motors are all sources of introduction of aquatic invasives. Small islands in this zone have been critically important in providing predator free seabird, wading bird and sea turtle habitat and the introduction of invasive terrestrial predators, such as rats and pythons, or even trash-subsidized native predators such as raccoons can be devastating. Contaminants such as mercury, pesticides, herbicides, and oil from aerial deposition, urban runoff, ships, and off-shore dumping are all problems. Catastrophic oil or chemical spills are a real concern as all parks are near or contain shipping lanes and St. Croix contains an oil refinery. Excessive trash levels from off-shore dumping, lost nets and lines, and storm debris 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. Visitor disturbance of nesting seabirds and sea turtles and illegal collection of eggs or rare plants are continuing concerns.

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.

The vital signs that relate to the Coastal Wetlands Zone conceptual model include:

- Air Quality-Deposition
- Air Quality-Mercury
- American crocodile
- Amphibians
- Bats-USVI
- Coastal Geomorphology
- Colonial Nesting Birds
- Contaminants
- Estuarine Salinity Patterns
- Focal Fish Species
- Forest Ecotones and Community Structure
- Invasive/Exotic Animals
- Invasive/Exotic Plants
- Island Insects
- Land Use Change
- Landbirds
- Mangrove-Marsh Ecotone
- Marine Exploited Invertebrates
- Marine Fish Communities
- Marine Infaunal Community
- Nutrient Dynamics
- Periphyton (Freshwater)
- Phytoplankton (Marine)
- Protected Marine mammals
- Reptiles-USVI
- Sawfish
- Sea Turtles
- Surface Water Hydrology
- Vegetation Communities Extent & Distribution
- Visitor Use
- Water Chemistry
- Wetland Ecotones and Community Structure

Sooty terns and brown noddys, DRTO.

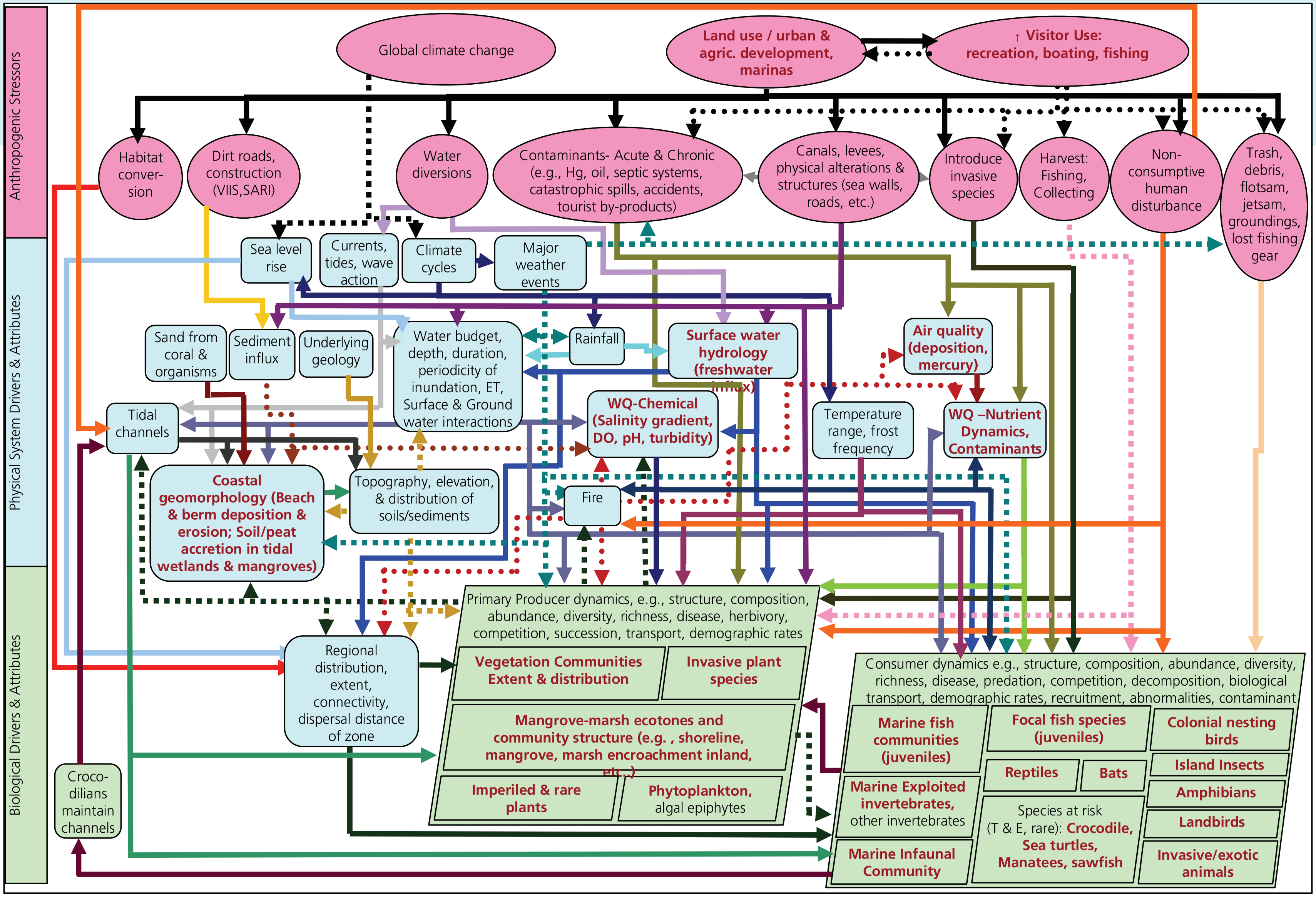


Figure 2-I. Coastal wetlands ecological zone conceptual model diagram. Solid and dotted lines show assumed effects of anthropogenic stressors, physical and biological drivers and attributes. Boxes with red print directly relate to a selected Vital Sign. (Use of dotted lines is to clarify and does not indicate lesser importance.)

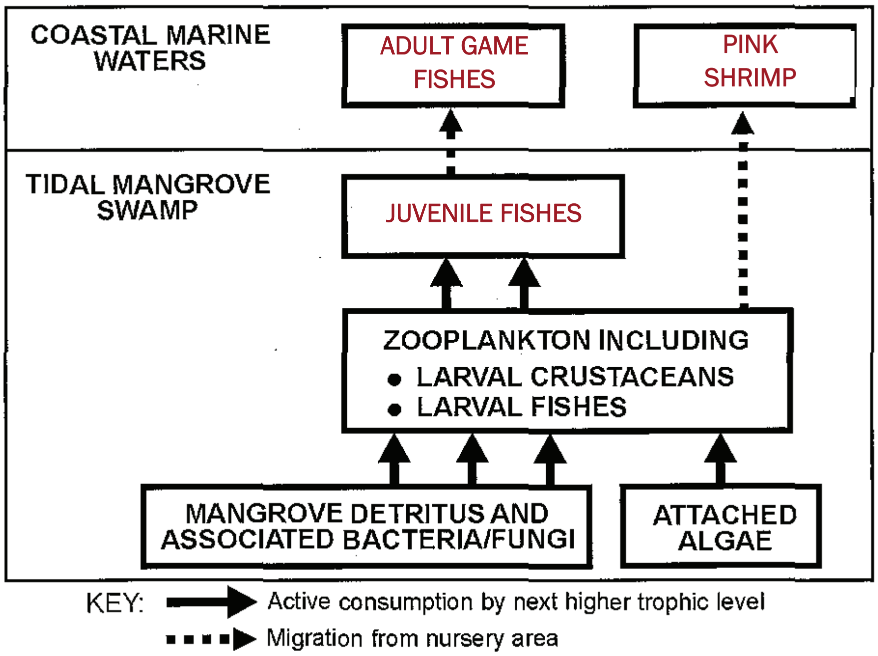
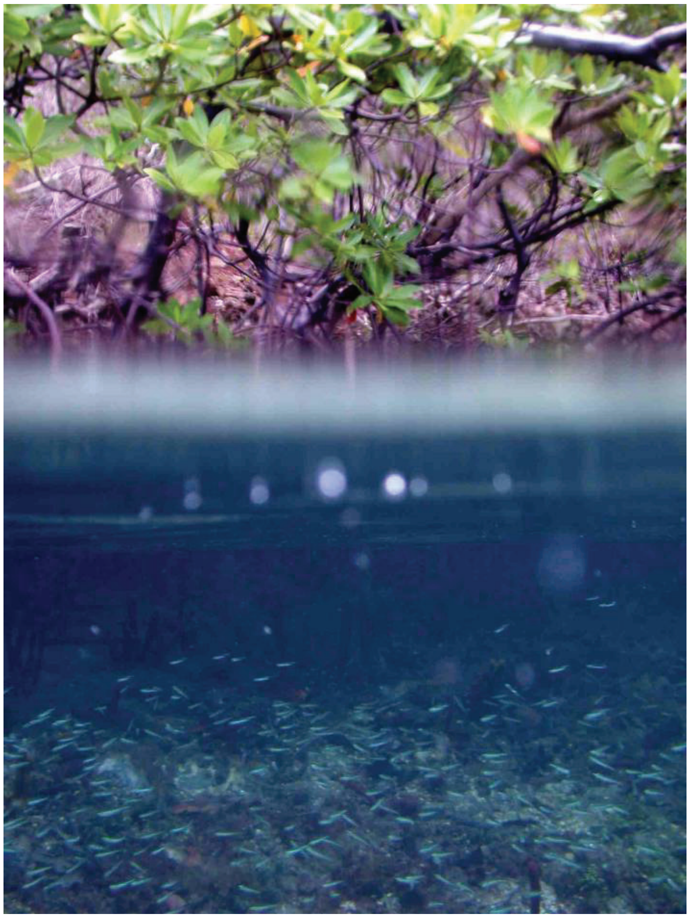


Figure 2-J. Mangrove estuarine effects on food web (From Lodge 2005; used with permission).



Fish among mangrove roots in VIIS.

2.6 Florida and Biscayne Bays Ecological Zone

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. 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, the turbidity of the bay has increased.

Top: Florida Bay from Flamingo, EVER.

Bottom: Biscayne Bay looking towards keys in background. Water quality station visible in lower right.

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. 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 (*Trichechus manatus*), 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 (*Panulirus argus*), crabs, and pink shrimp. Biscayne Bay is also valued for its good water quality and clarity.

A diagram showing the key drivers and stressors affecting vegetation community and consumer community dynamics is given in Figure 2-K. Issues are briefly summarized below with more details provided in Appendixes J.7 and J.9.

The extent and health of the seagrass beds within both shallow bays as well as the mangroves and tidal marshes bordering the bays all contribute to primary and secondary productivity within the bays. Seagrass covers large portions of the soft-bottom areas of Biscayne Bay and Florida

Bay. Seagrass community composition is a good indicator of water quality as composition changes in response to estuarine salinity patterns, nutrients levels, as well as currents, light, and time since disturbance. Seagrass beds in Biscayne Bay appear to be doing well. However, in Florida Bay a large seagrass dieoff occurred in 1987, the causes of which are still unclear and from which the bay has not recovered. Both Biscayne Bay and Florida Bay historically had greater freshwater surface and groundwater influx than at present. With the reduction of freshwater influx, both bays have become more saline with less areas of brackish water. Hardened structures such as the Flagler Railway have altered currents through Florida Bay and canals have restricted flows to Biscayne Bay which have reduced associated coastal wetlands. Rehabilitation of flows by the Comprehensive Everglades Restoration Plan (CERP) is expected to decrease the salinity in the bays which are expected to affect seagrass community composition as well as improving coastal wetlands. Effects of sea level rise are difficult to predict, but it may cause retreat of mangroves inland with some resulting expansion of both Biscayne and Florida Bays, increase in depths, alteration in currents within the basins in the bays, and increase of the tidal prism.

Other stressors of seagrass and other submerged aquatic vegetation are also impacting resources. Scarring of seagrass beds occurs by boat groundings and propeller scars from careless boat drivers. Hurricanes can cause seagrass “blow-outs” as well as increasing probabilities of boat groundings and debris which abrade habitats. Storms also alter coastal geomorphology and mud banks which in turn affect currents and tidal flushing. Seagrass scars can take decades to recover and can even expand through time depending on tides and currents. Damaging fishing methods such as trawls which drag across the bottom may also damage habitats. In addition to increased nutrient loading causing changes in seagrass communities, excessive nutrients have resulted in algal blooms, especially in southern Biscayne Bay, Card Sound, Barnes Sound and northeastern Florida Bay. Algal blooms are destructive, cutting off light to seagrass communities and, as the algae decomposes, reducing oxygen for fish and invertebrates. Black water events have also occurred which appear algae related but whose cause is less clear. Excessive nutrients are thought to come from agricultural runoff, construction projects and malfunctioning septic systems.

Seagrass bed in BISC.

The extent of seagrass, mangroves and tidal marsh strongly affects the associated fish and invertebrate communities that utilize these habitats. A simplified food web model that applies to both the bays and marine areas is given in Figure 2-L. Approximately 70 percent of South Florida's recreationally and commercially important fishes, crustaceans, and shellfish spend a portion of their young lives in the bays’ protective environment. Fish and other fauna migrate between the bays and the productive coral reefs and areas outside the bays. Manatees spend considerable time foraging in seagrass habitats and dolphins are a frequent sight. Coastal wetlands of the bays provide important habitat for juvenile fish and invertebrates that later move deeper into the bays and out onto the reefs of the coastal shelf. Reductions in freshwater input coupled with habitat conversion and channelizing of flows have severely restricted and in places eliminated

Water quality instrument in BISC.

brackish water and brackish estuarine habitat within the bays, especially Biscayne Bay, which in turn have greatly reduced nursery habitats for juvenile fish species, shrimp and crabs, causing local declines in species such as sea trout, common snook, red drum (*Sciaenops ocellatus*), tarpon (*Megalops Atlanticus*), oysters (*Crassostrea virginica*), manatees, and crocodiles and impacted shorebird, wading bird and seabird communities. The rapid increase in local human populations has lead to great increases in visitor use resulting in increased levels of boating and fishing that have strongly affected fish communities (both bays) and invertebrate communities (Biscayne Bay). In Biscayne Bay, abandoned or "ghost" traps continue to collect and eventually kill fish and crustaceans. Boat collisions with wildlife, especially manatees, remain a problem. Increases in contaminants and trash refuse have potentially impacted upper trophic level species such as dolphins, crocodiles, large fish, and manatees either directly or through changes in prey communities or bioaccumulation of toxins. Pollutants such as pharmaceuticals, birth control pill hormones, caffeine, antibiotics, etc. are an emerging concern as they are not normally filtered during sewage treatment. Dredging north of Biscayne Bay has the potential to release contaminants which will affect the park. Storms also have the potential to cause contaminant spills as water treatment systems are overwhelmed and boats are capsized. As a consequence of these changes, biota in the bays are under stress. Fish communities are changing and some species such manatees, sawfish, and crocodiles are federally listed as endangered.

Current major management issues in the Florida and Biscayne Bays Ecological Zone include rehabilitation of freshwater inputs, reductions in or mitigation of contaminants and debris, management of fishing, boating, and recreation, restoration of damaged seagrass or mangrove areas, 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.

The vital signs that relate to the Florida and Biscayne Bays Zone conceptual model include:

- Air Quality-Deposition
- Air Quality-Mercury
- American crocodile
- Benthic Communities Extent & Distribution
- Coastal Geomorphology
- Colonial Nesting Birds
- Contaminants
- Estuarine Salinity Patterns
- Focal Fish Species
- Invasive/Exotic Animals
- Land Use Change
- Mangrove-Marsh Ecotone
- Marine Benthic Communities
- Marine Exploited Invertebrates
- Marine Fish Communities
- Marine Infaunal Community
- Nutrient Dynamics
- Phytoplankton (Marine)
- Protected Marine mammals
- Sawfish
- Sea Turtles
- Surface Water Hydrology
- Visitor Use
- Water Chemistry

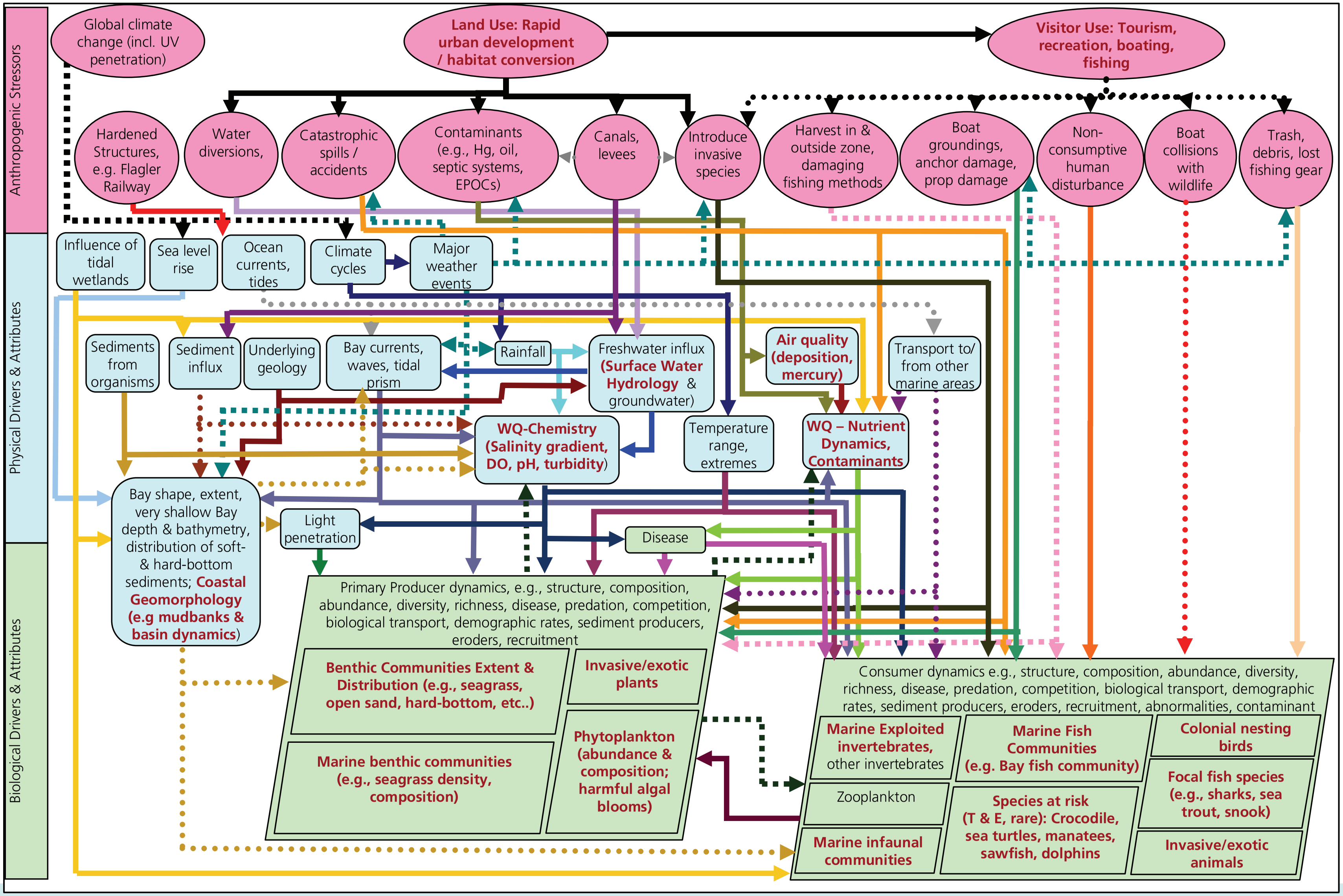


Figure 2-K. Florida and Biscayne Bays Ecological Zone conceptual model diagram. Solid and dotted lines show assumed effects of anthropogenic stressors, physical and biological drivers and attributes. Boxes with red print directly relate to a selected Vital Sign. (Use of dotted lines is to clarify and does not indicate lesser importance).

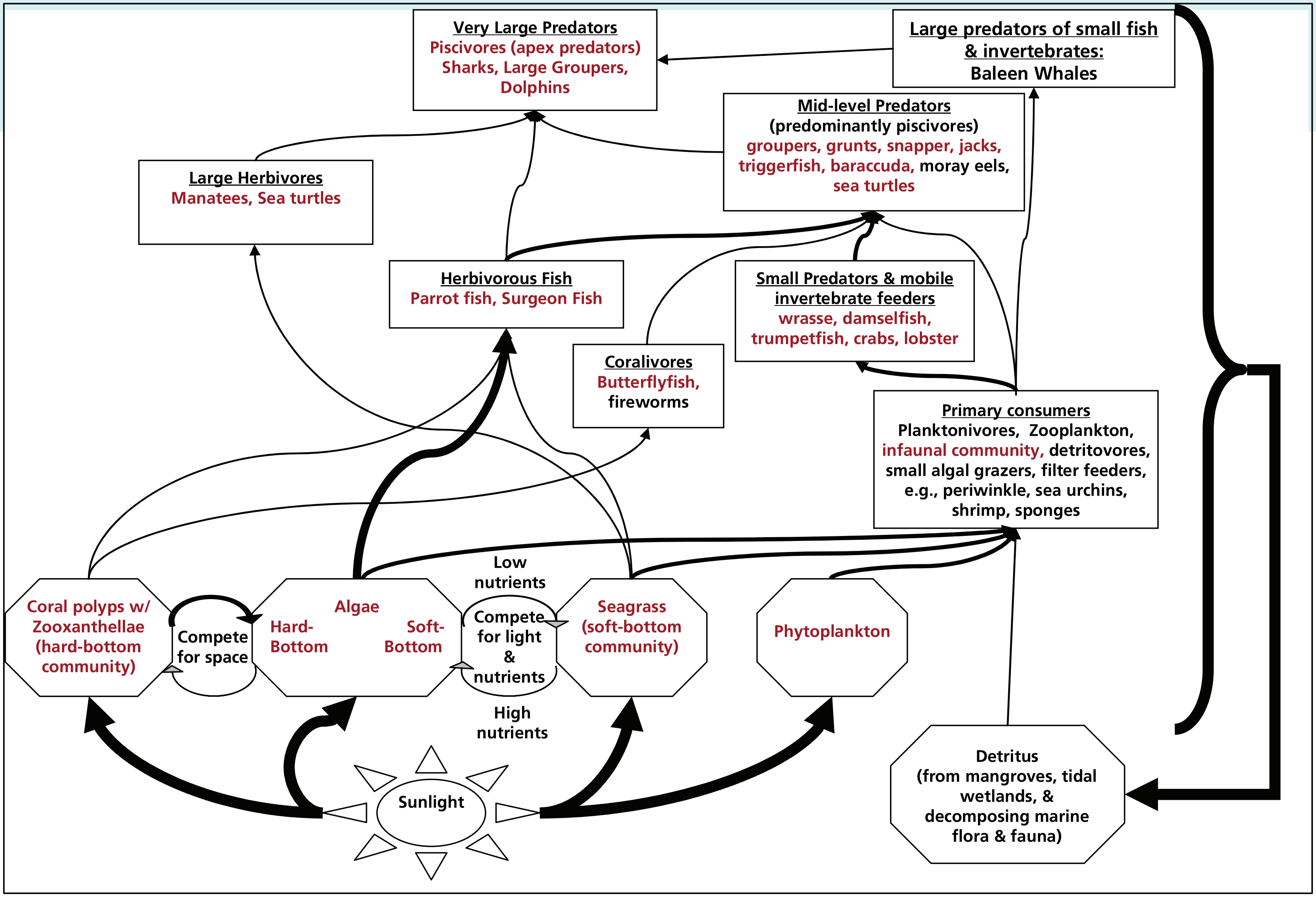


Figure 2-L. Simplified conceptual model of marine community food web in south Florida and Caribbean parks. The width of the connecting line represents the hypothesized effect strength. Sea turtles are located in both “Large Herbivores” & “Mid-level Predators” boxes.

2.7 Coastal Shelf and Deep Oceanic Ecological Zone

The Coastal Shelf and Deep Oceanic Ecological Zone includes the marine park areas with the exception of areas covered in the Florida Bay and Biscayne Bay model. Thus, this zone includes the marine areas of VIIS, BUIS, DRTO, SARI, 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 (not yet included in the network of SFCN parks).

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 large fish, sea turtles, dolphins, sharks, and whales.

A diagram showing the key drivers and stressors affecting vegetation community and consumer community dynamics is given in Figure 2-M. Issues are briefly summarized below with more details provided in Appendix J.8 and J.9.

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.

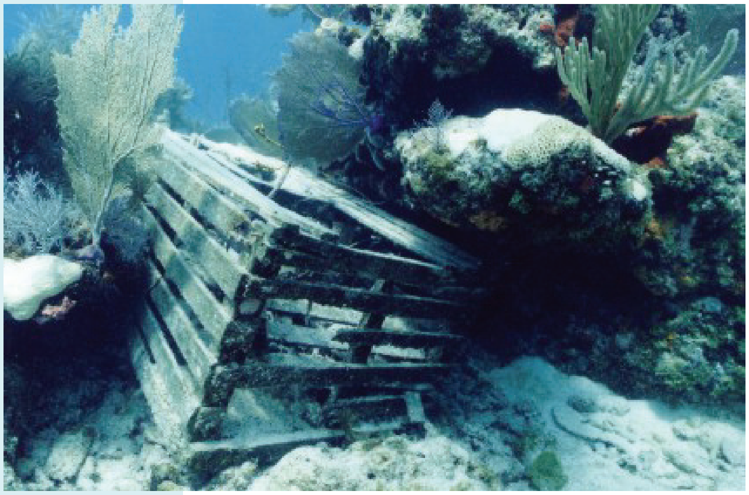
Elkhorn coral (*Acropora palmata*) at Hawksnest reef on north side of St. John, U.S. Virgin Islands.

The extent and distribution of hard-bottom and soft-bottom sediments affects the resulting benthic communities that emerge. Seagrass and other submerged aquatic vegetation dominate the soft-bottomed communities whereas hard- and soft-corals, sponges and algae dominate the hard bottomed communities. Many of the stressors affecting seagrass are similar to the bays model with a few exceptions: changes in salinity are not much of an issue in the coastal zone with the possible exception of Salt River Bay in SARI and occasionally during large rain runoff events in VIIS and west EVER. Nutrient enrichment is a concern primarily due to malfunctioning septic systems, problems during major storms, and possibly large cruise ships which carry as many as 5000 people. Sediment runoff is a large concern in the USVI due to the rapid development occurring on steep slopes causing problems for both seagrass and coral communities. Disease and invasive species could become issues in the future. Algal blooms are rarely a problem but could increase in frequency as development continues.

Blue tangs U.S. Virgin Islands.

Coral reef communities are already under severe stress Caribbean-wide. Outbreaks of coral disease, increased coral bleaching due to rising ocean temperatures, nutrient enrichment and sedimentation problems in VIIS, contaminant problems, altered food webs, boat groundings, anchor damage, and visitor disturbance (kicking, touching reef by divers) are all taking heavy tolls on the coral reefs. Lost traps and lines and storm debris abrade reefs causing even further damage. Losses of live coral cover are rarely, if ever, "recovered," with that lost substrate being colonized by algae for decades. Nutrient enrichment coupled with the loss of herbivorous fish and the herbivorous long-spined sea urchin (*Diadema antillarum*) have resulted in algal overgrowth that inhibits coral recruitment. Coral communities are so sensitive to water quality degradation, they have been proposed as a water quality indicator by the EPA. 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. 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. Black coral (*Antipathes* spp.) have been further hit by over-harvesting for jewelry and are now also considered rare. With increasing urban development and tourism coupled with global climate change and intense fishing pressures, these problems are expected to only get worse.

Lost trap lodged in coral reef at Biscayne National Park.



The simplified food web model given in Figure 2-L also applies to the Coastal Shelf and Deep Oceanic Zone. Marine fish and exploited 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 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. Recently, introduced species such as the lionfish (*Pterois spp.*) have become more of a concern. Contaminant concerns are similar to those discussed in the Florida and Biscayne Bays zone.

Buck Island Reef National Monument has been established as a no-fishing zone and a section of Dry Tortugas National Park has a Research Natural Area (RNA) zoned and implemented 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 long-term monitoring.

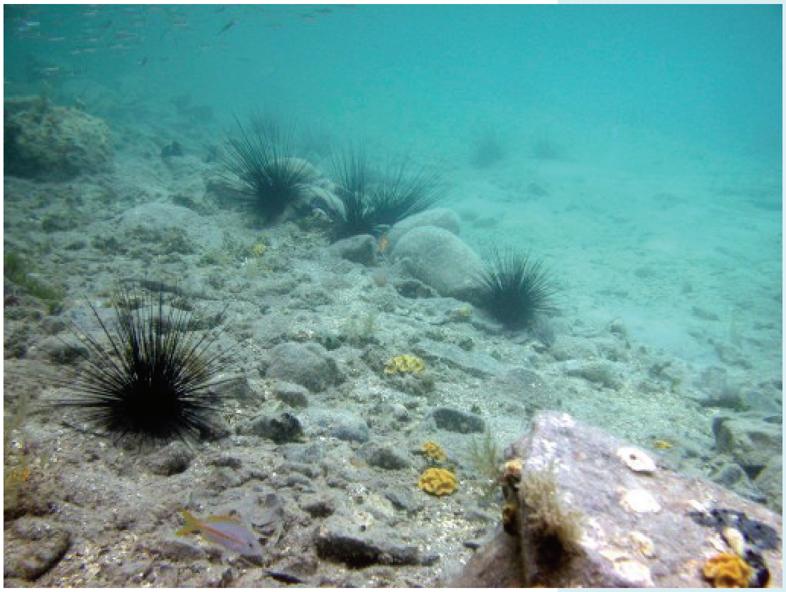
Current major management issues in the Coastal Shelf and Deep Oceanic Ecological Zone include reduction of sediment inputs, reductions in or mitigation of contaminants and debris, management of fishing, boating, and recreation, including "no-take" zones, and protection and management of rare plants and animals. Control of invasive species could become a larger concern in the future.

The vital signs that relate to the Coastal Shelf and Deep Oceanic Zone conceptual model include:

- Air Quality - Deposition
- Benthic Communities Extent & Distribution
- Contaminants
- Estuarine Salinity Patterns
- Focal Fish Species
- Invasive/Exotic Animals
- Land Use Change
- Marine Benthic Communities
- Marine Exploited Invertebrates
- Marine Fish Communities
- Marine Infaunal Community
- Marine Invertebrates-Rare, Threatened, Endangered (RTE)
- Nutrient Dynamics
- Phytoplankton (Marine)
- Protected Marine mammals
- Sawfish
- Sea Turtles
- Surface Water Hydrology
- Visitor Use
- Water Chemistry

Left: Undersized lobsters illegally taken at BISC (Photo from BISC staff).

Below: Long-spined sea urchins are important herbivores on reefs that appear to be recovering from a Caribbean-wide dieoff.



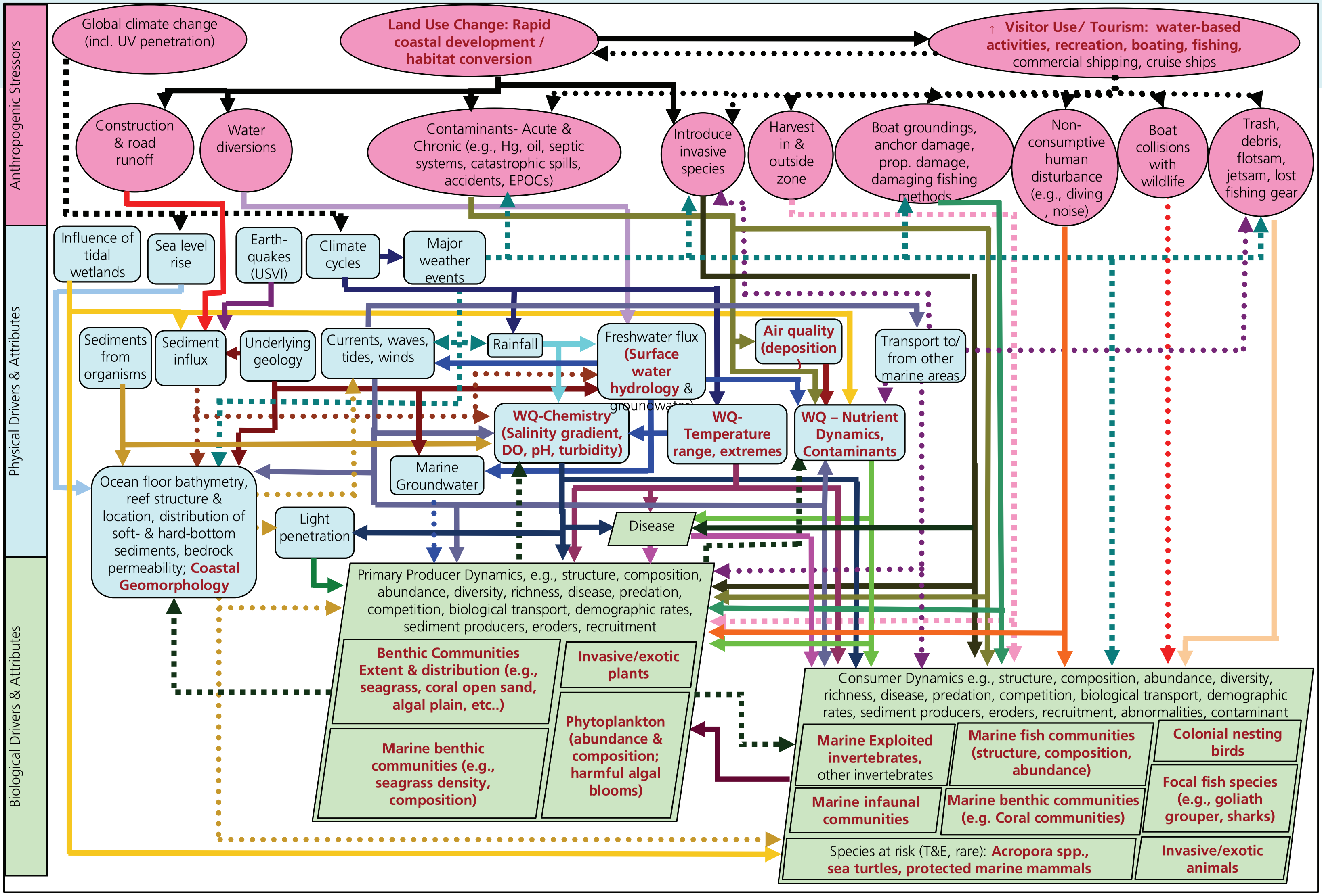


Figure 2-M. Coastal Shelf / Deep Oceanic Ecological Zone conceptual model diagram. Solid and dotted lines show assumed effects of anthropogenic stressors, natural system drivers, and biological attributes upon each other. Boxes with red print directly relate to a selected Vital Sign. (Use of dotted lines is to clarify and does not indicate lesser importance).

Chapter 3: Vital Signs

3.1 Introduction

"Vital Signs" are a "*subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values. The elements and processes that are monitored are a subset 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 those resources.*" (http://science.nature.nps.gov/im/monitor/glossary.cfm)

This chapter describes the 44 vital signs identified for the SFCN, the process used to identify them, their relationships in the conceptual models, which ones will be implemented with current funding, the subset of core vital signs that SFCN will be focusing most of its energy on, and the relationship to existing programs.

3.2 Process for Choosing Vital Signs

The network developed its prioritized list of vital signs through initial scoping of management issues in the parks, development of conceptual models, holding indicator identification workshops, conducting online web ranking, and meetings with the Board of Directors (BOD) and Science and Technical Committee (STC) (see Table 3-A).

The SFCN has been gathering information about natural resource management issues since 2001 through meetings, surveys, and data mining, which were used in the development of the network Conceptual Ecological Models (CEM) (See Chapter 2 and Appendix J). These models helped focus discussion and facilitate the identification of potential Vital Signs indicators at three Indicator Identification Workshops held from January through March of 2006:

1) Bays and Marine Ecosystems of South Florida;
2) Wetlands and Uplands of South Florida; and
3) United States Virgin Islands (USVI) Ecosystems.

The workshop participants reviewed the conceptual models, identified important indicators and developed indicator worksheets. In the USVI workshop, participants reviewed indicator worksheets developed in the two South Florida workshops, expanded those indicators and added new ones to ensure coverage of USVI ecosystems. The workshop and ranking process is covered in detail in Appendix O. The seventy workshop participants represented NPS staff, U.S. Geological Survey, National Oceanic and Atmospheric Administration, South Florida Water Management District, USVI-Department of Planning and Natural Resources, local universities, NGOs, and other local experts (full participant list in Appendix O.2).

Local experts identify indicators at South Florida Wetlands and Uplands indicator identification workshop.

Table 3-A. Summary of steps taken in identifying and prioritizing SFCN Vital Signs

Time	Event	Steps taken	Product
2001-2003	Management issues survey	Initial identification and ranking of park management issues and monitoring needs	Appendix G
January- August 2005	Conceptual model development	SFCN staff drafted conceptual models to assist Vital Signs identification	Appendix J
Sept. - Dec. 2005	Meetings with park staff	Presentations to park staff on vital signs process and lists of existing monitoring programs compiled	Appendix H
January - March 2006	Vital Signs Indicator Identification workshops	In three workshops, 72 workshop participants reviewed network conceptual models, identified 69 potential indicators, and filled out indicator worksheets	Appendix O.1, O.2, O.6
April 2006	Vital Signs Web-based Ranking Process	The indicator worksheets were loaded into an online database. 102 area scientists, park and agency staff ranked the indicators for "Ecological Significance" and "Feasibility"	Appendix O.3, O.4
May 2006	Vital Signs Ranking Meeting	SFCN Board of Directors and Science & Technical Committee reviewed the ranked list of indicators, reduced the number to 62 indicators, made minor modifications, and accepted the list.	Appendix O.5
June - Sept. 2006	Vital sign consolidation	SFCN staff consolidated the 62 indicators into 41 vital signs and assigned funding categories	Appendix O.6
October 2006	Science & Technical Committee Meeting	Review of revisions to vital sign list and funding assignments	
January – August 2007	Vital Sign Strategies & Protocol Development Summaries	SFCN staff draft vital sign strategies and protocol development summaries, assess funding/staff requirements & revise vital sign funding categories	Chapter 5, Appendix P, Q
Sept. 2007 – April 2008	Review & Finalize List	SFCN Vital Signs Plan reviewed by Science & Technical Committee, External Reviewers, and WASO. New vital signs added: Air Quality-Deposition; Air Quality-Mercury; Water Chemistry	Table 3.4-A

SFCN Vital Signs Ranking Meeting participants

69 indicator worksheets were uploaded into the SFCN ranking database and then ranked via the web for ecological significance and feasibility using neutral ranking criteria by 102 workshop attendees, park staff, and other interested members of the scientific community (see Appendix O.3).

During May 9-10, 2006 the SFCN Board of Directors and the Science and Technical Committee discussed the rankings, asked for some indicators to be consolidated, made some minor modifications below the top 20, and agreed upon the list. The group also agreed that monitoring contaminants was very important; but, was cost prohibitive to take on at the current level of network funding. Each park then prioritized the top half of the indicators with regards to importance to management (see Appendix O.5).

The revised list of 62 indicators 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 further consolidated the indicators, added two Air Quality vital signs and a Water Chemistry vital sign for a total of 44 vital signs, and placed them in the National Inventory and Monitoring Program framework (Table 3-B). The original indicator details (see Appendix O.6) and rankings were retained and used in the development of the final monitoring program.

3.3 Vital Signs for the South Florida / Caribbean Network

SFCN's 44 vital signs are shown in Table 3.3-A in the national framework by funding category and with suggested measures. Funding constraints will unfortunately allow SFCN to monitor only some of the vital signs. The criteria used to select those vital signs that SFCN will implement during the next 3-5 years included:

- Indicator rankings
- Opportunities to collaborate (e.g., CERP, park monitoring, NOAA)
- Opportunities where co-location or other techniques can reduce costs
- Suites of indicators that when monitored together synergistically add value by describing system condition more completely, even though some individually may have ranked lower
- Low-cost indicators which could be accomplished with little additional funding despite ranking slightly lower than more expensive indicators

It should be noted that NPS I&M funding cannot be used to replace existing monitoring program funding by other entities.

The vital signs were categorized by park as

- (+) Category 1: Vitals signs for which the network will develop protocols and implement monitoring using funding from the vital signs and water quality monitoring programs.
- (◊) Category 2: Vital signs that are being monitored by a network park, another NPS program, or by another federal or state agency using other funding. The network will collaborate with these other monitoring efforts. In some cases SFCN staff may participate in monitoring and/or analysis but commitment is $10K or less of staff time and resources per year.
- (○) Category 3: Vital signs which cannot currently be implemented because of limited staff and funding.
- (-) Vital sign either does not apply to the park or is of minimal importance to park management.

A revised rank for each vital sign was created by assigning each vital sign the rank of the highest ranking workshop indicator it contained and then collapsing the list. During the subsequent planning however, the original ranks and indicator worksheet details for the multiple indicators that compose each vital sign were kept in mind.

Some adjustments were made to the list to better coordinate with the National I&M program. The workshops identified generalized vegetation ecotones and community structure vital signs. However to fit with the National I&M program framework, these general vegetation vital signs were split into three – "Mangrove-Marsh Ecotone," "Forest Ecotones and Community Structure," and "Wetland Ecotones and Community Structure" – and assigned the same priority rank. Three additional vital signs were added after the vital signs ranking process to coordinate better with the NPS-Air Resources and NPS Water Resources Divisions: "Air Quality- Deposition", "Air Quality-Mercury", and "Water Chemistry."

For those who may be confused looking for a single "Water Quality" vital sign, multiple vital signs were included: "Estuarine salinity patterns," "Nutrient Dynamics," "Water Chemistry", and "Contaminants." A weather and climate vital sign was not identified in the workshops and is not included; however rainfall will be tracked as part of the "Surface water hydrology" vital sign.

3.4 Links of Vital Signs to Conceptual Models

Use of the conceptual models in Appendix J coupled with the high level of experience the workshop participants had with indicator selection relating to the Comprehensive Everglades Restoration Plan, the U.S. Virgin Islands Prototype, and other indicator identification efforts, led to selection of vital signs with strong linkages to the key issues and resources discussed in Chapter 2 and in greater depth in the Appendix J (see Table 3-C and Appendix J).

Hermit crab race used as ranking tie breaker

Table 3-B. SFCN Vital Signs and measures in national framework by level of funding.

National I & M Program Framework			Network Vital Sign [rank]	Measures	Funding Category						
Level 1	Level 2	Level 3			BICY	BISC	BUIS	DRTO	EVER	SARI	VIIS
Air and Climate	Air Quality	Wet & Dry Deposition	Air Quality-Deposition	Wet/dry deposition of anions, cations	○	○	○	○	◊	○	◊
		Air Contaminants	Air Quality-Mercury	Mercury deposition	○	○	○	○	◊	○	○
Geology & Soils	Geomor-phology	Coastal/ Oceanographic Features and Processes	Coastal Geomorphology [27]	Soil elevation change in mangroves & salt ponds, location & extent of mud banks, buttonwood embankment and berms	-	+	+	-	+	+	+
		Stream/River Channel Characteristics	Wetland substrate [35]	Extent and distribution of substrate type (marl vs. peat), sediment elevation changes in cypress strands/domes	○	-	-	-	○	-	-
Water	Hydrology	Surface Water Dynamics	Surface Water Hydrology [3]	Water stage, flow, timing, and duration, discharge of freshwater to specific estuaries, rainfall	◊	◊	+	◊	◊	+	◊
	Water Quality	Water Chemistry	Estuarine salinity patterns [9]	Conductivity converted to practical salinity units, pH, DO, temperature in the marine water bodies (coastal embankments, central bay, "open" bay)	-	◊	-	-	◊	○	○
			Water Chemistry	Temperature, DO, pH, Conductivity, organic carbon	◊	◊	◊	◊	◊	◊	◊
		Nutrient Dynamics	Nutrient Dynamics [4]	Flux measurements of nutrients at specific locations, N, P, DO, Chl a, and other currently collected parameters.	◊	◊	○	◊	◊	○	◊
		Toxics	Contaminants [19]	Concentrations in water column, organisms, and sediments: Hg (Total/Methyl); Metals, Hydrocarbons, PAHs, Pesticide/Herbicide/Insecticide, PCB's, EPOCs (Pharms, Caffeine, Estrogen/hormone related), non-regulated contaminants (vessel anti-fouling paint).	○	○	○	○	○	○	○
		Aquatic Macroinverte-brates and Algae	Periphyton (Freshwater) [17]	Community composition & structure, organic/inorganic (calcite) content, nutrient content	+	-	-	-	◊	-	-
			Phytoplankton (Marine)[34]	Location, size, duration, and type of algal bloom events	-	◊	○	○	◊	○	○
Biological Integrity	Invasive Species	Invasive/Exotic Plants	Invasive/Exotic Plants [5]	Invasive species present, aerial extent, distribution, new exotic species detected at common invasion points categorized by invasive potential, vegetation types invaded	+	+	+	+	+	◊	◊
		Invasive/Exotic Animals	Invasive/Exotic Animals [12]	Invasive species present, distribution, vegetation types invaded, new species detected along common invasion points (e.g. canals)	+	◊	◊	◊	+	◊	◊

\+ Vitals signs for which the network will develop protocols and implement monitoring using funding from the vital signs or water quality monitoring programs.
◊ Vital signs that are being monitored by a network park, another NPS program, or by another federal or state agency using other funding. The network will collaborate with these other efforts.
○ Vital signs which cannot currently be implemented because of limited staff and funding
\- Vital sign either does not apply to the park or is of minimal importance to park management
[] indicates priority rank. 1 is highest.

Table 3-B. SFCN Vital Signs and measures in national framework by level of funding (cont.).

National I & M Program Framework					Funding Category						
Level 1	Level 2	Level 3	Network Vital Sign	Measures	BICY	BISC	BUIS	DRTO	EVER	SARI	VIIS
Biological Integrity (cont.)	Focal Species or Communities	Marine Communities	Marine Benthic Communities [1]	Percent cover of major taxonomic groups (coral, algae, gorgonians, sponge), coral species diversity,community structure, rugosity, recruitment, disease mortality, algal community structure, episodic assaults (bleaching); Seagrass and other SAV community composition, cover and habitat quality of seagrass and other SAV habitat	-	+	+	+	◊	+	+
		Intertidal Communities	Mangrove-Marsh Ecotone [14,15,16]	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	+	+	○	+	+	+	+
		Wetland Communities	Wetland Ecotones and Community Structure [14,15,16]	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	◊	◊	-	-	◊	-	-
		Forest/Woodland Communities	Forest Ecotones and Community Structure [14,15,16]	Community composition & structure (e.g. canopy height, vegetative cover by species, canopy cover in each stratum (canopy, herb layer, shrub layer)), shifts in community boundaries (e.g. hammock/pine), soil depth, litter depth	+	+	+	+	+	+	+
		Marine Invertebrates	Marine Exploited Invertebrates [10]	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)	-	+	+	+	+	+	+
			Marine Infaunal Community [36]	Species composition, abundance, distribution, species richness/ diversity, in conjunction with water and sediment quality monitoring	-	○	○	○	○	○	○
		Freshwater Invertebrates	Aquatic invertebrates in wet prairies & marshes[32]	Community composition, abundance (density,relative abundance), MBI	+	○	-	-	○	-	○
		Terrestrial Invertebrates	Butterflies [40]	Population abundance, distribution	○	○	○	○	○	○	○
			Island Insects [41]	To be determined	-	○	○	○	○	○	○

\+ Vitals signs for which the network will develop protocols and implement monitoring using funding from the vital signs or water quality monitoring programs.
◊ Vital signs that are being monitored by a network park, another NPS program, or by another federal or state agency using other funding. The network will collaborate with these other efforts.
○ Vital signs which cannot currently be implemented because of limited staff and funding
\- Vital sign either does not apply to the park or is of minimal importance to park management
[] indicates priority rank. 1 is highest.

Table 3-B. SFCN Vital Signs and measures in national framework by level of funding (cont.).

National I & M Program Framework					Funding Category						
Level 1	Level 2	Level 3	Network Vital Sign	Measures	BICY	BISC	BUIS	DRTO	EVER	SARI	VIIS
Biological Integrity (cont.)	Focal Species or Communities (cont.)	Fishes (marine)	Marine Fish Communities [2]	Fish community taxonomic composition, richness/diversity/eveness, taxonomic dominance, trophic classification, index of trophic complexity, targeted species (Grouper, Snapper, (parrotfish, surgeonfish in USVI), baitfish) spatial/temporal distribution, abundance/density, size structure, recruitment, biomass, fishing pressure, spawning aggregation characteristics	○	+	+	+	◊	+	+
			Focal Fish Species [30]	Goliath Grouper (Red Hind in USVI), Sharks, Spotted Sea trout, Snook – relative abundance/density, occupancy, spatial/ temporal distribution, density, size structure, catch per unit effort	○	◊	◊	◊	◊	◊	◊
		Fishes (freshwater)	Freshwater fish and large macro-invertebrates [18]	Community composition, abundance (density and relative abundance), size structure, invasive species present	+	-	-	-	◊	-	○
		Amphibians & Reptiles	American Alligator [22]	Animals/km, sex ratio, size distribution, body condition index, alligators per hole, nests/km2	◊	-	-	-	◊	-	-
			Amphibians [25]	Proportion of area occupied, distribution, community composition, population structure, total mercury content	+	○	-	-	+	○	+
			Reptiles-USVI [37]	Population size,structure, proportion of habitat occupied.	-	-	○	-	-	○	○
			Florida Box Turtle [38]	Population size,structure, proportion of habitat occupied.	○	-	-	-	○	-	-
		Birds	Colonial Nesting Birds [8]	Location, size of colonies by species, fledging success	◊	+	◊	◊	◊	◊	◊
			Landbirds [24]	Abundance, distribution, community composition	○	○	○	○	○	○	○
		Mammals	Bats-USVI [39]	Roost locations, roost population counts, relative activity levels	-	-	○	-	-	○	○
	At-risk Biota	T&E Species and Communities	Marine Invertebrates-Rare Threatened, Endangered (RTE) [6]	Species dependent (Acropora, Diadema, Antipathes)	-	+	+	+	○	+	+
			Sea Turtles [20]	Nest counts by species, distribution of nests, nest crawl outcome (nest, no nest), egg counts/nest, nesting outcome, hatching success	-	◊	◊	◊	◊	○	◊
			American crocodile [21]	Animals/ shoreline km, nests/region, size distribution, body condition, annual survival, increase in body length	○	◊	-	-	◊	-	-

+ Vitals signs for which the network will develop protocols and implement monitoring using funding from the vital signs or water quality monitoring programs.
◊ Vital signs that are being monitored by a network park, another NPS program, or by another federal or state agency using other funding. The network will collaborate with these other efforts.
○ Vital signs which cannot currently be implemented because of limited staff and funding
- Vital sign either does not apply to the park or is of minimal importance to park management
[] indicates priority rank. 1 is highest.

Table 3-B. SFCN Vital Signs and measures in national framework by level of funding (cont.).

National I & M Program Framework					Funding Category						
Level 1	**Level 2**	**Level 3**	**Network Vital Sign**	**Measures**	**BICY**	**BISC**	**BUIS**	**DRTO**	**EVER**	**SARI**	**VIIS**
Biological Integrity (cont.)	At-risk Biota (cont.)	T&E Species and Communities (cont.)	Protected Marine mammals [28]	Distribution, abundance, size, condition/disease (manatees, dolphins)	◊	◊	○	○	◊	○	○
			Imperiled & Rare Plants [31]	Targeted rare plant species distribution,population sizes, mortality, recruitment, extent of habitat.	○	○	○	○	○	○	○
			Florida panther [33]	Population abundance, distribution, mortality, cub survivorship	◊	-	-	-	◊	-	-
			Sawfish [26]	Adult distribution & relative abundance, distribution of nurseries, recruitment, movement patterns	-	◊	-	○	◊	-	-
Human use	Visitor and Recreation Use	Visitor Use	Visitor Use [13]	Distribution and abundance of visitors including: activities, demographics, person days, spatial distribution/ density, numbers of people/cars/boats - both commercial and private	◊	◊	◊	◊	◊	◊	◊
Landscapes (Ecosystem Pattern and Processes)	Fire & Fuel Dynamics	Fire & Fuel Dynamics	Fire Return Interval Departure [29]	Fire location, size, perimeter, dates, ignition source (lightning, human), time since last burn	◊	-	-	-	◊	-	-
	Landscape Dynamics	Land Cover and Use	Vegetation Communities Extent & Distribution [7]	Extent, distribution, shape, orientation of vegetation community types using remote sensing	+	+	+	+	◊	+	+
			Benthic Communities Extent & Distribution [23]	Extent and distribution of benthic community types using remote sensing.	-	+	+	+	+	+	+
			Land Use Change [11]	Land use change, permitting/zoning changes, demographics within 1 mile of USVI parks, 75 miles of S. Florida parks	+	+	-	-	+	+	+

\+ Vitals signs for which the network will develop protocols and implement monitoring using funding from the vital signs or water quality monitoring programs.
◊ Vital signs that are being monitored by a network park, another NPS program, or by another federal or state agency using other funding. The network will collaborate with these other efforts.
○ Vital signs which cannot currently be implemented because of limited staff and funding
\- Vital sign either does not apply to the park or is of minimal importance to park management
[] indicates priority rank. 1 is highest.

Table 3-C. Linkages of Vital Signs to valued resources and key issues (physical drivers and stressors) from conceptual models.

National I & M Framework Level 1	SFCN Vital Sign	Valued Resources and/or Services	Key issues (Physical drivers and stressors) from Chapter 2														Conceptual Models					
			Climate & global climate change	Major weather events	Currents, transport & dispersal	Coastal geomorphology & sea level rise	Habitat conversion outside parks	Freshwater & estuarine hydrology and human alterations	Fire & altered fire regimes	Water Quality- Nutrient enrichment	Water Quality - Sedimentation	Water Quality - Contaminants	Air quality	Invasive fauna, flora and disease	Harvest & harvest methods	Human disturbance (e.g., visitor use, boat scars, trash)	Wet prairies and marshes	Forested Wetlands and Uplands	Island Interior	Coastal Wetlands	Florida Bay & Biscayne Bay	Coastal Shelf & Deep Oceanic
Air and Climate	Air Quality-Deposition												**D**				•	•	•	•	•	•
	Air Quality-Mercury												**D**				•	•	•	•	•	
Geology & Soils	Coastal Geomorphology			R	R	**D**													•	•	•	
	Wetland Substrate							R	R								•	•				
Water	Surface Water Hydrology		**D**	R		R	R	**D**									•	•	•	•	•	•
	Estuarine Salinity Patterns				R			R												•	•	•
	Water Chemistry		R	R	R			R		R	R		R				•	•	•	•	•	•
	Nutrient Dynamics			R	R		R	R		**D**						R	•	•	•	•	•	•
	Contaminants						R	R				**D**	R			R	•	•	•	•	•	•
	Periphyton (Freshwater)			R				R		R								•		•		
	Phytoplankton (Marine)				R					R										•	•	•
Biological Integrity	Invasive/Exotic Plants						R			R				**D**		R	•	•	•	•		
	Invasive/Exotic Animals			R			R	R						**D**		R	•	•	•	•	•	•
	Marine Benthic Communities	**D**	R	R	R					R	R	R		R	R	R				•	•	•
	Mangrove-Marsh Ecotone	**D**	R	R		R		R		R	R			R		R				•	•	
	Wetland Ecotones and Community Structure	**D**		R				R	R	R				R			•			•		
	Forest Ecotones and Community Structure	**D**	R	R				R	R	R				R				•	•	•		
	Marine Exploited Invertebrates	**D**			R			R				R			**D**					•	•	•
	Marine Infaunal Community				R			R		R	R	R								•	•	•
	Aquatic Invertebrates in Wet Prairies & Marshes							R		R		R		R			•					
	Butterflies	**D**					R		R				R					•	•			
	Island Insects						R						R	R					•	•		

Table 3-C. Linkages of Vital Signs to valued resources and key issues (physical drivers and stressors) from Ecological Zone Conceptual

National I & M Framework Level 1	SFCN Vital Sign	Valued Resources and/or Services	Key issues (Physical drivers and stressors) from Chapter 2: Climate & global climate change	Major weather events	Currents, transport & dispersal	Coastal geomorphology & sea level rise	Habitat conversion outside parks	Freshwater & estuarine hydrology and human alterations	Fire & altered fire regimes	Water Quality- Nutrient enrichment	Water Quality - Sedimentation	Water Quality - Contaminants	Air quality	Invasive fauna, flora and disease	Harvest & harvest methods	Human disturbance (e.g., visitor use, boat scars, trash)	Conceptual Models: Wet prairies and marshes	Forested Wetlands and Uplands	Island Interior	Coastal Wetlands	Florida & Biscayne Bays	Coastal Shelf & Deep Oceanic
Biological Integrity	Marine Fish Communities	**D**			R		R					R			**D**					•	•	•
	Focal Fish Species	**D**			R		R					R			**D**					•	•	•
	Freshwater fish and large macro-invertebrates							R		R		R		R			•	•	•			
	American Alligator	**D**					R	R				R		R		R	•	•				
	Amphibians	**D**					R	R			R	R	R	R		R	•	•	•	•		
	Reptiles-USVI	**D**					R							R		R			•	•		
	Florida Box Turtle	**D**					R									R	•	•				
	Colonial Nesting Birds	**D**	R	R			R	R				R		R		R	•	•	•	•	•	
	Landbirds	**D**					R		R			R		R		R	•	•	•	•		
	Bats-USVI	**D**					R					R				R			•	•		
	Marine Invertebrates-RTE	**D**	R	R	R					R	R	R		R	R	R						•
	Sea Turtles	**D**					R					R		R		R				•	•	•
	American crocodile	**D**					R	R				R				R				•	•	
	Protected Marine mammals	**D**					R	R				R		R		R				•	•	•
	Imperiled & Rare Plants	**D**		R				R	R	R			R	R	R	R		•	•			
	Florida panther	**D**					R					R		R		R		•				
	Sawfish	**D**					R	R				R				R				•	•	•
Human use	Visitor Use															**D**	•	•	•	•	•	•
Landscapes (Ecosystem Pattern and Processes)	Fire Return Interval Departure								**D**								•	•				
	Vegetation Communities Extent & Distribution	**D**	R	R		R		R	R	R							•	•	•	•		
	Benthic Communities Extent & Distribution	**D**		R	R			R		R						R					•	•
	Land Use Change						**D**										•	•	•	•	•	•

D=Vital Sign is a direct measure of a valued resource or key issue (stressor and/or driver)
R=Vital Sign strongly responds or otherwise relates to the key issue but is not a direct measure

3.5 SFCN Category 1 Vital Signs and Relationship between the Network, Park-Based, and External Agency Monitoring Activities

The justifications and strategy of approach for each vital sign are given in Appendix P. Table 3-D shows SFCN contributing towards data collection for 17 of the 34 vital signs for which some degree of reporting will occur (10 are deferred due to insufficient funds).

"Vegetation Communities Extent and Distribution" and "Benthic Communities Extent and Distribution" were not included in the list because the current SFCN mapping projects are being conducted with NPS I&M Program funding as a one-time effort. Future funding for mapping is unclear although it is hoped additional funding will become available in the future.

Thirty-three of the vital signs are already being monitored in some or all of the parks by park staff, other government agencies, and NGOs. The SFCN anticipates working closely with these ongoing monitoring activities across the network. For example, water quality monitoring is an important covariate and will be a critical dataset to evaluate when examining trends in biological indicators. Thus, coordinating with existing water quality sampling programs in South Florida and the USVI will be essential (see Appendix F.2). Most of the Threatened and Endangered species identified as vital signs are already being monitored by the parks or USFWS.

Agencies implementing the Comprehensive Everglades Restoration Plan (CERP), i.e. SFWMD & ACOE, spent about $8.7 million in monitoring and research in the CERP Greater Everglades and Southern Estuaries modules in 2007. The Restoration Coordination and Verification (RECOVER) arm of CERP has three primary responsibilities: 1) evaluate and assess Plan performance; 2) refine and improve the plan during the implementation period, and 3) ensure that a system-wide perspective is maintained throughout the restoration program. RECOVER's Assessment Team (AT) is developing the Monitoring and Assessment Plan (MAP). A number of the participants in the SFCN indicator

Table 3-D. SFCN Category 1 Vital Signs.

Group	SFCN Category 1 Vital Signs
Marine	Marine Benthic Communities *
	Marine Fish Communities *
	Marine Exploited Invertebrates *
	Marine Invertebrates – Rare, threatened, endangered (RTE)
Inter-tidal and above	Colonial Nesting Birds *
	Land-use Change *
	Wetland Ecotones and Community Structure *
	Forest Ecotones and Community Structure *
	Mangrove-Marsh Ecotone *
	Freshwater fish and large macro-invertebrates *
	Amphibians *
	Coastal Geomorphology *
	Invasive/Exotic Plants
	Invasive/Exotic Animals
	Surface Water Hydrology (weather stations)
	Periphyton
	Aquatic invertebrates in wet prairies & marshes

"*" = requiring >0.3 FTE of SFCN Staff time identification workshops have also been heavily involved in CERP and the development of the MAP. Eighteen of the SFCN Vital Signs overlap either in part or entirely with the CERP MAP, and SFCN staff members attend Assessment Team meetings to ensure coordination between the two programs. The CERP footprint doesn't fully cover all South Florida park units, and in some cases the SFCN will work to augment monitoring, where applicable to ensure park-wide coverage.

The marine ecosystems are monitored extensively by several groups within the National Oceanic and Atmospheric Administration (NOAA), including the Southeast Fisheries Science Center, the Biogeography Program, the National Coral Reef Institute at Nova Southeastern University, and others. The Florida Fish and Wildlife Conservation Commission's Fish and Wildlife Research Institute, University of Miami-RSMAS and Florida International University all have monitoring programs. The SFCN has established a strong working relationship with all of these groups, and intends to develop even stronger partnerships in the future as protocols are developed, and data is shared among programs.

Because so many of the vital signs are already being monitored either in their entirety or in part by other groups, SFCN has identified four basic roles with regards to the vital signs which are summarized in Table 3-E and described below:

- *SFCN implements monitoring:* SFCN either conducts or pays for field data collection and analysis, and will need to adopt an existing protocol or develop a new protocol
- *SFCN gathers data from other groups & analyzes:* SFCN expects to conduct additional data analyses on data collected by an existing program to report on trends within park boundaries (i.e. the other group is reporting regional trends), analyze multi-park trends, correlate to other vital signs, answer additional questions, and/or otherwise assist park staff
- *SFCN summarizes reports from other groups, provides web links:* an existing program is conducting the data collection, analysis and reporting. SFCN will gather these reports for posting on the SFCN internet/intranet webpage, review the reports and provide brief summaries on the web page and annual report
- *Deferred:* monitoring is deferred due to insufficient funding/staff time

Table 3-E. SFCN role for each Vital Sign component. Components are detailed in Chapter 4 and Appendix P. Grey rows indicate vital signs components for which a park or another agency is lead; for which outside funding would be required (mapping) or for which monitoring is deferred.

Network Vital Sign in Priority Rank Order	Rank	Component	SFCN Conducts monitoring	SFCN gathers data from other groups & analyzes	SFCN summarizes reports from other groups, provides web links	De-ferred
Marine Benthic Communities	1	Coral - Index sites	X			
		Coral - Extensive design 2-20m deep	X			
		Coral - Deep Coral >20m deep Feasibility Assessment	X			
		Coral - Temperature Monitoring	X			
		Seagrass - Outer BISC, DRTO, BUIS, SARI, VIIS	X (with park staff?)			
		Seagrass - Florida Bay & Biscayne Bay	?	?	X	
Marine Fish Communities	2	BISC (Coastal Shelf), DRTO	X (with NOAA, FWRI)	X	X	
		BISC - Bay	?	?		
		EVER - Florida Bay	?	?	X	
		BUIS, VIIS	X (with park staff, NOAA)	X	X	
		SARI	X			
Surface Water Hydrology	3	Weather stations - VIIS, SARI, BUIS	X (with park staff)			
		Hydrology - EVER, BICY			X	
		Hydrology - BISC		X	X	
		Hydrology - VIIS		X		
		Hydrology - SARI - Adding crest gage	X (with park staff)			
Nutrient Dynamics	4	BICY, BISC, DRTO, EVER		X	X	
		VIIS		X		
		BUIS, SARI				X
Invasive/Exotic Plants	5	SRF-Digital Sketch Mapping		X		
		Corridors of Invasiveness	X (with EPMT)			
		Voluntary Reporting Program		X		

Table 3-E. SFCN role for each Vital Sign component (cont.).

Network Vital Sign in Priority Rank Order	Rank	Component	SFCN Conducts monitoring	SFCN Gathers data from other groups & analyzes	SFCN summarizes reports from other groups, links to web pages	De-ferred
Marine Invertebrates-Rare, Threatened, and Endangered	6	*Acropora* species			X Assist protocol development?	
		Diadema	X			
		Black Coral Feasibility Assessment	X			
Vegetation Communities Extent & Distribution	7	EVER, BICY (eastern 2/3)			X	
		BISC, DRTO, BUIS, VIIS, SARI,BICY (western 1/3)	X (Funds from NPS Natl. Mapping Prgm)			
Colonial Nesting Birds	8	EVER - Colony monitoring, SRF flights		X	X	
		BISC - Colony monitoring, SRF flights	SFCN helps with initial location of colonies	X	X	
		BISC- Colony monitoring	X			
		DRTO - Colony monitoring	X (with park staff)			
		BUIS, VIIS - Colony monitoring		X		
		SARI - Colony monitoring	?	?		X
Estuarine salinity patterns	9			X	X	
Marine Exploited Invertebrates	10	Spiny lobster	X (with park staff)			
		Queen Conch	X (with park staff, NOAA)			
		Pink shrimp			X	
		Harvest data-Lobster, Shrimp, Crabs (Stone, blue, others), Sponges		X		
		Oysters, Whelk				X
Land-use Change	11	Land-use change	X			
		Permiting/zoning changes next 1-3 yrs		X		
Invasive/Exotic Animals	12	Surveying other programs for new species		X		
		Canals - EVER, BICY	X (with park staff)			
Visitor Use	13			X		
Wetland Ecotones & Community Structure	14, 15,16	EVER			X	
		BISC, BICY, supplement EVER	X			

Table 3-E. SFCN role for each Vital Sign component (cont.).

Network Vital Sign in Priority Rank Order	Rank	Component	SFCN Conducts monitoring	SFCN Gathers data from other groups & analyzes	SFCN summarizes reports from other groups, links to web pages	De-ferred
Forest Ecotones & Community Structure	14, 15,16	BISC, BICY, EVER, VIIS	X	X	X	
Mangrove-Marsh Ecotone	14, 15,16	All parks	X		X	
Periphyton (Freshwater)	17	BICY NW corner	X			
		EVER + NE BICY			X	
Freshwater fish and large macro-invertebrates	18	BICY NW corner	X			
		EVER + NE BICY			X	
Contaminants	19				X	
Sea Turtles	20			X	X	
American crocodile	21				X	
American Alligator	22				X	
Benthic Communities Extent & Distribution	23		X (Funds from NPS Natl. Mapping Prgm)	X		
Landbirds	24					X
Amphibians	25		X			
Sawfish	26				X	
Coastal Geomorphology	27	Sediment Elevation Tables (SETs)	X		X	
		Fl Bay - Mapping mud banks, berms	X (Funds from NPS Natl. Mapping Prgm)			
Protected marine mammals	28				X	
Fire Return Interval Departure	29			X		
Focal fish species	30				X	
Imperiled & Rare Plants	31					X
Aquatic invertebrates in wet prairies & marshes	32	BICY NW corner	X			
Florida panther	33				X	

Table 3-E. SFCN role for each Vital Sign component (cont.).

Network Vital Sign in Priority Rank Order	Rank	Component	SFCN Conducts monitoring	SFCN Gathers data from other groups & analyzes	SFCN summarizes reports from other groups, links to web pages	De-ferred
Phytoplankton (Marine)	34				X	
Wetland substrate	35					X
Marine Infaunal Community	36					X
Reptiles-USVI	37					X
Florida Box Turtle	38					X
Bats-USVI	39					X
Butterflies	40					X
Island Insects	41					X
Air Quality-Deposition	--			X	X	
Air Quality-Mercury	--			X	X	
Water Chemistry	--	BICY, BISC, DRTO, EVER		X	X	
		VIIS		X		
		BUIS, SARI				X

Chapter 4: Sampling Design

4.1 Introduction

Designing scientifically sound ecological monitoring programs is an emerging field which is still in a process of learning and development. Some principles that SFCN is employing include:

- Good clear monitoring questions/ objectives with a clearly defined target population and applicable to management decision-making
- Based upon best available scientific information, both ecological and statistical design
- Allows unbiased inference to the target population, across space and time
- Sufficient precision and statistical power to answer monitoring questions in a manner timely and informative to management
- Simple, robust and flexible through time
- Cost-effective and logistically feasible
- Leverages historical work, existing protocols and collaborates with existing programs, where doing so doesn't otherwise conflict with the principles above.

These principles involve tradeoffs – usually in costs and feasibility versus the rest. Because proper monitoring of natural resources is usually very expensive and time-consuming, the sampling designs should provide reliable information in a cost-efficient manner. Monitoring in the forests and wetland areas of EVER and portions of BICY and VIIS are particularly daunting because these parks contain large areas that are difficult to access and the wilderness area of EVER has limits on types of access, transportation, and tools used within the park. Monitoring the marine areas is challenged by the ever present dangers and limitations of repeated diving, plus limited knowledge of underwater habitats in SFCN parks. Some areas of BUIS are extremely deep, well below diveable depths. Consequently, practical considerations, such as accessibility, feasibility, knowledge, and cost, will limit design alternatives that can be realistically implemented in these parks. A design should also be flexible enough to allow continued sampling within a restricted range of high-priority areas or sites if funding drops to levels too low to support the full program.

The SFCN is composed of four small and widely separated parks (BUIS, DRTO, SARI, and VIIS) and three relatively large closely located parks (BICY, BISC, and EVER). A number of the parks within the SFCN (BICY, BISC, EVER, SARI, and VIIS) are surrounded by a radically altered matrix of rapid urbanization and habitat conversion. Additionally, the Comprehensive Everglades Restoration Plan (CERP), which affects some 18,000 mi^2, is a driving force in the water management of the three large parks (BICY, BISC, and EVER) of the network. Thus, a great deal of monitoring is currently underway (see Appendixes F & H). ***As thirty-three of the vital signs are already being monitored or partially monitored by the parks, other government agencies and NGOs, SFCN's role in the sampling design of many of these programs is limited unless assistance is requested with power analysis and improving the rigor of such designs.*** In this chapter, we discuss basic concepts and terminology of sampling design, summarize the sampling designs for all vital signs components in a table, and describe in greater detail the sampling designs of SFCN's core set of vital signs plus a few additional vital signs involving SFCN sampling design planning.

4.2 Basic Concepts and Terminology

In this section we introduce terminology and provide the conceptual framework for our proposed sampling designs for monitoring vital signs in SFCN parks discussed later in this chapter. Much of the following is adapted from the Southwest Alaska Network Phase 3 report (Bennett *et al.* 2006). We begin by defining *status* as a measure of a current attribute, condition, or state, and *trend* as a measure of net change, which includes contributions from immigration or emigration as well as those occurring within the area of interest. Status applies to specific points in time, whereas trend pertains to measurements across multiple time periods. A sampling design used for monitoring vital signs dictates where, when, and how often to sample. We distinguish a *sampling design* which describes the distribution of sampling units in time and space from the *sampling unit methodology*, which describes how to best record information from sample locations.

One of the most important steps in developing a sampling design is clearly identifying monitoring questions/ objectives and the target population about which any sampling will be used to draw inferences. The sampling design should be optimized to answer the objectives. The *target population* or *sampling frame* is the collective population(s) of animals, plants, natural resources, or environmental attributes of interest within a specified geographic area. Note that this is a statistical population; it may or may not refer to a biological population, e.g., the target population may be amphibian communities within Everglades National Park while the true biological population will extend outside park boundaries. The target population is divided into *sampling units*. Sampling units are non-overlapping collections of elements or attributes which are measured such as individual animals or plants. Common examples of sampling units include plots, quadrats, point counts, transects, or individual nests. A *sample* is a subset of units chosen to record the elements through counts, observation, or other form of measurement. Frequently the definition of the target population and monitoring objectives are refined as sampling design development proceeds, such as the target population for amphibians in EVER may be restricted to "amphibian communities in buffered areas along roads, trails and other accessible areas within Everglades National Park" due to feasibility constraints.

Two common types of error common to surveys are bias and precision. *Bias* refers to a persistent error that is not due to random chance – for example, if a temperature recorder consistently records one degree lower than the actual temperature or if a portion of the bird nests counted are always hidden from view. The degree of spread or variance in estimates from repeated samples is referred to as *precision*. The precision can be improved through using better sampling unit methodologies that reduce variation due to instrumentation, different observers, and by using spatially balanced sampling designs.

There are two basic components of a sampling design for monitoring natural resources: membership and revisit designs. A *membership design* dictates how sampling units are chosen to become members of a panel, which includes how to spatially allocate sampling effort (McDonald 2003, as cited in Bennett *et al.* 2006). Sample selection methods used in membership designs can be placed in one of two categories: non-random and random sampling.

Non-random sampling is a choice of units based on convenience, perceived representativeness, haphazard contact, or other subjective criteria – unfortunately statistical inference is limited to those sites actually sampled. Attempting to expand beyond these sites will nearly always result in selection bias, usually of an unknown magnitude. This bias could potentially be mitigated if the relationship between vital sign metrics in non-randomly sampled units and unsampled units is reasonably approximated by a model (e.g., known habitat or environmental associations). In addition, bias will likely be reduced if a large proportion of the target population is (non-randomly) sampled, especially if sample locations are spatially balanced. However, neither of these scenarios can be assumed without validation, which is one reason why non-random sampling approaches have been criticized in the literature (e.g., see Anderson 2001, Morrison *et al*. 2001).

However, in cases where only a few samples units (1-2) can be analyzed, using best judgment in their placement makes as much sense as a random selection. We will refer to them as *index sites*. Some of the vital signs are monitored with non-randomly selected index sites chosen by best judgment. For example, SFCN will be placing one weather station each in BUIS and SARI and possibly DRTO. Since the variance in the parameters of interest (e.g., air temperature, rainfall, wind speed) across the island is of less interest than seasonal trends and extremes, these stations will be placed using best judgment in areas that meet the minimum standards for appropriate operation of the equipment and are easily accessible to park staff. Other examples of non-randomly selected monitoring that have value are those which have been measuring long-term trends, even if the geographic scope of inference is limited. These include permanent water quality and water stage stations, alligator transect monitoring, sooty tern monitoring, and some long-term vegetation plots.

However, the preferred membership design involves random or probability sampling which employs some form of randomized procedure to select units. Because of this, each potential sample has a known probability of selection and results can be statistically inferred to the larger target population. Common examples of probability sampling schemes include simple random, systematic, and stratified sampling (or some combination thereof, see Thompson 2002). The generalized random-tessellation stratified (GRTS) (Stevens and Olsen 2004) design is a recently proposed probability sampling method that is spatially balanced and increases program flexibility by allowing sampling units to be easily removed while still maintaining a balanced design in cases of decreased funding.

Not all sampling units need to be selected with the same probability. For example, the target population may be partitioned into different homogeneous strata based upon geology, hydrology, access, or some other non-changing feature. Sampling can be portioned among these different strata to allow increased sampling in some and decreased sampling in others to reduce overall sampling variance or reduce sampling costs. This can allow decreased sampling in areas that are difficult to access or increased sampling in areas of higher variance where greater effort is needed.

Some typical strata considerations that may be included in SFCN sampling designs include

- Marine:
    - Hard-bottom versus soft-bottom habitat
    - Different types of hard-bottom habitat and/or coral reef communities
    - Accessibility: <2m, 2m-20m, >20m depth
- Intertidal & above:
    - Hydrology/elevation/topography
    - Coastal versus inland
    - Underlying geology (i.e. pine rocklands in EVER & BICY)
    - Accessibility (distance to roads & trails; "wilderness" designation)

A *revisit design* determines when and how often selected units are sampled (or visited) among sampling occasions and hence how to temporally allocate sampling effort (McDonald 2003; as cited in Bennett *et al.* 2006). For example, members of one panel may be sampled during every sampling occasion and members of another panel may be sampled every tenth sampling occasion. Sampling frequency will be dictated both by level of temporal variation in the vital sign measure and by logistical/funding constraints.

An important consideration when choosing a revisit design is the tradeoffs between using permanent sampling units versus re-randomizing units versus some combination of the two. For communities with a high degree of spatial variance such as coral or vegetation, using permanent transects or plots can greatly reduce variance and consequently sample sizes. There is a tradeoff however, in that using permanent sampling units can reduce the future flexibility of sampling designs in the face of habitat succession or other changes. Thus, for mobile species such as fish, birds, and amphibians, the tradeoffs of using permanent plots versus re-randomizing each year must be considered.

In order to achieve sufficient sample size within current staffing constraints, SFCN may distribute sampling across time by rotating sampling efforts through different panels or collections of sampling units during different years (see Figure 4-A). We define a panel of sampling units to be those that are sampled together during the same sampling period (McDonald 2003; as cited in Bennett *et al.* 2006). For example, it may be feasible to sample only a fifth of selected vegetation plots during a given year so a different fifth is sampled each year over a 5-yr period, which would be a rotating panel design consisting of five panels. SFCN may choose to rotate sampling within all parks each year or may instead consider rotating sampling among parks, in which all sampling units are sampled in one or two parks in a given year, and then other parks in subsequent years.

Another source of bias occurs when the detection of an animal or plant when present is less than 100%. The probability of detecting an individual or species within a sampling unit, given it is present, is called the probability of detection or detectability. Organisms such as amphibians, fish, birds, rare plants, etc., may not always be detected by the observer even when present. This leads to an underestimation of abundance or occupancy, greater variance in results, and possibilities for misinterpretation of data when changes in detectability, for example, due to a change in observers or vegetation succession are misinterpreted as a trend. Methods such as proportion of area occupied (MacKenzie *et al.* 2002), double-observer (Nichols *et al.* 2000), dual-frame, capture-recapture (Amstrup *et al.* 2005) and distance sampling (Buckland *et al.* 2001) have been developed to account for this component of individual detectability and factor them into estimates (see also Williams *et al.* 2002, Thompson 2002). Accounting for detectability makes results less biased and more defensible by creating estimates of the true abundance or occupancy rather than relative abundance which is typical of many sampling programs. It also allows greater flexibility in changes in protocols through time as changes in detectability due to different methods and observers are now factored directly into the estimates. SFCN will work to promote sampling unit methodologies that incorporate methods that properly account for incomplete detectability whenever possible as well as incorporate them into the SFCN monitoring protocols.

SFCN will work to create scientifically defensible yet feasible and flexible sampling designs for the protocols for which it is responsible and for those other vital signs that it is asked to provide assistance. Well designed sampling programs make the subsequent steps of analysis and reporting much easier and readily explainable to management.

	Sampling Occasions																			
Panel	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
All sampling units revisited each year																				
1	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
One permanent panel while other sampling units are re-randomized each year																				
1	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
2		X																		
3			X																	
4				X																
5					X															
6						X														
7							X													
8								X												
9									X											
10										X										
:											:									
:											:									
5 year rotation																				
1	X					X					X					X				
2		X					X					X					X			
3			X					X					X					X		
4				X					X					X					X	
5					X					X					X					X
One panel always sampled, others 10 year rotation																				
1	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
2	X										X									
3		X										X								
4			X										X							
5				X										X						
6					X										X					
7						X										X				
8							X										X			
9								X										X		
10									X										X	
11										X										X
Panels sampled twice, then again after 4 years (allows estimate of inter-annual variation)																				
1	X	X					X	X					X	X					X	X
2		X	X					X	X					X	X					
3			X	X					X	X					X	X				
4				X	X					X	X					X	X			
5					X	X					X	X					X	X		
6						X	X					X	X					X	X	

Figure 4-A. Examples of different sampling panel designs distributing effort through space and time. A panel is a group of sampling units that are sampled together during the same sampling period.

4.3 Episodic monitoring

SFCN network parks are subject to a number of major disturbance events including hurricanes, coral bleaching, fire, and algal blooms. Increased sampling in the wake of such events allows an immediate understanding of the current status of park resources, can clarify the role those events had in trends versus other long-term factors, and can sometimes resolve critical uncertainties. To allow for this increased effort, sampling of other vital signs may be delayed or even postponed until the following year. Vital signs components that could receive increased monitoring by SFCN staff following a hurricane include coral monitoring, sediment elevation tables, and vegetation monitoring. SFCN is not undertaking water quality monitoring or endangered species monitoring, but may provide assistance to other groups in the wake of a hurricane, when practical.

4.4 Minimum Sample Size Required for Detecting a Trend

The minimum number of units sampled across space and time is dictated by

- the minimum change that management would like to detect,
- the acceptable Type 1 Error (probability of a false positive or false conclusion of change),
- the acceptable Type 2 Error (probability of a false negative or failure to detect change),
- the unexplained variance involved with the protocol, and
- budgetary restrictions

Detecting a large change will require fewer sampling units and less robust data than a small change. Determining appropriate sample sizes requires consulting with management and/or local experts regarding the level of change that is desirable to detect and the level of Type 1 and Type 2 errors that are acceptable. Estimates of variance are made by either gathering some initial pilot data or gathering similar data from the literature to provide estimates of temporal and spatial variability and detection probabilities (Elzinga *et al.* 2001, p.192, has compiled a list). Selecting well-designed sampling unit methodologies that minimize sampling variation due to instrumentation and observer variation also contribute to lower sample sizes. Sometimes a complete shift in approach is necessary as in the case of monitoring amphibians where calculating proportion of area occupied is now considered a more cost-effective and less biased approach than estimating abundances.

Depending on the complexity of the sampling design, sample sizes may be initially estimated by using standard equations (e.g., Thompson 1998) or by using commercial software (e.g., SAS Institute, Inc.) or freeware (R; http://www.r-project.org/) statistical programs to run simulations to estimate sample sizes required under various design scenarios. Determining sample sizes will be an iterative process such that after 3-5 years of data are gathered, another analysis may be conducted to refine sample size requirements and improve the design over time.

4.5 Overview of SFCN Sampling Designs

Below we discuss the sampling designs of the "Category 1" SFCN Vital Signs towards which SFCN plus a section on water quality monitoring. Only a few vital signs will work well together by being co-visited/located. These are shown in Table 4-A. Table 4-E at the end of this chapter summarizes the target populations, sampling and revisit designs and lead agency for *all* SFCN vital signs. Additional details are given in the Protocol Development Summaries in Appendix Q.

Table 4-A. SFCN Category 1 vital signs showing co-located/co-visited vital signs

Group	SFCN Category 1 Vital Signs	Co-visited/located vital signs
Marine	Marine Benthic Communities	Marine Invertebrates-Rare, Threatened, Endangered - *Diadema*; Marine Exploited Invertebrates- Conch; sub-set of Marine fish communities monitoring; coral reef temperature
	Marine Fish Communities	
	Marine Exploited Invertebrates	
Intertidal and above	Colonial Nesting Birds	
	Wetland Ecotones and Community Structure	
	Forest Ecotones and Community Structure	
	Mangrove-marsh ecotone	Coastal Geomorphology
	Freshwater fish and large macro-invertebrates	Periphyton; Aquatic invertebrates
	Amphibians	
	Land-use Change	
	Invasive/Exotic Plants	
	Invasive/Exotic Animals	
	Surface water hydrology (rainfall, crest gage)	

4.5.1 Marine Benthic Communities (with Marine Invertebrates-RTE (Diadema); Marine Exploited Invertebrates (conch); subset of marine fish communities)

SFCN has divided the marine benthic world into two main types of substrate: hard-bottom and soft-bottom, which strongly affect the communities that establish. The primary focus of this vital sign is on coral reef communities on hard-bottom substrate and submerged aquatic vegetation on soft-bottom substrate with very different sampling designs and sampling unit methodologies in each. Although other communities exist such as algal plains, these were not selected as the focus of this effort.

1) Coral Reef Communities:

The monitoring strategy for coral communities in the SFCN is split into four different components:

- Index coral monitoring sites at BISC, BUIS, DRTO, VIIS
- Extensive assessments of stony coral communities containing reef building coral species < 20m depth
- Deep stony coral communities >20m depth
- Coral - water temperature monitoring at reef depth

Index coral monitoring sites at BISC, BUIS, DRTO and VIIS: 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 in 2004. 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. Twenty permanent, ten meter transects were randomly selected at each site. Each transect is videotaped annually and analyzed. During unusual events (e.g., bleaching/disease outbreaks) the frequency may increase. 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.

Extensive assessments of stony coral communities containing reef building coral species 2- 20m depth: 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 coral communities with >5% stony coral cover and between 2-20m depth throughout the park and will allow inside versus 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 (1600m^2) of 4 transects, distributed throughout hard-bottom habitat in the parks, sampled in a rotating design. The majority of sampling effort and revisit frequency would be at sites with higher coral cover (>5% stony coral cover) but a low-level focus and long revisit interval (10-20 years) would be used for low coral cover hard-bottom. SFCN also hopes to establish such designs at BISC, BUIS, and SARI. Resource management at VIIS felt the 5 intensive sites already established there were sufficient to answer their questions.

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.

A pilot project will be conducted to determine the feasibility of monitoring recruitment along these transects or a subset thereof using high-definition videography or other methods. The time involved may make recruitment monitoring unfeasible.

SFCN will also investigate whether there is a way to cost-effectively supplement the protocol at DRTO and BISC to make it comparable to another pilot coral monitoring effort that is currently conducted with fish monitoring in Florida Keys and DRTO by NOAA, RSMAS, and FWC, 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.

Deep stony coral communities >20 m depth: SFCN will assess feasibility of the use of underwater remotely operated vehicle (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.

Coral –water temperature monitoring at reef depth: At each intensive site and at a subset of the park-wide sites, continuous data loggers are being used to record water temperature at reef depth to serve as a covariate when assessing sudden changes.

2) Seagrass and other SAV <20m depth:

Existing monitoring programs for seagrass are being conducted in Florida Bay and Biscayne Bay by South Florida Fish Habitat Assessment Program (FHAP-SF) and Dade County Environmental Resource Management (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 Fourqueron of Florida International University (FIU). Florida Bay is divided by basins and Biscayne Bay into 3 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 ten 0.25 m^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 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 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.

Co-located protocols with marine benthic communities protocols

Monitoring of black long-spined sea urchins (*Diadema antillarum*) will occur along coral monitoring transects as simple relative abundance counts. SFCN staff have already been collecting such data as part of the prototype monitoring, but the protocol needs to be formalized. A pilot monitoring protocol for conch will be tested to determine if co-measuring conch at each seagrass monitoring sampling unit will yield sufficient power to assess trends in conch abundance, size structure, and maturity/immature ratios. Conch data are already available from the NOAA Biogeography team's fish and conch monitoring in USVI parks to assess power using their methodology in the USVI.

4.5.2 Marine Fish Communities

Considerable existing monitoring efforts are underway for South Florida and the U.S. 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 of marine protected areas), fish in seagrass/bays.

Reef fish – South Florida

SFCN will be collaborating with the ongoing University of Miami and NOAA fish monitoring (Jerry Ault and Jim Bohnsack respectively) being conducted at BISC and DRTO. The sampling design is a two-stage stratified random design on coral reef habitats only with eight 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 survey 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 will work with the University of Miami and NOAA 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 (RNA; a no-fishing marine protected area). This monitoring is also critical to meet the needs of the Research Natural Area Science Plan (SFNRC and FWC, 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 the University of Miami is not conducting it. SFCN will also provide assistance with the park-specific supplemental analyses, if needed.

Marine Fish Communities - USVI

The NOAA Center for Coastal Monitoring and Assessment (CCMA) Biogeography Team 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 include benthic habitat (hard-bottom versus soft-bottom), management (inside versus outside protected area) and geographic zone. The overall design is stratified random with the sampling unit protocol being a visual belt transect and a visual point count conducted by SCUBA divers. Simultaneous measurements of benthic habitat (seagrass, coral), and other species of interest (lobster, conch, *Diadema*) occur. Sufficient information on conch may be gathered to establish trends, but lobster data was insufficient for assessing trends. It is unclear at this point whether the South Florida and the USVI protocols will be standardized or not. SFCN has assisted with the BUIS and VIIS/VICR fish "blitzes" monitoring efforts and expects to continue doing so in the future.

It is unclear at this time whether this effort has long-term funding or not. If this effort ceases to be funded, SFCN does plan 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.

SFCN also has a juvenile fish monitoring program underway at VIIS. This program is at a point where analysis of the data for trends and power would be very useful.

Bays & Mangroves – S. 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 and 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.

4.5.3 Marine Exploited Invertebrates

Sampling design and specific sampling unit protocols for monitoring lobster in SFCN parks are still to be determined. Long-term monitoring conducted by FWC-FWRI in the Florida Keys 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.

Monitoring for conch is co-located with monitoring seagrass and is discussed under Marine Benthic Communities.

4.5.4 Colonial Nesting Birds

Colonial nesting birds include Great Egrets, Wood Storks, White ibis, Snowy Egrets, Rosette Spoonbills, Tricolor Herons, Little Blue Herons, Magnificent Frigatebirds, Least terns, Pelicans, Brown Boobies, Masked Boobies, Brown Noddies, Roseate terns, and Sooty Terns. These are being monitored through a combination of colonial nest surveys and in south Florida using systematic reconnaissance flights (SRF).

Colonial nest surveys

Colonial nest surveys involve surveying all known colonies with new colonies added through opportunistic reporting or systematic reconnaissance flights. At each colony (rookery) the peak number of nests are assessed by species with serial surveys.

Colonial nest surveys are currently occurring in EVER and sporadically at BICY. At BUIS and VIIS brown pelican nesting is being monitored by the park. At BUIS monitoring of least terns is also underway. At DRTO, Sonny Bass has a detailed monitoring study of Sooty Terns underway since the 1950s but samples only a small portion of the sooty tern nests. SFCN will initiate monitoring of colonial nesting birds in BISC and supplement current monitoring at BICY, DRTO, and possibly SARI. At BISC this will require identifying colony locations, determining the probable nesting periods and sampling at monthly intervals. SFCN will work with BUIS and VIIS to analyze and report their brown pelican and least tern data as needed. US Fish and Wildlife Service (USFWS) and Virgin Islands Dept. of Fish and Wildlife (VIDFW) 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 procedures and help with database development and analysis and reporting processes for existing programs as needed.

Systematic reconnaissance flights

In South Florida, systematic reconnaissance flights (SRF) are used to conduct monthly large-scale aerial surveys via small airplane of the park lands and waters for relative abundance for wading birds in South Florida from December through June. 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 colonial bird rookery surveys. The SRF program is a base funded monitoring program for Everglades National Park. EVER's SRF program covers the southern portion of BICY south of Loop Road and the South Florida Water Management District SRF program covers a portion of northeastern BICY. SFCN will pull together the results from these different SRF monitoring programs (using the South Florida Wading Bird Report) to present general findings for both parks.

4.5.5 Vegetation - Wetland Ecotones and Community Structure; Forest Ecotones and Community Structure; Mangrove-Marsh Ecotone

Although there are three different vegetation community related vital signs (Wetland Ecotones and Community Structure; Forest Ecotones and Community Structure; and Mangrove-Marsh Ecotone) to be consistent with the national Vital Signs framework, SFCN will approach monitoring for all three from a more holistic viewpoint as many of these vegetation types can transition into each other over time.

Table 4-B. Plan for ecotone monitoring

Park	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		

A= monitored with aerial photography
F= monitored with field plots

Table 4-C. Plan for long-term within-community monitoring plots

Park	Pineland	Hardwood Hammock	Mangroves	Marshes	Island Moist Forest	Island Deciduous Forest	Island Scrub/ Shrub
BISC		+,♦	+				
BICY	♦	+	+				
EVER	♦	+,♦	♦	♦			
DRTO			+				
SARI			+	?			
BUIS						+	+
VIIS			+		+,♦	+,♦	+

\+ = SFCN monitoring
♦ = Existing monitoring program
? = Unclear priority for monitoring

The monitoring design will focus on two key areas: shifting ecotones and within-community change. These may require either two separate sampling strategies or a carefully integrated design. Shifting ecotones such as those shown in Table 4-B will be monitored through a combination of aerial photography and field transects or plots. The changes in community composition due to plant succession from agriculture, non-native species, disturbance (hurricanes, fire), diseases, climate, etc. will be monitored with field plots. Table 4-C shows the communities SFCN will be targeting for within-community vegetation monitoring.

A great deal of existing monitoring is underway, especially in EVER but also in BICY and VIIS. SFCN has entered a cooperative agreement for a post-doc to review the existing monitoring programs and lead the effort in identifying priorities, determine which existing efforts to coordinate with and which areas of focus SFCN will take the lead, and determine the sampling design. Stratification issues are still to be determined but will likely involve issues such as distance to coast, hydrology/elevation, management unit, and possibly accessibility issues. Plots/transects will likely be visited in a rotation panel design with a revisit frequency of somewhere between 5-10 years or after a major disturbance event such as a hurricane or fire.

Monitoring of Sediment Elevation Tables (Coastal Geomorphology vital sign) will be co-located with a subset of mangrove monitoring plots.

4.5.6 Freshwater fish and large macro-invertebrates

Long-term monitoring of freshwater fish and large macro-invertebrates (i.e. crayfish, grass shrimp) funded by CERP RECOVER MAP is underway in Shark River Slough. This monitoring 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 index site monitoring is also being conducted by Joel Trexler and Jeff Kline. SFCN feels this monitoring is sufficient in EVER and does not anticipate expanding this monitoring.

A CERP RECOVER funded effort is also underway in northeastern BICY downstream of the L28 Canal which CERP RECOVER plans to modify. The BICY Resource Manager said the unfunded northwestern portion of BICY was a priority due to upstream development and agriculture impacts on water quality and quantity affecting that area. SFCN plans to work with the CERP RECOVER funded effort in northeastern BICY to develop a sampling design and protocols for northwestern BICY. Sampling would focus in the area of northwest Big Cypress. Periphyton samples & macro-invertebrate samples would be collected simultaneously. The CERP funded pilot study found that throw-traps appear to be the best method to use (compared with drop traps, lift traps, drift fences, and 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). The sampling design and final sampling unit protocols are still to be determined, but assuming the design and effort will be similar to a single management unit of marshes of Everglades then about 12 sites would be visited 2 times each year with 3 throw-traps each. As with the NE 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 a hydrological stage clock. 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 would be considered.

4.5.7 Amphibians

SFCN plans to monitor amphibian communities in BICY, EVER, and VIIS using a "Proportion of Area Occupied" approach similar to a pilot protocol used by USGS during their inventory work (Rice *et al.* 2004; 2005a; 2005b). At this time, SFCN plans to restrict the target population to amphibian communities in a buffered area around roads, trails (including airboat trails), and accessible areas. Sampling unit methods include night-time visual encounter surveys, vocalization surveys, and PVC tubes. Less accessible areas will be excluded from sampling due to feasibility constraints because utilizing helicopters to provide access at night is both prohibitively expensive and dangerous. An initial pilot study will be conducted to see to what degree amphibian communities change along transects moving away from roads and trails to assess how biased an estimate of the overall park populations this restriction will be. Sampling units will be spatially balanced using a GRTS design (see Section 4.2 for explanation). The within-year revisit schedule is still to be determined but will probably involve 3 revisits per sampling unit to provide accurate estimates of detection probability. Stratification decisions are still to be determined but may involve elevation/hydrology issues (e.g., to ensure sufficient sampling in guts in VIIS which proportionately are a very small fraction of the park).

A separate sampling effort in EVER and BICY will involve annual collection of pig frogs for population size structure and mercury analysis at a separate set of random points in deeper sloughs and canals, assuming the state of Florida is willing to analyze them.

4.5.8 Land-use change

SFCN proposes monitoring two key aspects of land-use change: a) the current extent and distribution of various land-use types, and b) the location and extent of proposed development near and within park boundaries.

Mapping of current land-use will occur within 1 mile of USVI parks and for Collier, Miami-Dade, and Monroe counties in South Florida and will be done in coordination with Florida International University, South Florida Water Management District, county and Territorial efforts. GIS Layers of in-holdings will be collected.

Evaluation of future planned land-use changes 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.

4.5.9 Invasive/exotic plant species

Monitoring invasive plant species will involve three main thrusts: complete surveys of highly visible invasive plants, monitoring corridors of invasion for new problem species, and asking other programs to opportunistically report species.

The Florida/Caribbean Exotic Plant Management Team (EPMT) is already utilizing two methods 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 (see Appendix P for more details). DASM 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 locations of 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 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 design and implement a protocol for “Corridors of invasiveness” that will involve an experienced botantist surveying corridors (public roads, fire roads, trails, beaches and canals) at low speeds for newly emerging 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. 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 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 userfriendly 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 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 (Daubenmire method), richness, and diversity, as well as canopy cover. Implementation is expected to be by the EPMT with assistance by SFCN in developing the protocols involved.

4.5.10 Invasive/exotic animal species

Canals along the eastern border of Everglades which commonly overwash into the park (L31W, L31N, C111), nearby canals, canals along the northern boundary of EVER, and canals in BICY (Tamiami canal, L-28, L31W, Loop road) are routes for exotic fish species invasion into EVER and BICY. SFCN will work in cooperation with EVER and BICY park personnel to use electrofishing and/or other methods in these canals to detect new exotic fish species while populations are still small and can still be targeted for control by a multi-agency team as part of Everglades Cooperative Invasive Species Management Area (CISMA, http://www.evergladescisma.org). The strategy would be a complete annual sample of problem hotspots (e.g., eastern EVER canals) and depending on staff time constraints, a rotation of sampling for other canals and potential problem areas on a 3-5 year rotation. If there is sufficient SFCN and BISC staff time, the effort may be expanded to BISC canals which empty into Biscayne Bay.

A large amount of existing monitoring is underway in the parks. SFCN will also have a technician or intern contact the major monitoring programs annually to determine if their monitoring has detected any exotic species or "unknown" species and help get that information channeled quickly to park staff and into the regional south Florida exotic species reporting and assessment process (CISMA) until such a time that these programs are regularly taking the initiative to report exotic species.

4.5.11 Surface water hydrology – weather stations, SARI gaging station

Weather stations at BUIS 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.

SFCN is constructing a single crest gage station to be placed at a road culvert in Salt River as it enters SARI. Park staff will assist in maintaining the station and downloading the data.

For the remainder of South Florida and USVI hydrology indicators, SFCN plans to post links to regional hydrology summaries by Bob Sobczak of BICY; the Everglades Depth Estimation Network (EDEN) which pulls together interagency hydrology data across the Greater Everglades (EVER + WCAs); USGS stream gage data on two guts in St. John (VIIS); Joe Boyer's (FIU) and SFWMD canal discharge data into Biscayne Bay (BISC); and Kevin Kotun's work at EVER. The sampling design placement for these stations has already been chosen by the implementing agencies.

4.5.12 Vegetation and marine benthic mapping

Various vegetation mapping and benthic mapping projects are underway as part of the SFCN Inventory and Monitoring Program inventory process with funding from the NPS National I&M Program in cooperation with several partners. The largest partner is CERP which is funding, through SFWMD, the mapping of most of EVER and 2/3 of BICY. On the marine side, NOAA, USGS, FWC-FWRI and SFWMD have been key partners in benthic mapping. SFCN plans to thoroughly document the inventory mapping process and hopes to work with the NPS National I&M Program to get funding to remap SFCN parks every 10-15 years. SFCN is working under the assumption that CERP will be re-mapping EVER and 2/3 of BICY, although the schedule of remapping may change from the current plan of complete remaps every 5 years. Mapping Florida Bay mud banks and berms would be done concurrent with re-doing of benthic maps in Florida Bay unless other imagery becomes available.

4.5.13 Water quality - Current water quality monitoring programs within the South Florida / Caribbean Network and review of regional hydrology summaries.

There is an extensive multi-agency water quality monitoring program within the SFCN park boundaries with 947 water quality stations that are actively being monitored by seven lead agencies (National Park Service, United States Geological Survey, National Ocean and Atmospheric Administration, Environmental Protection Agency Water Quality Protection Plan, South Florida Water Management District, Florida International University-Southeast Environmental Research Center, Miami-Dade County Department of Environmental Resource Management, Virgin Islands Division of Environmental Protection / Department of Planning and Natural Resources Protection (VIDEP/VIDPNR) within the SFCN boundaries (see Table 4-D and Figures 4-B to 4-H for a maps of water station locations). A more detailed description of water quality monitoring occurring in each park is provided in Appendix F, including which data is currently copied to STORET. This extensive monitoring is needed to answer a number of simultaneously occurring, interrelated, complex management questions regarding how the hydrology (water quality, quantity, timing and distribution) drives ecosystem structure and function across space and time.

The SFCN approach to water quality monitoring is to focus on pulling together and summarizing existing physical water quality data and/or compiling and reviewing the extensive reports currently being produced by the multitude of agencies on the water parameters. Disseminating this information (e.g., via the SFCN webpage http://science.nature.nps.gov/im/units/sfcn/waterrs.cfm) (Figure 4-I) and reporting on trends and changes in the surface water hydrology, nutrient dynamics and estuarine salinity pattern vital sign indicators will be made utilizing the resources outlined in Appendix F.2. The coral reef water temperature monitoring protocol is discussed briefly as part of marine benthic community vital sign above.

Table 4-D. Summary of physical and water quality stations in SFCN parks. More details in Appendix F.2.

Park	Temperature	Conductivity	DO	pH	N	P	Water Stage/ Depth / Flow	Fecal Coliform
BICY	36	16	16	16	16	16	20	
BISC	75	73	39	20	39	39	54	
BUIS	2							2
DRTO	18	16	15		15	15	1	
EVER	340	36	9	8	21	21	740	
SARI	1	1						1
VIIS	20	15	15	15	15	15		1

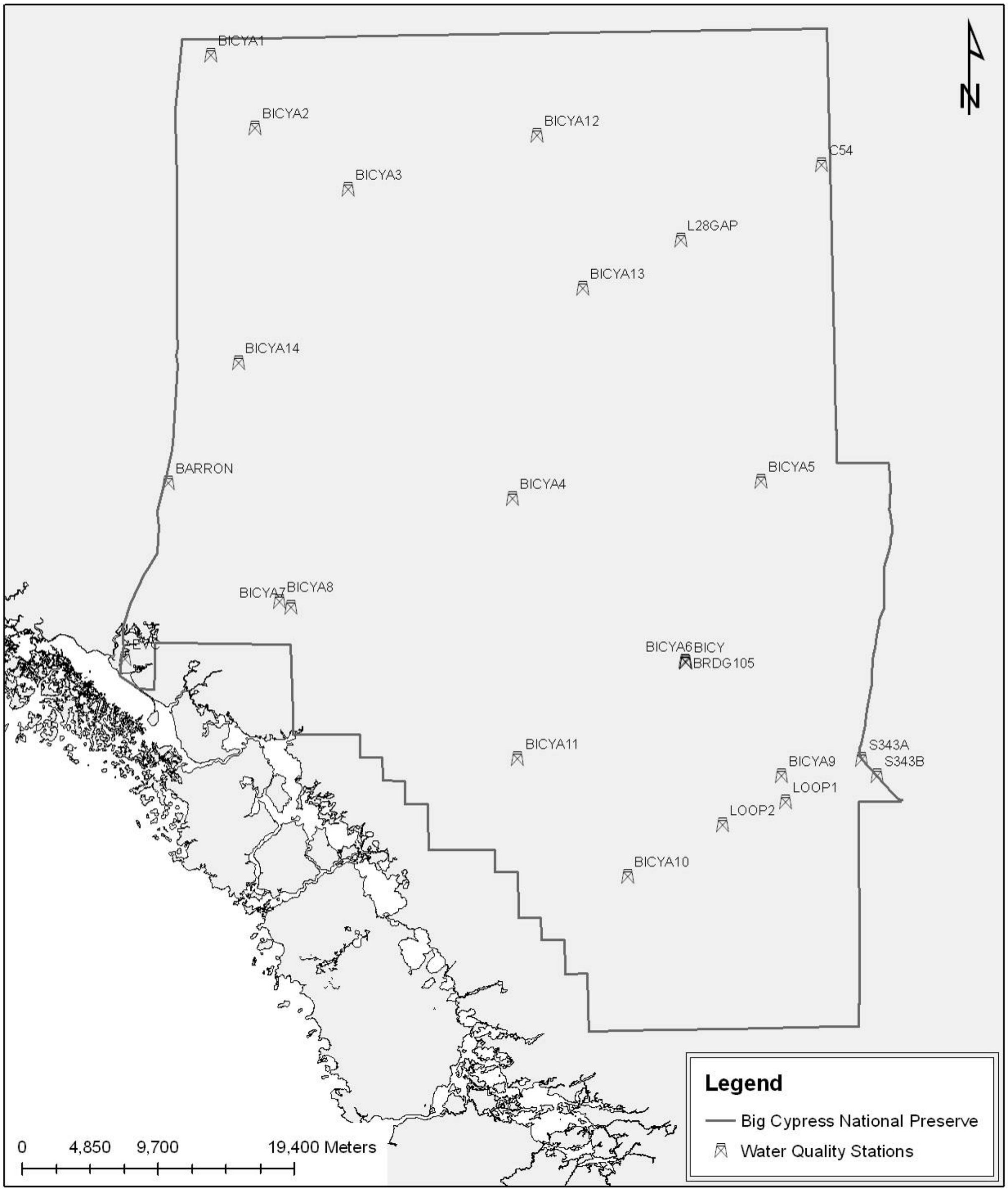


Figure 4-B. Big Cypress National Preserve water quality monitoring stations.

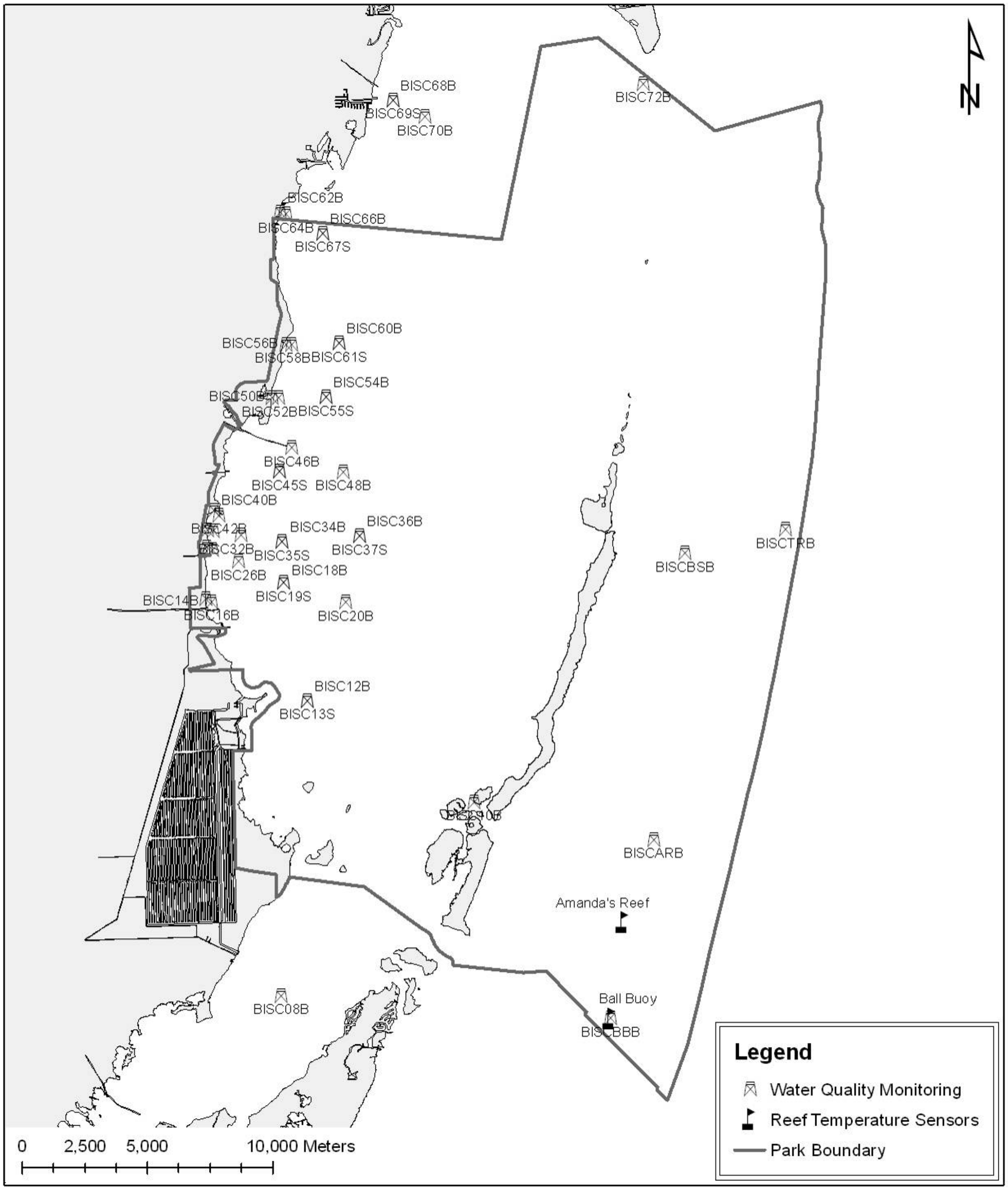


Figure 4-C. Biscayne National Park water quality monitoring stations.

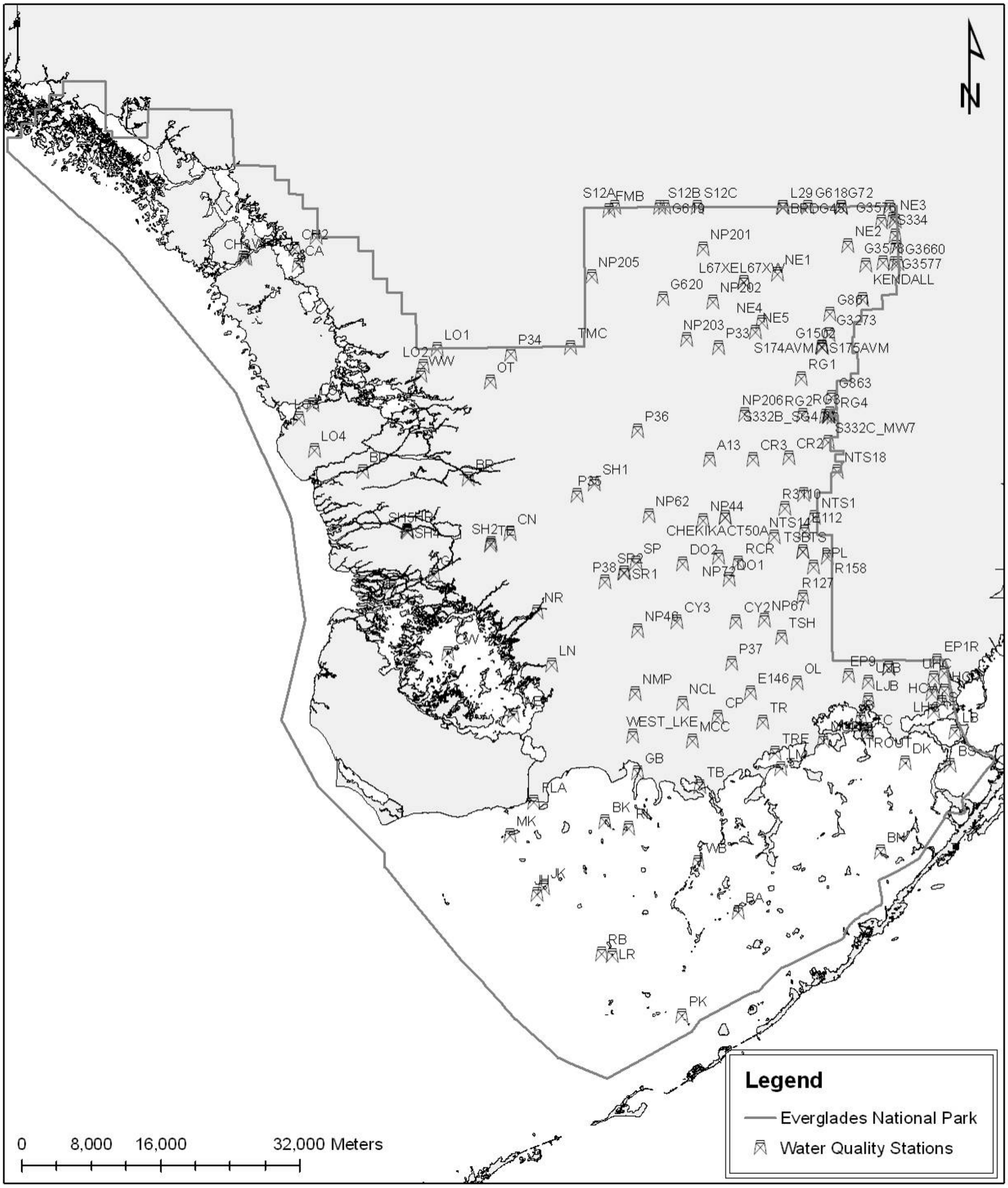


Figure 4-D. Everglades National Park water quality monitoring stations.

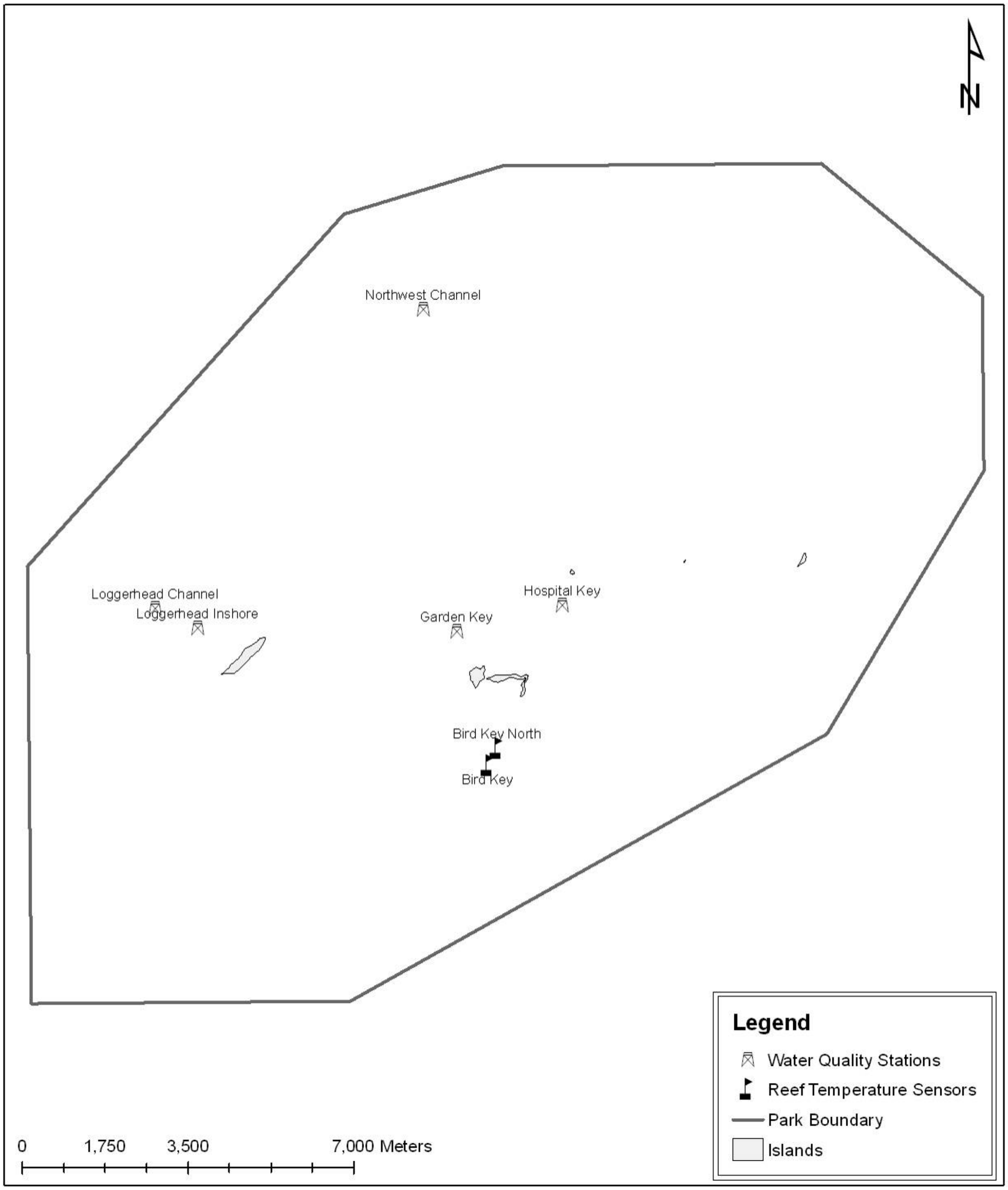


Figure 4-E. Dry Tortugas National Park water quality monitoring stations.

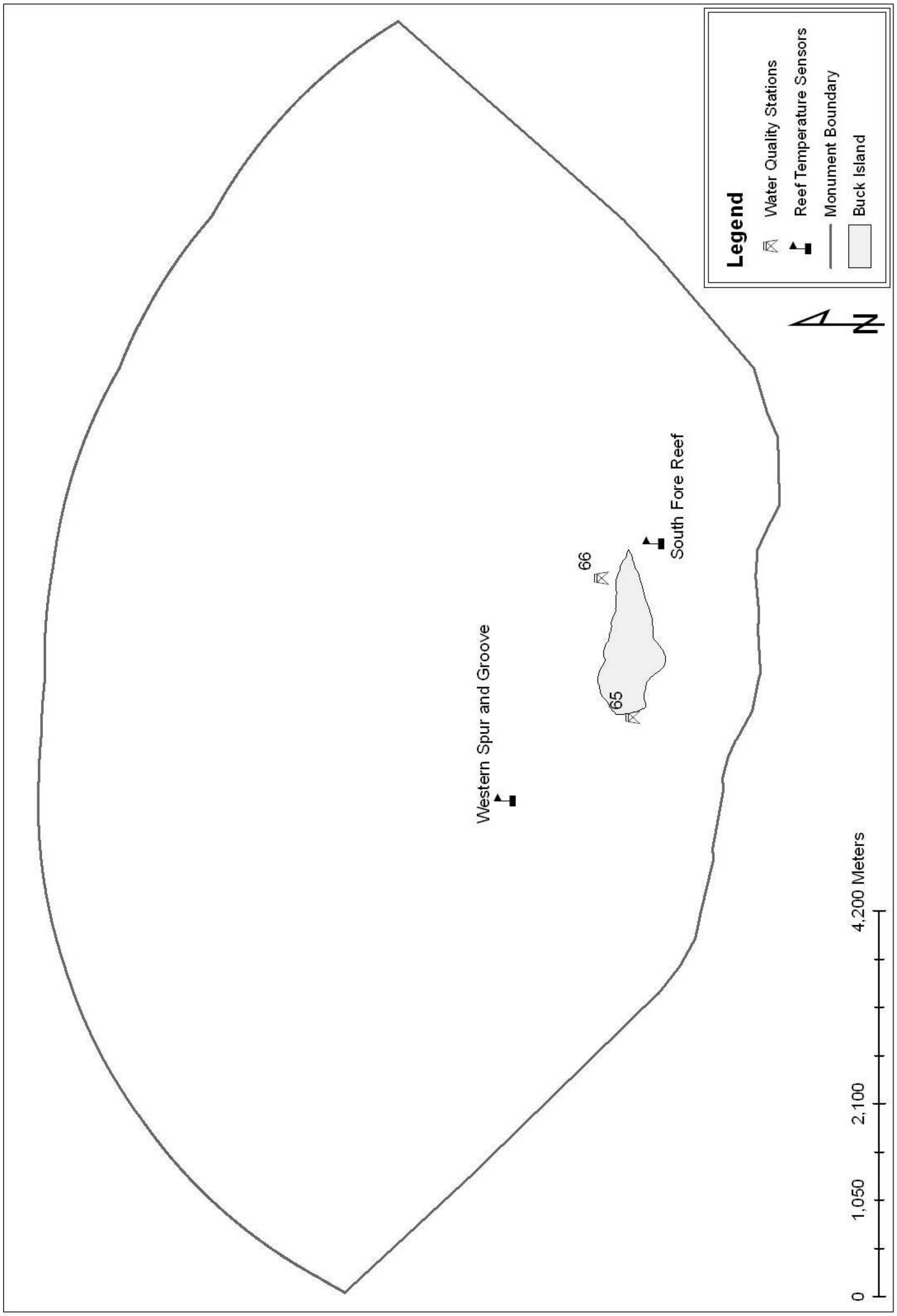


Figure 4-F. Buck Island Reef National Monument water quality monitoring stations.

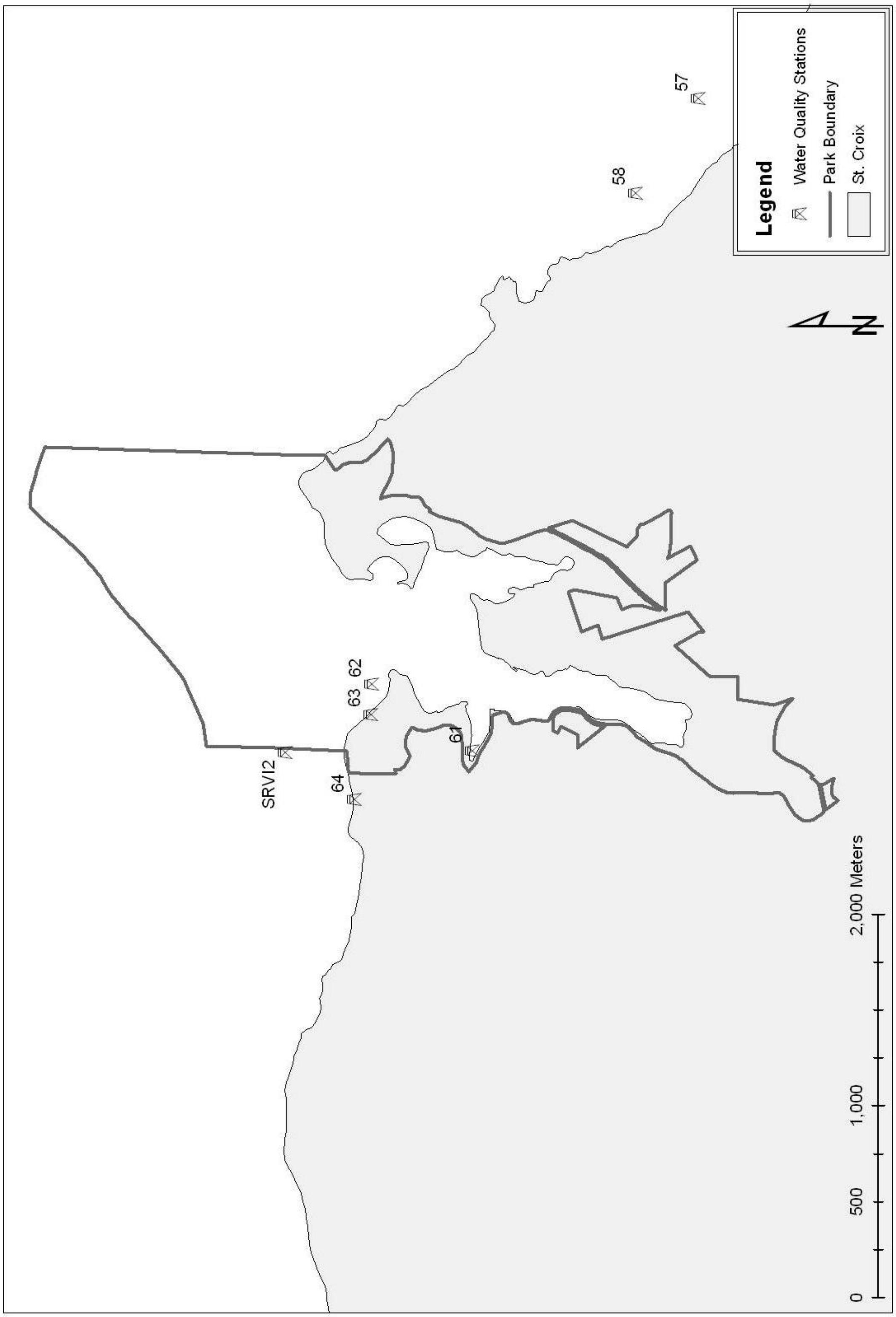


Figure 4-G. Salt River Bay National Historic Park and Ecological Preserve water quality monitoring stations.

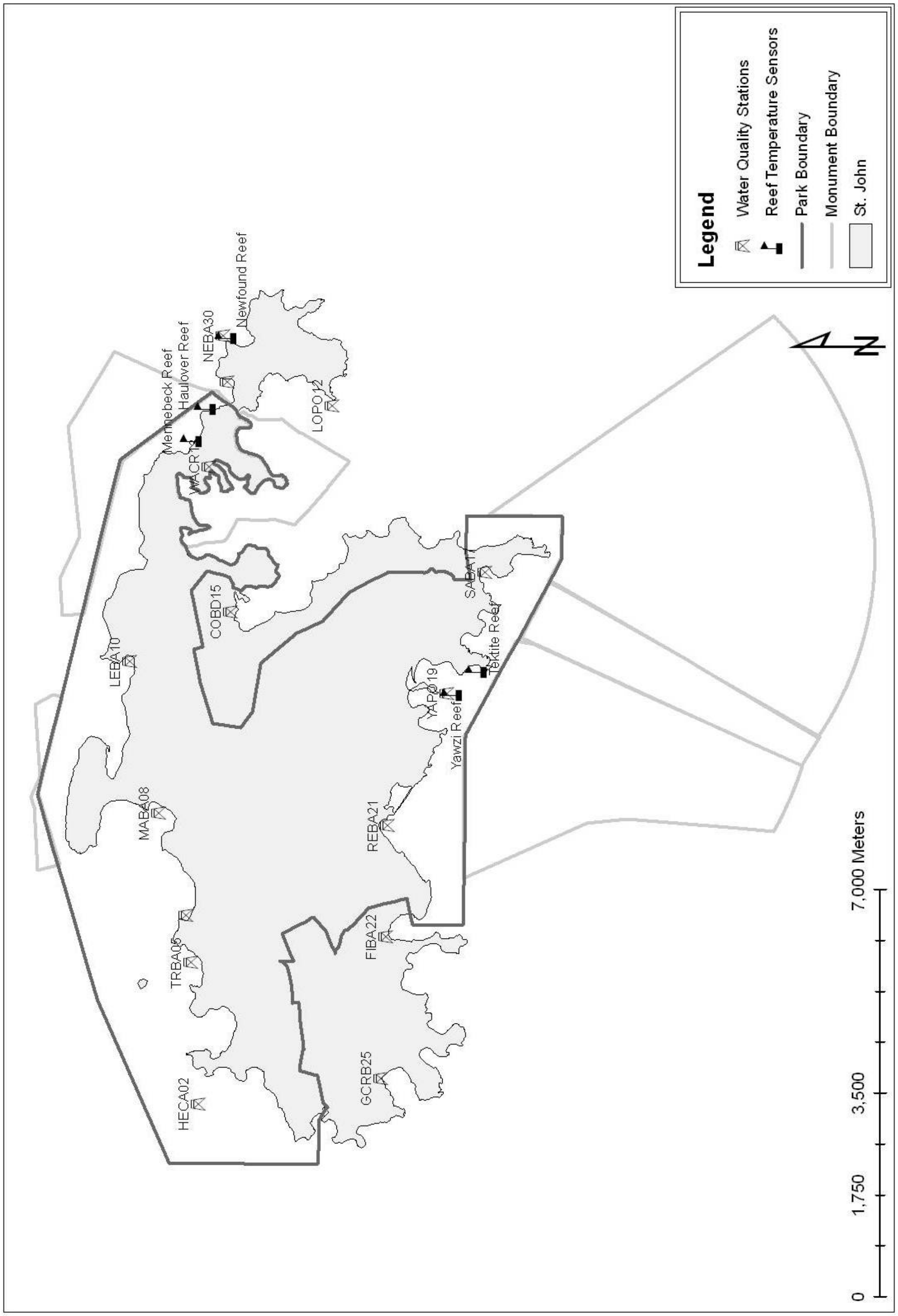
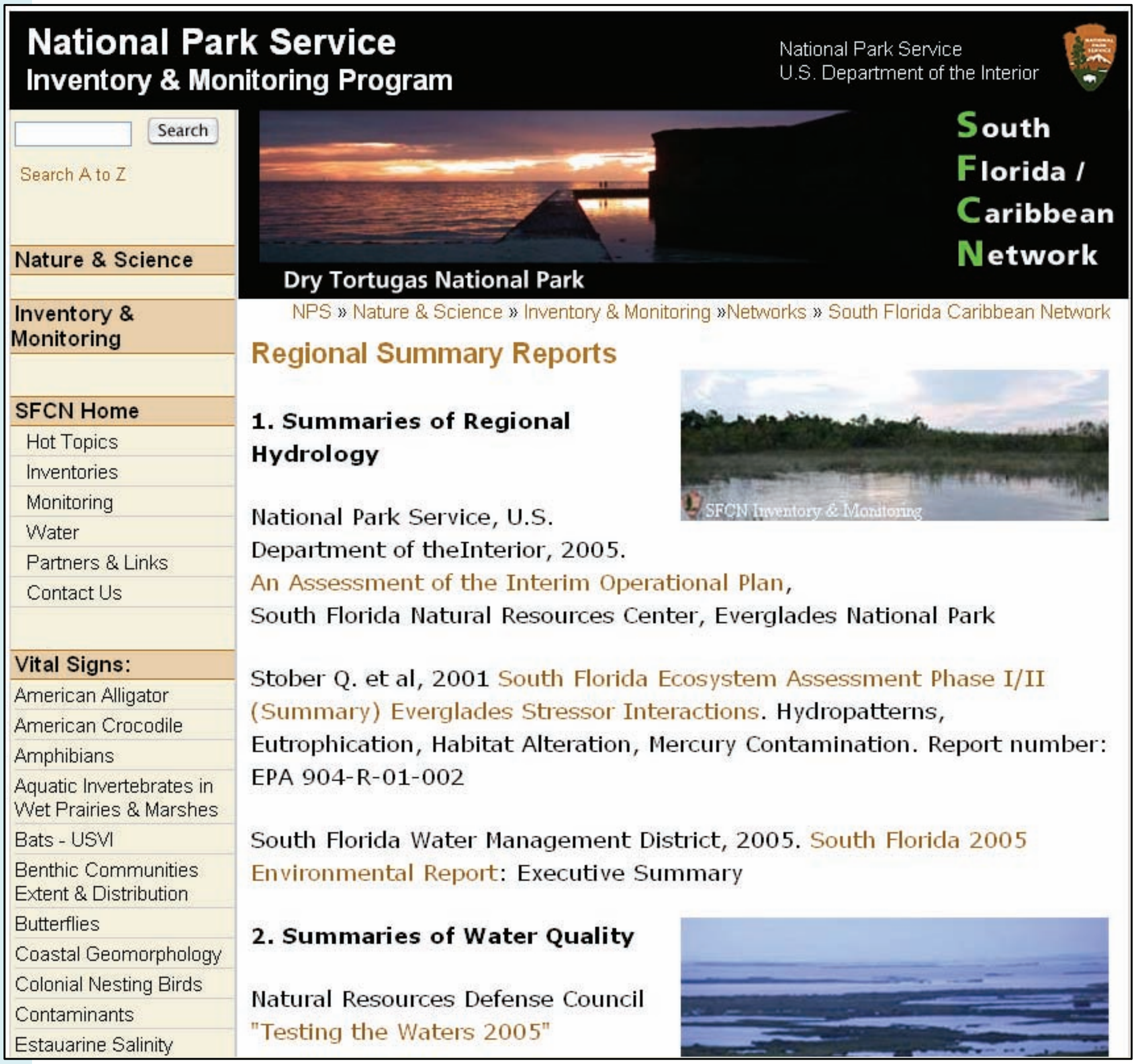


Figure 4-H. Virgin Islands National Park water quality monitoring stations.


National Park Service
Inventory & Monitoring Program

National Park Service
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South Florida / Caribbean Network

Dry Tortugas National Park

NPS » Nature & Science » Inventory & Monitoring »Networks » South Florida Caribbean Network

Regional Summary Reports

1. Summaries of Regional Hydrology

SFCN Inventory & Monitoring

National Park Service, U.S. Department of theInterior, 2005. An Assessment of the Interim Operational Plan, South Florida Natural Resources Center, Everglades National Park

Stober Q. et al, 2001 South Florida Ecosystem Assessment Phase I/II (Summary) Everglades Stressor Interactions. Hydropatterns, Eutrophication, Habitat Alteration, Mercury Contamination. Report number: EPA 904-R-01-002

South Florida Water Management District, 2005. South Florida 2005 Environmental Report: Executive Summary

2. Summaries of Water Quality

Natural Resources Defense Council "Testing the Waters 2005"

Figure 4-I. SFCN webpage disseminating regional water summary reports.

Table 4-E. Sampling design components for SFCN Vital Signs. White rows are those vital signs components for which SFCN is the lead agency or for which SFCN anticipates expending substantial field effort in cooperation with another agency. Grey rows indicate vital signs components for which a park or another agency is lead; for which outside funding would be required (mapping) or for which monitoring is deferred; TBD abbreviates "To be developed." Vital Sign Strategies are further described in Appendix P. Protocols are further described in Chapter 5 and in Appendix Q. Priority rank is given in brackets [ ].

Network Vital Sign in Priority Rank Order	Component	Target population	Membership design	Revisit design	Co-location/ Co-visitation protocols	Lead Agency or University
Marine Benthic Communities [1]	Coral - index sites	Coral reefs of management interest	Index sites with random permanent transects within site	1-2 yr rotation	Coral-temperature monitoring; *Diadema*; subset of marine fish communities	SFCN
	Coral – extensive design 2-20m deep	Hard-bottom habitat 2-20m deep	TBD; probably GRTS selection of permanent sites within hard-bottom with increased effort in areas with moderate to high coral cover	Rotation TBD	Coral-temperature monitoring; *Diadema*; Subset of marine fish communities	SFCN
	Coral - deep coral >20m feasibility assessment	Coral reefs >20m deep	TBD	TBD		SFCN
	Coral - temperature monitoring	Water temperature at reef depth within parks	Sub-set of coral monitoring sites	Continuous	Coral-index sites; coral - extensive design	SFCN
	Seagrass - outer BISC, DRTO, BUIS, SARI, VIIS	Seagrass density, composition in soft-bottom habitat within each region or management unit	TBD; probably GRTS or stratified random permanent within regions	5 yr rotation	Marine fish communities; queen conch	SFCN/ Park staff/ NOAA
	Seagrass - Florida Bay & Biscayne Bay	Seagrass density, composition in soft-bottom habitat within each sub-basin	Stratified random	1-5 yr rotation	Queen Conch?	FHAP-SF, DERM, SFCN/Park staff?
Marine Fish Communities [2]	BISC (Coastal Shelf), DRTO	Reef fish communities	Two-stage stratified random	Annual or biennial	Subset overlap with coral monitoring	NOAA, FWRI with SFCN assistance
	BUIS, VIIS, SARI	Reef fish communities	Stratified random	Annual or biennial	Subset overlap with coral monitoring; seagrass monitoring	SFCN/Park staff/NOAA
	Biscayne Bay & Florida Bay	Bay fish communities	Stratified random	Annual or biennial		SFCN with others?

Table 4-E. Sampling design components for SFCN Vital Signs (cont.)

Network Vital Sign in Priority Rank Order	Component	Target population	Membership design	Revisit design	Co-location/ Co-visitation protocols	Lead Agency or University
Surface Water Hydrology[3]	Weather stations - SARI, BUIS, possibly DRTO	Air temperature, rainfall, winds at selected index sites to provide covariates for other vital signs	Index sites chosen for convenience	Continuous		SFCN with Park staff
	Hydrology – EVER, BICY	Water depth, timing, duration into and across EVER & BICY and into FL Bay	Permanent stations chosen at gates, by best judgment, and where models showed deficiency	Continuous		Park staff, SFWMD, USGS
	Hydrology – BISC	Canal flows into Biscayne Bay	Permanent stations at canals	Continuous		Joe Boyer/FIU
	Hydrology – VIIS	Guinea gut, Lameshur Bay Gut	2 stream gages in ephemeral guts selected by best judgment	Continuous		USGS (continued funding uncertain)
	Hydrology - SARI - adding crest gage	Flows into Salt River Bay	Permanent station selected by best judgment on Salt River near park boundary	Continuous		SFCN with Park staff
Nutrient Dynamics[4]	BICY	Freshwater prairies nutrient levels	16 freshwater permanent sites	Monthly grab samples		Park Saff/ SFWMD
	BISC	Biscayne Bay marine nutrient levels	25 permanent sites	Monthly grab samples	Estuarine salinity patterns; pytoplankton	FIU/DERM /SFWMD
	DRTO	Park-wide marine nutrient levels	15 permanent sites	Monthly grab samples		FIU
	EVER	Freshwater prairies; marine nutrient levels	75 permanent sites	Monthly grab samples	Estuarine salinity patterns; pytoplankton	Park Saff/ SFWMD/FIU/USGS
	VIIS	Nutrient levels, conductivity, pH, DO in 15 bays	1 site per bay selected by best judgment	Biannual grab samples		Park staff

Table 4-E. Sampling design components for SFCN Vital Signs (cont.)

Network Vital Sign in Priority Rank Order	Component	Target population	Membership design	Revisit design	Co-location/ Co-visitation protocols	Lead Agency or University
Invasive/Exotic Plants [5]	SRF-Digital Sketch Mapping	Visible targeted invasive plant species populations in parks	Complete aerial survey	Annual or biennial		EPMT with SFCN assistance
	Corridors of Invasiveness	Newly established exotic and invasive species in parks	Two-phase design - All roads, trails, campgrounds, entry points sampled with either complete samples or random transects depending on area	Revisit schedule to each area weighted by likelihood of problem		EPMT & SFCN
	Voluntary Reporting Program	All invasive plant species within south Florida	Voluntary reporting	Opportunistic		EPMT with SFCN assistance
Marine Invertebrates-Rare, Threatened, Endangered [6]	*Acropora* species	Acroporiid populations within parks	TBD	Annual or biennial		Park staff
	Diadema	*Diadema* population size at coral reefs in parks	Co-located on coral-index site transects and park-wide transects	Rotation TBD	Coral - index sites; coral - extensive design	SFCN
	Black Coral Feasibility Assessment	Black coral within network parks (at diveable depths?)	TBD	TBD		SFCN
Vegetation Communities Extent & Distribution [7]	EVER, 2/3 BICY	All natural areas in WCAs and parks	Complete map	Every 10-15 years	CERP/ SFWMD	CERP/ SFWMD
	BISC, DRTO, BUIS, VIIS, SARI, 1/3 BICY	All natural areas within parks	Complete map	Every 10-15 years		SFCN with NPS Natl. Mapping Prgm

Table 4-E. Sampling design components for SFCN Vital Signs (cont.)

Network Vital Sign in Priority Rank Order	Component	Target population	Membership design	Revisit design	Co-location/ Co-visitation protocols	Lead Agency or University
Colonial Nesting Birds [8]	EVER - colony monitoring, SRF flights	All wading bird colonies in BICY, BISC, EVER and WCAs	Complete aerial surveys	SRF, monthly Dec-Jun		Park staff
	BICY – colony monitoring	All wading bird colonies at BICY visible from helicopter surveys	Complete surveys	SRF, monthly Dec-Jun		FAU with SFCN assistance to locate colonies
	BISC- colony monitoring	All wading and shorebird colonies at BISC visible from helicopter surveys	Complete surveys	Weekly or monthly, Dec-Jun		SFCN
	DRTO - colony monitoring	Sooty tern & brown noddy colonies at DRTO (other species also counted)	Surveys during breeding season (sub-sample in time)	2-3 times during breeding season		Park staff with SFCN
	BUIS, VIIS - colony monitoring	Brown Pelican nesting	Complete surveys	Annual or biennial		Park staff
	SARI - colony monitoring	TBD	TBD	TBD		SFCN with Park staff
Estuarine salinity patterns [9]	Biscayne & Florida Bays	Salinity levels through time in Biscayne & FL Bays	Permanent sites	Continuous and monthly	Nutrient dynamics; phytoplankton	Park staff, NOAA, AOML, FIU, DERM
Marine Exploited Invertebrates [10]	Spiny Lobster	Population size, size distribution, sex ratio within parks	TBD	Annual		SFCN
	Queen Conch	Population size, size distribution, maturity ratio within seagrass in parks	TBD; probably GRTS or stratified random within regions	5 yr rotation	Seagrass monitoring	SFCN, NOAA with others
	Pink Shrimp	Juvenile pink shrimp relative abundance in West, South Central & North Central Florida Bay, the Southwest Coast, Biscayne Bay	Mixture of historic design plus stratified random in newer sites	2x annually		NOAA- SEFSC /USGS
	Harvest data-lobster, shrimp, crabs (Stone, Blue, others), Sponges	South Florida commercial harvest	Fishing boat captain reporting	Continuous		FWRI, Park staff

Table 4-E. Sampling design components for SFCN Vital Signs (cont.)

Network Vital Sign in Priority Rank Order	Component	Target population	Membership design	Revisit design	Co-location/ Co-visitation protocols	Lead Agency or University
Land-use Change [11]	Land-use change	Land-use within 5 miles of USVI parks, 75 miles of S. Florida parks	Complete map	Every 5 years		SFCN
	Permitting/zoning changes next 1-3 yrs	New permits/zoning changes along & near park boundaries	Complete survey	Annual		SFCN
Invasive/Exotic Animals [12]	Surveying other programs for new species	Exotic species detected by various monitoring programs within parks	Varies with program	Annual		SFCN/Park staff
	Canals - EVER, BICY	New exotic aquatic species in canals adjacent to parks	TBD: Probably sample of hotspots using transects within canals	1-2 yr rotation		SFCN/Park staff
Visitor Use [13]		Park visitation by general use type	Park visitation counts, vendor reporting, trailhead surveys	Continuous		Park staff
Wetland Ecotones and Community Structure [14/15/16]	EVER-CERP funded	CSSS marl prairies; transitions between marl prairies and ridge & slough; ridge & slough	CSSS monitoring pts & transects within marl prairies; permanent randomly selected transects from prairies to slough; permanent unequal probability selection of ridge & slough plots	3 yr rotation of CSSS Marl Prairies (?); 5-10 yr rotation of marl prairie-slough transects (?); longer rotation for ridge & slough plots (?)		CERP, FIU, SFWMD, FAU
	BISC, BICY, supplement EVER?	Vegetation communities structure & composition; gradients along critical ecotones	TBD; probably combination of historical sites plus stratified random selection of additional community sampling units and ecotonal transects	5-10 yr rotation		SFCN/ Park staff

Table 4-E. Sampling design components for SFCN Vital Signs (cont.)

Network Vital Sign in Priority Rank Order	Component	Target population	Membership design	Revisit design	Co-location/ Co-visitation protocols	Lead Agency or University
Forest Ecotones and Community Structure [14/15/16]	BISC, BICY, EVER, VIIS	Vegetation communities structure & composition; gradients along critical ecotones	TBD; probably combination of historical sites plus stratified random selection of additional community sampling units and ecotonal transects	5-10 yr rotation		SFCN, Park staff, other prgms
Mangrove-Marsh Ecotone [14/15/16]	All parks	Vegetation communities structure & composition; gradients along critical ecotones	TBD; probably combination of historical sites plus stratified random selection of additional community sampling units and ecotonal transects	5-10 yr rotation		SFCN, USGS, CERP, FIU, FAU, other programs
Periphyton (Freshwater) [17]	EVER	Periphyton composition & structure in EVER Shark River Slough, Taylor Slough, and WCAs	EVER-multistage with GRTS selection of main units, mapping each unit, 3 subsamples/unit; NE BICY - pilot study	2-5x annually	Freshwater fish and large macro-invertebrates; aquatic invertebrates	FIU, SFWMD
	BICY NW corner	Periphyton composition & structure in NW corner of BICY	TBD; Control-impact design w/ restricted random selection of paired sampling sites of marsh/cypress domes, 3 samples per unit & 5 throws/sample. (possible restrictions due to access & proximity to hydrology stations)	2x annually	Freshwater fish and large macro-invertebrates; aquatic invertebrates	SFCN

Table 4-E. Sampling design components for SFCN Vital Signs (cont.)

Network Vital Sign in Priority Rank Order	Component	Target population	Membership design	Revisit design	Co-location/ Co-visitation protocols	Lead Agency or University
Freshwater fish and large macro-invertebrates [18]	EVER + NE BICY	FW fish, crayfish, grass shrimp abund., community composition & structure in EVER Shark River Slough, Taylor Slough, and WCAs	EVER-multistage with GRTS selection of main units, mapping each unit, 3 subsamples/unit; NE BICY - pilot study	2-5x annually	Periphyton	FIU, FAU, Park staff, USGS, Audubon of Florida
	BICY NW corner	FW fish, crayfish, grass shrimp abund., community composition & structure in six basins in NW corner of BICY (3 impacted, 3 not-impacted)	TBD; Control-impact design w/ restricted random selection of paired sampling sites of marsh/cypress domes, 3 samples per unit & 5 throws/sample. (possible restrictions due to access & proximity to hydrology stations)	2x annually	Periphyton; aquatic invertebrates	SFCN
Contaminants [19]		Research, varies	Research, varies	Research, varies		Various researchers, agencies
Sea Turtles [20]		Sea turtle nesting occurrences & successful reproduction on park nesting beaches	Complete sample or large sub-sample of nesting beaches	Daily-biweekly during nesting season		Park staff
American crocodile [21]		Population size, growth, survival in south Florida	Historic or reference sites	Annual		USGS/UF
American Alligator [22]		Population size, body condition, nesting success within EVER and WCAs, reported by region & sub-region	Historic or reference sites	Annual		USGS/UF
Benthic Communities Extent & Distribution [23]		Major benthic communities extent & spatial distribution	Complete map	Every 10-15 years	FL Bay-mapping mud banks, berms	SFCN with NPS Natl. I & M Prgm

Table 4-E. Sampling design components for SFCN Vital Signs (cont.)

Network Vital Sign in Priority Rank Order	Component	Target population	Membership design	Revisit design	Co-location/ Co-visitation protocols	Lead Agency or University
Amphibians [25]		Amphibian communities in buffered areas along roads, trails, accessible areas of parks	GRTS with strata	Annual or bi-annual, 3x per sampling year		SFCN
Sawfish [26]		Regional sawfish population size, distribution, location of nursery grounds, reproduction, habitat use	Preliminary work: Mark-recapture of adults, nursery surveys, creel surveys	Annual		MOTE
Coastal Geomorphology [27]	Sediment Elevation Tables (SETs)	Coastal mangroves and salt pond elevations	TBD	Annual	Mangrove-marsh ecotone	SFCN, USGS
	Fl Bay - mapping mud banks, berms	FL Bay mud banks & berms	Complete map	Every 10-15 years	Benthic Communities Extent & Distribution	SFCN with Park staff; NPS Natl. I & M Prgm
Protected Marine mammals [28]		South Florida manatee population size, mortality	Aerial survey counts of all visible adults	Annual		FWRI, FKNMS
Fire Return Interval Departure [29]		BICY, EVER vegetation	All known burns within BICY, EVER	Annual		Park staff with SFCN/USGS
Focal fish species [30]		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	Creel-census (fishery dependent); reef fish monitoring (stratified random); individual studies (juv. sea trout monitoring; MOTE shark monitoring; USVI red hind)	Variable		Park staff, FWRI, MOTE, RSMAS, SFNRC, UVI
Aquatic invertebrates in wet prairies & marshes [32]	BICY NW corner	Aquatic invertebrates community composition & structure in NW corner of BICY	TBD; Control-impact design w/ restricted random selection of paired sampling sites of marsh/cypress domes, 3 samples per unit & 5 throws/sample. (possible restrictions due to access & proximity to hydrology stations)	2x annually	Freshwater fish and large macro-invertebrates; periphyton	SFCN

Table 4-E. Sampling design components for SFCN Vital Signs (cont.)

Network Vital Sign in Priority Rank Order	Component	Target population	Membership design	Revisit design	Co-location/ Co-visitation protocols	Lead Agency or University
Florida panther [33]		Regional and within park panther population size, home ranges, denning, habitat use	Radio-collaring of all adults	Annual		Park staff in cooperation with regional efforts
Phytoplankton (Marine) [34]		Algal blooms using Chlorophyll a as proxy by region within EVER, BISC & adjacent waters	Permanent water quality monitoring stations selected by best judgment and continuous synoptic sampling	Monthly	Nutrient dynamics; estuarine salinity patterns	FIU, NOAA, SFWMD, USF
Air Quality-Deposition		Regional air quality	1 Index site each at EVER, VIIS	Weekly		Park staff w/NPS-ARD
Air Quality-Mercury		Regional air quality	Index site at EVER	Weekly		Park staff w/SFWMD

Chapter 5: Sampling Protocols

"Monitoring protocols 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. Protocols are necessary to ensure that changes detected by monitoring actually are occurring in nature and not simply a result of measurements being taken by different people or in slightly different ways. . . . A good monitoring protocol will include extensive testing and evaluation of the effectiveness of the procedures before they are accepted for long-term monitoring. Peer review of protocols and revisions are essential for their credibility. The documentation should include reviewers' comments and authors' response."
Oakley, et al. (2003)

5.1 Protocol Development and SFCN Role Relative to Existing Programs

SFCN will be developing twelve formal monitoring protocols during the first five years (Table 5-A). Monitoring protocols identify methods for gathering data, outline a process to collect data, and establish how data will be analyzed and reported. A good monitoring protocol should be appropriate for the task, accurate, reliable, feasible, and cost-effective (Margoluis *et al.* 1998). Good rigorous protocols contain detailed study plans, clear objectives, unambiguous step-by-step Standard Operating Procedures (SOPs) for data collection, management, QA/QC and analysis, training and equipment requirements, documentation of protocol changes, and relevant support information. Careful design and documentation of protocols is necessary to ensure that changes detected by monitoring actually are occurring in nature and do not stem from measurement variability introduced when different people or methods are used (Oakley *et al.* 2003). Rigorous protocols are essential for effective monitoring of vital signs through time.

The National Park Service Inventory and Monitoring Program requires that all monitoring towards which SFCN funding is to be used either A) use an existing protocol developed by another agency or program that has already been peer-reviewed and field-tested or B) if developed internally must: (1) follow the Oakley *et al.* (2003) protocol standards, (2) be peer-reviewed, and (3) be approved by the Regional I&M Coordinator before they are finalized for long-term monitoring.

The Oakley *et al.* (2003) format basically consists of three main types of information: a narrative, SOPs, and any supplemental materials. The narrative contains an overview of the background and objectives, sampling design, field methods, data handling, analysis and reporting, personnel requirements and training, and operational requirements. The SOPs are detailed procedures for all components described in the narrative. Supplemental materials include databases, GIS layers, related data and reports, reviewer comments, etc.

Thirty-three of the vital signs are already being monitored either in their entirety or in part by other groups. For vital signs already being monitored by existing programs, SFCN will work to gather and archive copies of the existing protocols, SOPs and QA/QC guidelines. As appropriate, SFCN will develop SOPs for how the network will analyze and report results from these other groups. Some CERP funded programs are still in the process of developing protocols and final versions may not be available for several years. CERP has its own protocol documentation and quality review process

Table 5-A. SFCN protocols to be developed in Oakley *et al.* (2003) format sorted by year due. Many will be adaptations or expansions of existing protocols.

Protocol	Component	Year Due
Marine Benthic Communities	Coral - Index sites	2007
	Coral – Extensive design, 2-20m deep	2008
	Coral - Deep Coral >20m Feasibility Assessment	2014
	Coral - Temperature Monitoring	2007
	Seagrass - Outer BISC, DRTO, BUIS, SARI, VIIS	2009*
	Diadema	2007
	Conch	2009**
Colonial Nesting Birds	BISC	2009
Invasive/Exotic Plants – Corridors of invasiveness	Corridors of Invasiveness	2009
Land-use Change	Land-use change	2009
	Permitting/zoning changes next 1-3 yrs	2009
Marine Fish Communities	BISC (Coastal Shelf), DRTO	2009
	BUIS, VIIS, SARI	2009*
	Florida Bay & Biscayne Bay (EVER, BISC)	2009***
Soil Elevation	Soil Elevation Tables (SETs)	2009
Forest Ecotones & Community Structure	BISC, BICY, EVER, VIIS	2010
Freshwater fish, invertebrates, and periphyton	BICY NW corner	2010
Invasive/Exotic Fish - Canals	Canals - EVER, BICY	2010
Mangrove-Marsh Ecotone	All parks	2010
Spiny Lobster	Network-wide	2010
Amphibians	BICY, EVER, VIIS	2012

* Partially dependent upon whether NOAA Coastal Monitoring and Assessment Program continue to fund monitoring in USVI
** SFCN may defer if co-sampling with seagrass monitoring does not yield sufficient power
*** May be deferred if existing programs sufficiently cover the bays and if reef fish monitoring takes more staff time than initially anticipated

which is outlined in the *Quality Assurance Systems Requirements (QASR) Manual for the Comprehensive Everglades Restoration Plan* (CERP 2006).

5.2 Protocol Development Summaries

Table 5-B provides the 12 protocols SFCN is developing, the vital signs to which each protocol relates, justifications, monitoring objectives, and parks in which each protocol will be implemented. SFCN has written a 1-6 page "Protocol Development Summary" (PDS) for each of the twelve protocols in Appendix Q.

5.3 Protocol Work completed

By September 2008, drafts of the following components of the Marine Benthic Communities protocol have been completed:

Coral – Index sites
Coral – Temperature monitoring
Diadema

Table 5-B. SFCN protocols with relevant vital signs, justifications, monitoring objectives and year due.

Protocol	Justification	Monitoring Objectives	Parks
	2008		
Marine Benthic Communities *Relevant Vital Signs:* Marine Benthic Communities Marine Invertebrates: Rare, Threatened, Endangered Marine Exploited Invertebrates	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 Caribbean and Atlantic coral reefs within the National Park Service. 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. The enabling legislation and/or presidential proclamations for VIIS, BUIS and DRTO specifically mention coral reefs within these park units as significant environmental communities. 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 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.	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*). 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. 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). 4. Determine status and trends in adult and juvenile conch density and size structure within seagrass communities <20m deep. 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 feasibility, safety and cost-effectiveness. 6. Determine status and trends in stony coral recruitment, pending a pilot study to establish feasibility, safety and cost-effectiveness.	BISC BUIS DRTO EVER VIIS SARI

Table 5-B. SFCN protocols with relevant vital signs, justifications, monitoring objectives and year due (cont.).

Protocol	Justification	Monitoring Objectives	Parks
	2009		
Colonial Nesting Birds *Relevant Vital Signs:* Colonial Nesting Birds	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. 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.	1. Determine long term trends in annual peak nest count in colonial nesting bird colonies at BISC 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.	BISC EVER BICY BUIS SARI DRTO VIIS
Invasive/ Exotic Plants – Corridors of invasiveness *Relevant Vital Signs:* Invasive/Exotic Plants	Invasive plants are one of the most serious threats to maintaining ecosystem integrity in SFCN parks. Multiple laws and executive orders deal specifically with invasive species. Detecting new problem species early before they have a chance to spread and while they are still in small controllable populations is important to cost-effective resource management.	1. Routinely search roads, trails, canals, campgrounds, and other "Corridors of Invasiveness" to detect newly emerging and existing invasive plant species.	BISC BICY BUIS DRTO EVER
Land-use Change *Relevant Vital Signs:* Land-use Change	Changes in land-use, sizes of the non-urban buffers around park boundaries, development of in-holdings 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.	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. 2. Compile and summarize current approved building permits for selected areas to provide advisories to the park. 3. Compile and summarize current applications for changes in land zoning, and approved zoning-changes for selected areas to provide advisories to the park. 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.	BISC EVER BICY SARI VIIS

Table 5-B. SFCN protocols with relevant vital signs, justifications, monitoring objectives and year due (cont.).

Protocol	Justification	Monitoring Objectives	Parks
Marine Fish Communities *Relevant Vital Signs:* Marine Fish Communities	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.	1. Determine status, trends, and variability in exploited reef fish species (Grouper/Snapper species plus parrotfish, surgeonfish, and baitfish in USVI parks) abundance (density), distribution and size structure. 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. 3. Determine status, trends and variability in reef fish community relative abundance (density), distribution, biomass, size distribution, fish community taxonomic composition, species richness, recruitment. 4. Compile data on status, trends, and variability in reef fish species from other sources to allow comparison inside vs. outside marine protected areas. 5. Determine recruitment, relative abundance (density), and distribution of nearshore and estuarine (bay) fish communities. 6. Document locations and approximate sizes of spawning aggregations in network parks when encountered.	BISC BUIS DRTO EVER VIIS SARI
Soil Elevation *Relevant Vital Signs:* Coastal Geomorphology	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. Another important issue in the USVI is sediment runoff filling of ephemeral guts and salt ponds from upland development.	1. Determine changes in soil elevation (accretion, subsidence, and erosion) in mangroves, mudbanks and salt ponds.	BISC EVER BUIS SARI VIIS

Table 5-B. SFCN protocols with relevant vital signs, justifications, monitoring objectives and year due (cont.).

Protocol	Justification	Monitoring Objectives	Parks
	2010		
Forest Ecotones & Community Structure *Relevant Vital Signs:* Forest Ecotones & Community Structure	Forests provide habitat for many species, are important primary producers, and are dominant physical structure components in terrestrial natural systems. Consequently forests are a primary focus of management. Forest community composition and structure change due to forest succession, disturbance, hydro-pattern (including groundwater), fire regime, disease or insect outbreak effects, and native/non- native species, etc. Forest ecotones are transition zones between habitats, are generally dynamic locations for flora and fauna, and are expected to move, expand and contract, for example, in response to changes in fire management, water management and sea level rise. In particular, hardwood 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 and forests expand into wet prairies and marshes. But fires can destroy hammocks. Fire management is critical to maintaining a habitat balance.	1. At approximately 5 to 10 year intervals, document changes in the location of the pineland-hammock ecotones. 2. At approximately 5 to 10 year intervals, document changes in the location of the forest- marsh ecotones. 3. Determine long term trends in forest community structure and composition.	BISC EVER BICY BUIS SARI DRTO VIIS
Freshwater fish, invertebrates, and periphyton *Relevant Vital Signs:* Freshwater fish and large macro-invertebrates Periphyton Aquatic invertebrates in freshwater prairies and marshes	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. The total biomass and timing of concentration of fish and macro-invertebrate populations are critical for wading bird nesting success. Periphyton and aquatic invertebrate community composition are strongly influenced by water quality, esp. nutrient enrichment, as well as duration of flooding.	1. Determine status and trends in community composition, abundance (density & relative abundance), size structure, and distribution of fish, large macroinvertebrates, aquatic invertebrates, and periphyton in Northwestern Big Cypress.	BICY

Table 5-B. SFCN protocols with relevant vital signs, justifications, monitoring objectives and year due (cont.).

Protocol	Justification	Monitoring Objectives	Parks
Invasive/ Exotic Fish in Canals *Relevant Vital Signs:* Invasive/ Exotic Animals	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 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.	1. Routinely search canals bordering EVER (and BICY pending an analysis of effort) to detect new exotic fish species.	BICY EVER
Mangrove-Marsh Ecotone & Mangrove Community *Relevant Vital Signs:* Mangrove-Marsh Ecotone	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. Mangrove-marsh ecotones are dynamic transition zones between habitats for which changes in location and physical drivers 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. 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).	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. 2. Determine status and trends of mangrove community structure and composition.	BISC EVER BICY BUIS SARI DRTO VIIS
Spiny Lobster *Relevant Vital Signs:* Marine Exploited Invertebrates	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.	1. Determine trends in the relative abundance/density, size structure and sex ratio of spiny lobster	BISC BUIS DRTO EVER VIIS SARI

Table 5-B. SFCN protocols with relevant vital signs, justifications, monitoring objectives and year due (cont.).

Protocol	Justification	Monitoring Objectives	Parks
	2012		
Amphibians *Relevant Vital Signs:* Amphibians	Amphibians comprise a large amount of the resident vertebrate biomass, generally are a strong intermediate link in the food web, and are sensitive to changes in water hydrology, water quality, invasive species, and contaminants. The rising numbers of exotic species (e.g., Cuban tree frog, *Osteopilus septentrionalis*) that are out-competing and preying upon native fauna are also a concern. In EVER and BICY, shifts in population structure of pig frogs, *Rana grylio*, a dominant anuran in the freshwater marsh, have been related to water management. Additionally, pig frogs bioaccumulate mercury and currently are being monitored by the State of Florida (FWRI) for mercury levels.	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. 2. Determine status and trends in the sex and age structure of pig frogs in EVER and BICY. 3. Document concentrations of mercury in pig frogs in EVER and BICY.	BICY EVER VIIS

Chapter 6: Data Management

Information is the common currency among the activities and staff involved in natural resource management in the National Park Service. The central mission of the National Park Service's I&M Program is to acquire, manage, analyze, and distribute scientific information on the status and trends of specific park natural resources. Intended users of this information include park managers, cooperators, researchers, congress, policy makers, and the general public. A cornerstone of the Inventory and Monitoring Program is the strong emphasis placed on data management. The SFCN expects to invest over thirty-three percent of its available resources in data management, analysis, and reporting activities. Because of the size and complexity of the elements comprising network data management, a separate Data Management Plan has been developed and is included in this report as Appendix R.

6.1 The SFCN Data Management Plan

The goal of the South Florida/Caribbean Network's data management program is to maintain, in perpetuity, the ecological data and related analyses that result from the network's inventory and monitoring work. The SFCN Data Management Plan describes the resources and processes required to ensure the accuracy, security, longevity, and accessibility of data acquired or managed by the SFCN.

6.1.1. Data Accuracy

The quality of the data collected and managed by the I&M Program is paramount. Analyses performed to detect ecological trends or patterns require data with minimal error and bias. Inconsistent or poor-quality data can limit the detection of subtle changes in ecosystem patterns and processes, which can lead to incorrect interpretations and conclusions that could lead to poor management decisions and greatly compromise the credibility and success of the I&M Program. To ensure that the SFCN produces and maintains data of the highest possible quality, procedures are established to identify and minimize errors at each stage of the data lifecycle.

6.1.2. Data Security

Digital and hard-copy data must be maintained in environments that protect against loss, either due to electronic failure or to poor storage conditions. Digital data of the SFCN are stored in multiple formats on a secure server and are backed up through an integrated backup routine that includes rotation to off-site storage locations. In addition, the SFCN is working with NPS museum curators and archivists to ensure that related project materials such as field notes, data forms, specimens, photographs, and reports are properly cataloged, stored, and managed in archival conditions.

6.1.3. Data Longevity

Countless data sets have become unusable over time either because the format is outdated (e.g., punchcards), or because metadata is insufficient to determine the data's collection methods, scope and intent, quality assurance procedures, or format. Proper storage conditions, backups, and migration of data sets to current platforms and software standards are basic components of data longevity. Comprehensive data documentation is another essential component. The SFCN uses a suite of metadata tools to ensure that data sets are consistently documented, and in formats that conform to current federal standards.

6.1.4. Data Accessibility

One of the most important responsibilities of the Inventory and Monitoring Program is to ensure that data collected, developed, or assembled by the

Table 6-A. Data that are provided on the SFCN and national I&M websites.

Web Application Name	Data available at site
SFCN Website	Reports and metadata for SFCN projects; certified species lists; search and reporting tools for data; data downloads; database templates (http://science.nature.nps.gov/im/units/sfcn/)
IRMA	Integrated Resource Management Application: Entry portal for the applications listed below.
NPSpecies	Database of vascular plant and vertebrate species known or suspected to occur on NPS park units (http://science.nature.nps.gov/im/apps/npspp/).
NatureBib	Bibliography of park-related natural resource information (http://www.nature.nps.gov/nrbib/).
NPSFocus	Portal to a variety of NPS information sources; will include NatureBib and NR/GIS Data Store links (http://npsfocus.nps.gov/).
NPS Data Store	Park-related metadata and selected data sets (spatial and nonspatial) (http://science.nature.nps.gov/nrdata/).

SFCN staff and cooperators are made available for decision-making, research, and education. Providing well documented data in a timely manner to park managers is especially important to the success of the program. The SFCN must ensure that:

- Data are easily located and obtained
- Data are subjected to full quality control before release
- Data are accompanied by complete metadata
- Sensitive data are identified and protected from unauthorized access and distribution

The SFCN's main mechanism for distribution of the network's Inventory and Monitoring data will be the Internet, which will allow data and information to reach a broad community of users. As part of the NPS I&M Program, web-based applications and repositories have been developed to store a variety of park natural resource information (Table 6-A).

The South Florida/Caribbean Network's information acquires its real value when it reaches those who can apply it. If these web portals do not meet a specific user's requirements, SFCN data management staff will work with users on an individual basis to ensure receipt of the desired information in the requested format.

6.2 Data Sources and Priorities

There are multiple sources of data related to natural resources in the SFCN parks. The types of work that may generate these data include:

- Inventories
- Monitoring
- Protocol development pilot studies
- Special-focus studies performed by internal staff, contractors or cooperators
- External research projects
- Studies performed by other agencies on park or adjacent lands
- Resource impact evaluations related to park planning and compliance
- Resource management and restoration work

Because the I&M Program focuses on natural resource inventories and long-term monitoring, the SFCN's first data management priority is the data that result from these efforts. However, the standards, procedures, and approaches to data management developed by the SFCN are being applied to other natural resource data sources.

For example, all natural resource parks need a basic suite of resource inventory data in order to effectively manage their resources and support a successful monitoring program. The national Inventory and Monitoring Program has determined that a minimum of 12 inventory data sets, including both biotic and abiotic components, should be acquired by all parks. The SFCN is working with individual parks and national NPS programs to acquire and standardize these basic resource data sets, and make them widely available. These data sets are:

- Natural resource bibliography
- Base cartographic data
- Air quality data
- Air quality related values
- Climate inventory
- Geology resources inventory
- Soil resources inventory
- Water body location and classification
- Baseline water quality data
- Vegetation inventory
- Species lists
- Species occurrence and distribution

Prioritizing data management efforts in a sea of unmanaged data

- Highest priority is to produce and curate high-quality, well-documented data originating with the Inventory and Monitoring Program.
- Assist with data management for current projects, legacy data, and data originating outside the Inventory and Monitoring Program that complement program objectives.
- Help ensure good data management practices for park-based natural resource projects that are just beginning to be developed and implemented.

6.3 Data Management Categories

Data from park and network sources can generally be placed in the following data management categories:

1. *Data managed in service-wide databases.* The SFCN has used three databases developed by the I&M WASO office. NatureBib is a bibliographic tool for cataloging reports, publications, or other documents that relate to natural resources in park units. Dataset Catalog is used to document primarily non-spatial natural resource-related databases or other data assemblages. NPSpecies is used by the network to develop and maintain lists of vertebrates and vascular plants in network parks, along with associated supporting evidence. With the development of IRMA, the SFCN will use this data portal as the primary portal for accessing data.
2. *Data developed or acquired directly by the network as a result of inventory, monitoring, or other projects, and managed by the SFCN.* This category includes project-related protocols, field data, reports, spatial data, and associated materials such as field forms and photographs provided to the SFCN by the parks, contractors or developed by the SFCN staff. Projects can be short-term (one to three years duration) or long-term (ongoing monitoring).
3. Data that, while not developed or maintained by the SFCN, are used as primary data sources or provide context to other data sets. Examples of this category include: GIS data developed by parks, other agencies or organizations; national or international taxonomic or other classification systems; climate, air quality, or hydrologic data collected or assembled by regional or national entities.
4. *Data acquired and maintained by network parks that the SFCN assists in managing.* Because of the range of data management expertise in network parks, the SFCN provides data management assistance for high-priority data sets or those that

may benefit from standardized procedures.

The categories above can contain one or more of the following data formats:

- Hard-copy documents (e.g., reports, field notes, survey forms, maps, references, administrative documents)
- Physical objects (e.g., specimens, samples, photographs, slides)
- Electronic text files (e.g., MSWord files, email, websites)
- Electronic tabular data (e.g., databases, spreadsheets, tables, delimited files)
- Spatial data (e.g., shapefiles, coverages, remote-sensing data)
- Miscellaneous electronic files (images, sounds, other files with proprietary formats)

Each of these data formats has specific requirements for ongoing management and maintenance, which are addressed in the Data Management Plan.

6.4 Data Management and the Project Lifecycle

Inventory and monitoring projects are typically divided into five broad stages: planning and approval; design and testing; implementation; product integration; and evaluation and closure (Fig. 6-A). During all stages data management staff collaborate closely with project leaders and participants. Specific data management procedures correspond to these stages and are fully detailed in the chapters of the Data Management Plan. Building upon the data management framework presented in Chapters 1 through 4, Chapter 5 is devoted to data acquisition and processing, and Chapter 6 provides a framework for verifying and validating data that have been collected and entered into databases. Dataset documentation is the subject of Chapter 7, reporting in Chapter 8, and data dissemination, including issues such as data ownership, data sensitivity, and compliance with the Freedom of Information Act, are addressed in Chapter 9. Chapter 10 provides a framework for the long-term maintenance, storage, and security of SFCN data. For monitoring projects, extensive protocol Standard Operating Procedures (SOPs) provide detailed guidance on all stages of a project's data lifecycle. These SOPs are specific to each project, y*et all* fall within the guidelines established in the Data Management Plan.

6.5 Water Quality Data

Water quality data collected as part of the network's monitoring program have distinct data management requirements. The SFCN Coral Reef temperature data set will be managed according to guidelines from the NPS Water Resources Division (WRD). This includes using the NPSTORET desktop database application at the network to help manage data entry, documentation, and transfer to WRD. The SFCN will ensure the content is transferred at least annually to NPS Water Resource Division for upload to the Environmental Protection Agency's STORET (STORage and RETrieval) database (Fig. 6-B). For the other water quality indicators (listed below) the SFCN will be reporting on summarized datasets for which the network parks already have established archiving procedures.

- Nutrient Dynamics
- Estuarine Salinity Patterns
- Surface Water Hydrology

In addition to data that the SFCN will be collecting and transferring to the Water Resource Division data, 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.

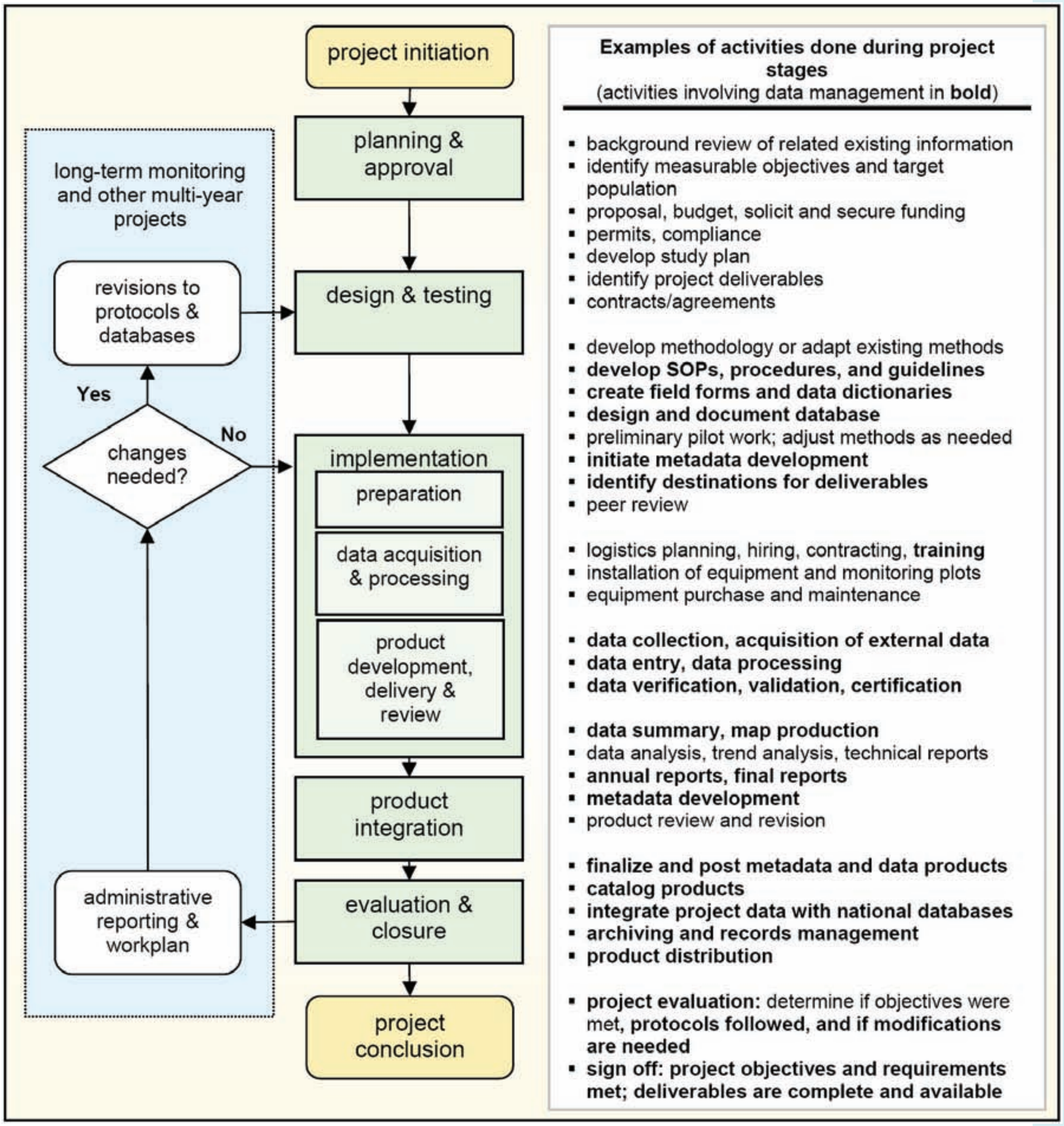

Figure 6-A. Model of data lifecycle stages.

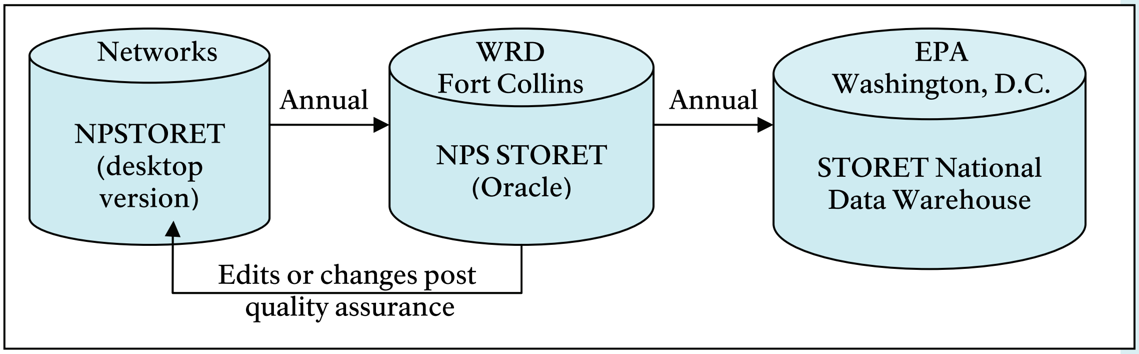

Figure 6-B. Data flow diagram for water quality data.

6.6 Data Management Plan Maintenance

The SFCN approach is to maintain a Data Management Plan that is useful to a broad audience, and that can provide guidance on data management practices at a number of different levels. The SFCN intends to keep the plan simple, flexible, and evolving, and to include data users in the decision-making process whenever possible. The document will undergo an initial prescribed review process that will include both an internal network review (i.e., by members of the technical committee and network staff), and a service-wide review that involves the regional data/GIS coordinator and data management staff from the NPS Washington Office I&M Program. External reviewers from other agencies will also be sought to provide a more balanced and comprehensive review of this plan.

The SFCN will update the plan to ensure that it reflects accurately the network's current standards and practices. Recommendations for changes can be forwarded to the network data manager by any interested party or user of network inventory and monitoring data (e.g., park resource managers, project leaders, technicians, superintendents, external users). These recommendations will be discussed by data management and network staff and actions decided upon. Simple changes can be made immediately in the document, while substantive changes will be made during version updates. Plan updates will be distributed to members of the network Science and Technical Committee before implementation. Otherwise, the plan will be scheduled for a full revision and review at a minimum of every five years. The most current version of the plan is available on the SFCN website (science.nature.nps.gov/im/units/SFCN/).

6.7 Implementation

The data management plans (DMP) 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.

The main body of the plan broadly addresses relevant subjects, but directs most of the details into individual appendixes that serve as stand-alone documents for ease of locating and retrieving specific information of greatest value to most users. The next plan revision should be completed within three years or by October 1, 2010, and then every five years afterward. Plan appendixes, 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.

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.

Goals for the first 3 years should include:

- All staff of targeted programs and their cooperators understand the fundamentals of data and information management, including:
  - File management
  - Documentation

  - o Quality assurance and quality control
  - o Electronic storage
  - o Archive storage
- Implementing improved data management practices:
  - o Accepted database design standards
  - o Thorough testing of databases, data collection methods, and their integration prior to field work
  - o Quality assurance and control procedures at every stage of project development
- Common SOPs and guidance documents for multiple protocols
- Detailed specifications for data management consistent with the DMP included in every vital signs monitoring protocol
- Procedures and outlets for communication within and among Network parks and with the public

Beyond the first three years, goals should include the development and assessment of:

- Procedures to facilitate the summarization and reporting of monitoring data
- Framework and gateway for integration of monitoring data with other agencies or networks
- 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

Implementation and improvement of the data management system will be an ongoing process. The practices and procedures identified in this plan will continue to be encouraged broadly within the Network, and in time, we expect them to be widely accepted and adopted by all SFCN park programs.

SFCN SCA interns and park Youth Conservation Corps interns scanned unique, single copy technical documents at BUIS to create digital copies off-site in case of catastrophe and to make them more widely accessible.

Chapter 7: Data Analysis and Reporting

Monitoring information is "wasted if it is not analyzed correctly, archived well, reported timely or communicated appropriately" (Gibbs *et al.* 1999). One third of the network resources are dedicated to data management, analysis, and reporting. In this chapter, we describe strategies and key audiences for analysis and reporting of results, including who is responsible, plus the various presentations, reports and other products of the monitoring effort, including what they will include, who the intended audience is, how often they will be produced and in what format.

7.1 Strategies and Key Audiences for Analysis and Reporting of Monitoring Results

An essential role for the SFCN is the analysis, synthesis, and reporting of inventory and monitoring data and information to a wide audience, including park superintendents and other managers, park planners, scientists (agency and academic), interpreters, and the general public. Data and information are the common currency among the many different activities and people involved in the stewardship of a park's natural resources: activities such as park planning, inventories, monitoring, research studies, restoration, control of invasive species, management of threatened and endangered species, fire management, and interpretation all either require or provide natural resource data and information to others. As part of the NPS's effort to improve park management through greater reliance on scientific knowledge, a primary role of the I&M program is to develop, organize, and make available natural resource data and to facilitate the transformation of scientific data into information through analysis, synthesis, and modeling. The SFCN network will work with data from many sources, including data collected by park staff and other programs and agencies as well as new field data collected by network or park staff, and the results of the analysis will be provided to multiple audiences at the local, regional, and national levels (Figure 7-A).

Information quality is dependent upon effective, appropriate analysis of high-quality data. SFCN will initially ensure data quality through careful design and implementation of sampling designs and monitoring protocols that are supported by robust data management procedures, as described in Chapters 4, 5, and 6. SFCN will ensure that these monitoring data are effectively converted into reliable information about resource status and trends by emphasizing careful and detailed development of data analysis and interpretation as a key component of each monitoring protocol (see Section 7.2). The network will collaborate and coordinate with other data-collection and analysis efforts, and will promote the integration and synthesis of data across projects, programs, and disciplines. Timeliness of information reporting will be ensured by establishing a firm data analysis routine and schedule for each protocol, followed by a reporting system and schedule whereby we can effectively and promptly disseminate important resource information to a wide range of users.

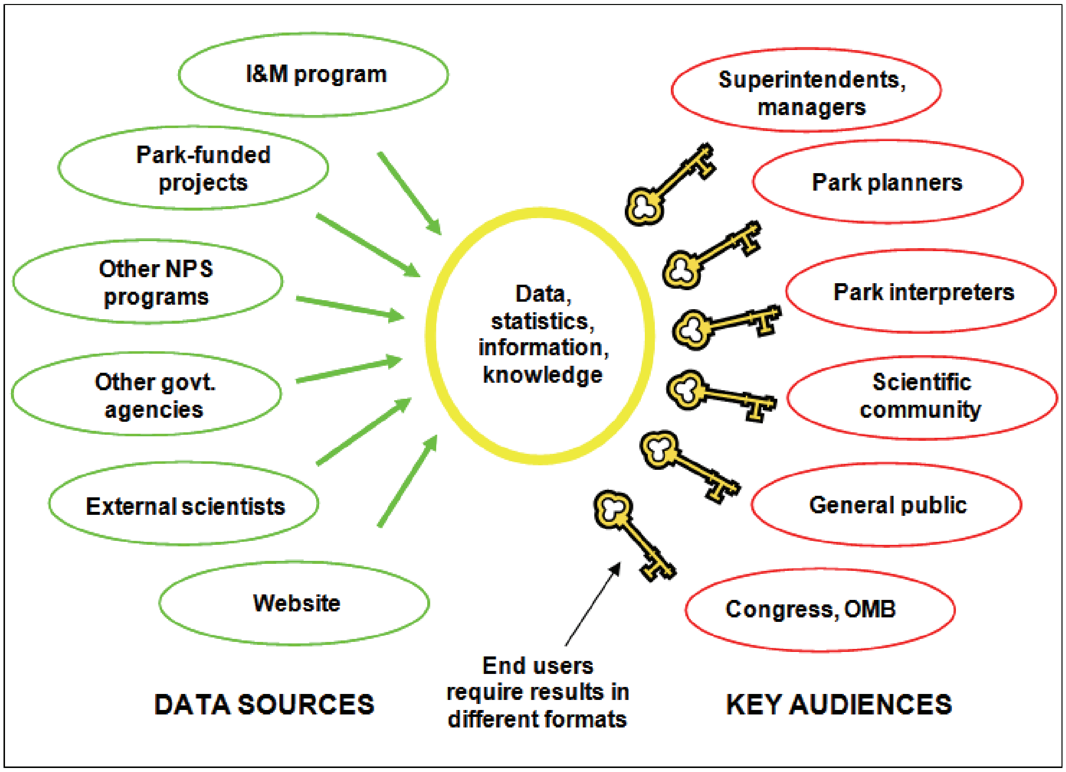

Figure 7-A. Expected SFCN data sources and key audiences. The primary audience is park superintendants and resource managers.

SFCN recognizes that information reporting is not effectively met by a uniform approach; we have to meet the needs of many audiences. The primary utility for many of our products is at the park level, where the key role of the I&M program is to provide park managers, planners, interpreters, and other park staff with the information they need to make better-informed decisions and to work more effectively with other agencies and individuals for the benefit of park resources. These key audiences have different needs and desires relative to what, how, and when information is provided to them. In addition, certain data are needed at the regional or national level and, as stated by the National Park Advisory Board, the findings "must be communicated to the public, for it is the broader public that will decide the fate of these resources."

The SFCN vision for reporting includes the following central themes: (1) We will prepare monitoring reports that are understandable and useful to our primary audience: park resource managers and planners; (2) We will prepare reports promptly, and (3) All reports will be readily available. To achieve this vision, the network has adopted the following strategies:

- The budgets and staff time allotted for each Vital Sign will include adequate funding to support the production of required annual and periodic reports.
- All monitoring data and all reports and information generated from the monitoring data will be made available promptly via the NPS intranet, and information that does not contain sensitive or commercially-valuable data that might jeopardize a species or resource will eventually be made available on the network's internet website following appropriate peer review.
- Protocols, inventory reports, annual data summary reports, trend reports, synthesis reports, and other products of the I&M efforts will be published in the NPS Natural Resource Report

or Natural Resource Technical Report series, unless they are published in a peer-reviewed journal, or a numbered report series of a collaborating agency or university. Reports published in these numbered series meet a set of minimum standards and are peer-reviewed to ensure that the information provided is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.
- The use of graphical methods for presenting data will be encouraged.

7.2 Data Analysis

Appropriate analysis of monitoring data is directly linked to the monitoring objectives, the spatial and temporal aspects of the sampling design used, the intended audiences, and the management uses of the data. Analysis methods need to be considered when the objectives are identified and the sampling design is selected, rather than after data are collected. Each monitoring protocol (see Chapter 5) will contain detailed information on analytical tools and approaches for data analysis and interpretation, including the rationale for a particular approach, advantages and limitations of each procedure, and SOPs for each prescribed analysis.

Four general levels of data analysis are anticipated during implementation of our monitoring protocols and program: (1) descriptive and summary statistical analysis; (2) determination of conditional status for a monitored resource; (3) determination of trends in condition over time for a monitored resource; and (4) synthesis of status and trend information across multiple resources over time to depict larger-scale aspects of ecosystem health and function (Table 7.A). Descriptive analysis may be performed at any time following data collection and entry. Status and trends analysis will be performed on protocol-specific schedules. Larger-scale synthesis across multiple resources and monitoring efforts will occur only after adequate amounts of data have become available for all considered resources and variables. In addition, trend analysis and synthesis can only occur after appropriate time has passed to adequately capture temporal scales of considered phenomena. Long-term trend reports and syntheses will be subject to peer review, as appropriate. Data analysis may be performed by many different people, including the project lead, quantitative ecologist, network data manager, GIS specialist, network coordinator, and/or associated technicians and interns. Generally, analysis will be supervised and coordinated by the key project lead and/or quantitative ecologist.

7.3 Communications and Reporting

The various approaches and products we plan to use to disseminate the results of the monitoring program and to make the data and information more available and useful to our key audiences are organized into the following seven categories and described in the following sections and Tables 7-B and 7-C:

1. Annual Reports for Specific Protocols and Projects
2. Annual Briefings to Park Managers
3. Resource Briefs
4. Analysis and Synthesis Reports
5. Protocol and Program Reviews
6. Scientific Journal Articles and Book Chapters, and Presentations at Scientific Meetings
7. Internet and Intranet Websites

Reports will be published in the NPS Natural Resource Report (NRR) and Natural Resource Technical Report (NRTR) series unless reports are put in some other peer reviewed, numbered series.

Table 7-A. Four general categories of analysis for SFCN vital signs, and the individuals responsible for analysis.

Levels of Analysis	Description	Lead Analyst & Support
Data Summarization/ Characterization	Calculation of basic statistics of interest and initial screening, including: • Measures of central tendency [mean, median] and variation [range, variance, S.E.] • Identification of missing values and outliers [box-and-whisker plots, queries, QA/QC] • Graphical summaries & visual inspection of data Summarization procedures are specified in the monitoring protocols and include measured and derived variables and indices for community analyses.	Lead: Project Leader for protocol Support: Field crew leads, Network staff, Park staff
Status Determination	Analysis and interpretation of vital sign status to answer: • Do observed values exceed a regulatory standard or a known ecological threshold? • How do observed values compare with the range of historical variability for a vital sign? • What is the precision (i.e., variability) and confidence in the status estimate? • What is the spatial distribution (park, Network, ecoregion) of observed values at evaluation time? • Do these patterns suggest relationships with other factors not accounted for in the design? • What environmental factors function as covariates and influence the measurement values? Estimates are coupled with historical data, regulatory thresholds, and/or expert knowledge to determine status	Lead: Project Leader for protocol Support: Network staff, Park staff, Cooperators or Partners, Regulatory and Subject matter experts
Trend Evaluation	Evaluations of interannual trends will seek to address: • Is there continued directional change in indicator values over the period of measurement? • What is the estimated rate of change (and associated measure of uncertainty)? • How does this rate compare with rates observed from historical data, other indicators from the same area, or other comparable monitoring in the region? • Are there unforeseen correlations that suggest other factors should be incorporated as covariates? [correlations, regression analyses] • If no trend was detected, what was the power to detect trend, given observed levels of variability? Analysis of trends will employ graphic portrayals (Cumulative Sum (CUSUM) and control charts), as well as repeated-measures and time-series using mixed linear models, control/impact designs and BACI designs to evaluate management zones (e.g., no-fishing) and catastrophic events (e.g., coral bleaching/disease mortality)	Lead: Project Leader for protocol Support: Network staff, Statisticians, Park staff, Cooperators or Partners, Regulatory and Subject matter experts
Synthesis	Examination of patterns across vital signs and ecological factors to gain broad insights on ecosystem processes and integrity, which may include: • Tests of hypothesized relationships, congruence among indicators, and covariate influence • Development of analytical and predictive models • Integrative approaches [ordination of community data, multiple regression, diversity and conservation-value indices, Bayesian hierarchical and graphical models] • Evaluation of competing *a priori*-specified models that explain dynamics in vital signs; model averaging, variable weights, and prediction Synthetic analysis will require close interaction with academic and agency researchers and has great potential to explore ecological relationships in the non-experimental context of vital signs monitoring. Integration with results from other monitoring and research is critical.	Leads: Quantitative Ecologist & Project Leads Support: Network staff, Statisticians, Data management staff, Park staff, Cooperators or Partners, Regulatory and Subject matter experts

Table 7-B. Types of written reports produced by SFCN.

Type of Report	Purpose of Report	Primary Audience	How Often?	Peer Review Process	Initiator
Annual Administrative Report and Work Plan	Account for funds and FTEs expended; Describe objectives, tasks, accomplishments, products of the monitoring effort; Improve communication within park, network, region, program;	Superintendents, network staff, regional coordinators, and Service-wide program managers; Admin. Report used for annual Report to Congress.	Annual	Review and approval by SER Regional Office and Service-wide Program manager	Network coordinator with SFCN staff
SFCN Vital Signs Program Report	Describe current conditions of park resources; Report interesting trends and highlights of monitoring activities; Identify situations of concern; Explore future issues and directions	Superintendents; Park resource managers; network staff; external scientists; public	Annual	Internal NPS Review	Network coordinator; Quantitative ecologist with SFCN staff
Annual Reports for each Vital Sign or Vital Sign component	Archive annual data and document monitoring activities for the year; Describe current condition of the resource and provide alert if data are outside bounds of known variation; Document changes in monitoring protocols; Communication within the park or network	Park resource managers; network staff; external scientists	Annual	SFCN Staff Review	Vital Sign reporting lead: Network Coordinator; Quantitative ecologist; Community ecologist; Marine ecologist; Fisheries biologist; Data manager
Resource Briefs	Provide short, digestible synthesis of Vital Sign monitoring results on status and trends of resource condition	Superintendents; Park resource managers; interp; public	Varies	SFCN Staff review; internal NPS review; external review as necessary	Vital Sign reporting lead: Network Coordinator; Quantitative ecologist; Community ecologist; Marine ecologist; Fisheries biologist; Data manager

Table 7-B. Types of written reports produced by SFCN (cont.).

Type of Report	Purpose of Report	Primary Audience	How Often?	Peer Review Process	Initiator
Analysis and Synthesis reports—trends	Determine patterns/trends in condition of resources being monitored; Discover new characteristics of resources and correlations among resources being monitored; Analyze data to determine amount of change that can be detected by this type and level of sampling; Context – interpret data for the park within a multi-park, regional or national context; Recommend changes to management of resources (feedback for adaptive management)	Superintendents, park resource managers, network staff, external scientists	3-5 year intervals for resources sampled annually	Internal NPS Review; External peer review solicited as necessary	Quantitative Ecologist; Community Ecologist; Marine Ecologist; Fisheries Biologist
Program Review reports	Periodic formal reviews of operations and results (5 year intervals)	Superintendents, service-wide program managers	5 year intervals	Peer reviewed at regional or national level	WASO Office
Protocol Review Reports	Review protocol design and products to determine if changes needed	Network staff; park resource managers; external scientists	Varies	Internal NPS review; External peer review solicited as necessary	Network Coordinator
Scientific journal articles & book chapters	Document and communicate advances in knowledge; Part of quality assurance – peer review process;	Park resource managers; network staff; external scientists	Varies	Peer reviewed by journal or book editor	SFCN Staff
Other symposia, conferences, & workshops	Review and summarize information on a specific topic or subject area; Communication of latest findings with peers; Helps identify emerging issues and generate new ideas;	Park resource managers; network staff; external scientists	Varies	May be peer reviewed by editor if written papers are published	SFCN Staff

Table 7-C. Presentations of SFCN results to park staff.

Type of Report	Purpose of Presentation	Primary Audience	Location	Frequency	Primary Presenter(s)
Technical Committee Consultation	Provide an update on network activities and findings. Receive feedback from Technical Committee on resource issues and monitoring program	Park resource managers and partners from other agencies	Miami	Annual	Network Coordinator, Marine, Community, & Quantitative. Ecologists, Data Manager
Board of Directors Briefing	Update park management and NPS program managers on network operations, present draft budget and work plan. Obtain feedback and guidance on administrative and programmatic issues	Superintendents Regional I&M Coordinator	Miami	Annual	Network Coordinator
Park "All Hands" Meeting	Communicate network mission and results to a non-technical audience. Receive feedback on resource and monitoring issues in park operations	Park staff and volunteers, particularly from divisions other than resource management	At each park	Annual	Network Coordinator, Marine, Community and/or Quantitative Ecologist, or Data Manager
Executive Briefing	Update superintendent on park-specific findings and potential resource issues; suggest action items, where appropriate	Individual superintendents	At each park	Annual	Network Coordinator, Marine, Community and/or Quantitative Ecologist

7.3.1 Annual Reports for Specific Protocols and Projects

The primary purposes of annual reports for specific protocols and projects are to:

- summarize and archive annual data and document monitoring activities for the year;
- document changes in monitoring protocols; and,
- increase communication within the park and network.
- describe current condition of the resource;

The primary audiences for these reports are park superintendents and resource managers, network staff, park-based scientists, and collaborating scientists. Most annual reports will receive peer review at the network level, although a few may require review by subject matter experts with universities or other agencies. Many of our monitoring protocols involve data collection each year, and those protocols will generate an annual report each year (Table 7-B). However, some sampling regimes do not involve sampling every year - those projects will produce "annual" reports only when there are significant monitoring activities to document. Wherever possible, annual reports will be based on automated data summarization routines built into the MS Access database for each protocol. The automation of data summaries and annual reports will facilitate the network's ability to manage multiple projects and to produce reports with consistent content from year to year at timely intervals. For analyses beyond simple data summaries, data will first be exported to external statistical software.

7.3.2 Annual Briefings to Park Managers

Each year, in an effort to increase the availability and usefulness of monitoring results for park managers, the network coordinator will take the lead in organizing a 1-day "Science briefing for park managers" (possibly in conjunction with a Board of Director's meeting) in which network staff, park scientists, USGS scientists, collaborators from academia, and others involved in monitoring the parks' natural resources will provide managers with a briefing on the highlights and potential management action items for each particular protocol or discipline. These briefings may include park staff and collaborators from other programs and agencies to provide managers with an overview of the status and trends in the high-priority vital signs being monitored by the SFCN. Unlike the typical science presentation that is intended for the scientific community, someone representing each protocol, program, or project will be asked to identify key findings or "highlights" from the previous year's work, and to identify potential management action items. The scientists will be encouraged to prepare a 1- or 2-page Resource Brief or other short briefing statement that summarizes the key findings and recommendations for their protocol or project.

7.3.3 Resource Briefs

SFCN will develop resource briefs for the 12 protocols it is implementing and possibly other vital signs if appropriate and will encourage parks and collaborating scientists to do so as well. The resource brief or other short briefing statement summarizes the key findings, status and trends, and recommendations for the protocol or project.

7.3.4 Analysis and Synthesis Reports

The role of analysis and synthesis reports is to:

- determine patterns/trends in condition of resources being monitored;
- discover new characteristics of resources and correlations among resources being monitored;
- analyze data to determine amount of change that can be detected by this type and level of sampling;
- provide context: interpret data for the park within a multi-park, regional or national context;
- recommend changes to management of resources (feedback for adaptive management).

The primary audiences for these reports are park superintendents and other resource managers, park-based scientists, network staff, and collaborating scientists. These reports will receive peer review by at least 3 subject-matter experts. Analysis and synthesis reports can provide critical insights into resource status and trends, which can then be used to inform resource management efforts and regional resource analyses. This type of analysis, more in depth than that of the annual report, requires several seasons of sampling data. Therefore, these reports are usually written at intervals of every three to five years for resources sampled annually, unless there is a pressing need for the information to address a particular issue. For resources sampled less frequently, or which have a particularly low rate of change, intervals between reports may be longer.

7.3.5 Protocol and Program Reviews

Periodic formal reviews of individual protocols and the overall monitoring program are an important component of the overall quality assurance and peer review process. A review of each protocol will be conducted before the first 5-year Analysis and Synthesis Report and at least at 10-year intervals. (Because protocols must be reviewed in light of the data they produce, it is most efficient to review protocols coincident with these synthesis reports). Features of these protocol reviews include:

- A network or park scientist, outside contractor or academic is enlisted to analyze data and evaluate results of the monitoring protocol and report findings.

- Subject-matter experts/peers are invited to review the Analysis and Synthesis Report and protocol.
- Subject-matter experts/peers are invited to a workshop to discuss the protocol, results of the data analysis and evaluation, whether or not the protocol is meeting its specific objectives and is able to detect a level of change that is meaningful, and to recommend improvements to the protocol.
- The protocol P.I., network coordinator, or contractor writes a report summarizing the workshop. The report is reviewed and edited by the participants, and then the final report is posted on the network's website. Copies of the report are sent to NPS regional and national program offices.

Periodic program reviews are an essential component of quality assurance for any long-term monitoring program. The national I&M Program office will organize and lead a review of the SFCN monitoring effort approximately three years after this monitoring plan has been approved and implemented. Subsequent reviews of the program will occur at approximately five-year intervals. Topics to be addressed during the program review include program efficacy, accountability, scientific rigor, contribution to adaptive park management and larger scientific endeavors, outreach, partnerships, data management procedures, and products. These reviews cover monitoring results over a longer period of time, as well as program structure and function to determine whether the program is achieving its objectives, and also whether the list of objectives is still relevant, realistic, and sufficient.

7.3.6 Scientific Journal Articles, Book Chapters, and Presentations at Scientific Meetings

The publication of scientific journal articles and book chapters is done primarily to communicate advances in knowledge, and is an important and widely-acknowledged means of quality assurance and quality control. Putting a program's methods, analyses, and conclusions under the scrutiny of a scientific journal's peer-review process is basic to science and one of the best ways to ensure scientific rigor. Network staff, park scientists, and collaborators will also periodically present their findings at professional symposia, conferences, and workshops as a means of communicating the latest findings with peers, identifying emerging issues, and generating new ideas.

All journal articles, book chapters, and other written reports will be listed in the network's Annual Administrative Report and Work Plan that is provided to network staff, Technical Committee, Board of Directors, and regional and national offices each year. Additionally, all scientific journal articles, book chapters, and written reports will be entered into the NatureBib bibliographic database maintained by the network.

7.3.7 Internet and Intranet Websites

Websites are a key tool for promoting communication, coordination, and collaboration among the many people, programs, and agencies involved in the network monitoring program. The 32 I&M networks are required to develop and maintain a parallel series of Intranet (NPS only) and Internet (Public) websites to be used as a key means of communicating and disseminating inventory and monitoring results to park managers, planners, interpreters, and other internal and external audiences. Network staff will use these websites as a primary means of making Resource Briefs, data summaries, progress reports, technical reports, trend reports, interpretive materials, and other information available to internal and external audiences.

All written products of the monitoring effort, unless they contain sensitive or commercially valuable information that needs to be restricted, will be posted to the main network website: http://science.nature.nps.gov/im/units/sfcn

SFCN staff Jeff Miller gives a presentation on coral monitoring results showing greater than 50% coral mortality from 2005 coral bleaching and disease event to the Coral Reef Task Force Meeting, 2006.

Chapter 8: Administration / Implementation of the Monitoring Program

8.1 Introduction

This chapter explains the operation and administration of the South Florida/Caribbean Network Inventory and Monitoring Program. Staff and personnel management, oversight committees, cooperators, and revision procedures are described in the following pages. The SFCN has been fortunate to merge the prototype program with the network, increasing both staff and budget. This consolidation provides network expertise in conducting marine monitoring, and a robust data set on benthic communities and fisheries from several of the network parks to help build from with expanded monitoring.

8.2 Core Duties

The WASO office has provided guidance regarding activities that are considered "core" to I&M networks and those which are considered secondary of nature in the document "*Updated Guidance Relative to the Ongoing Operation and Maintenance of Vital Signs Monitoring Networks*" accompanying memorandum N16 (2370) from Associate Director, Mary Foley, on February 28, 2008. The following is excerpted from that document:

> *"As defined in the Natural Resource Challenge, the primary mission of the monitoring networks is to collect, manage, analyze and report long-term data for a modest set of vital signs (measurements of resource condition), and to effectively deliver those data and related information on resource conditions to local park managers, planners, interpreters, and other key audiences. Fundamentally, network personnel are expected to devote the majority of their time and effort to completing tasks associated with that mission. Their FTE's were requested from OMB and have been assigned to the networks for that purpose. Chief among the network responsibilities which must be performed are the following:*
>
> - *Providing "one stop shopping" for resource condition and trend information – For the high-priority vital signs identified in the network's monitoring plan and currently being monitored, this should be thought of as "the" core network function. Accordingly, network staff should maintain intranet and internet websites (see below) as the key means of communicating data and information collected and organized by the network to park managers, planners, and park staff for decision-making, education, and research.*
> - *Synthesizing key findings in succinct statements for managers and planners – This likewise is considered to be a core network function, especially for network priority vital signs. Network staff should place priority on developing resource briefs and technical documents for each vital sign, and preparing synthesis reports that analyze data across vital signs as well as data from other sources and disciplines to help interpret results of vital signs monitoring. In addition, priority should be given to posting these reports on the network's websites to ensure their availability to all interested parties.*
> - *Collaboration with other programs and agencies – As noted above, collaboration and coordination with other programs and agencies has*

Figure 8-A. Current makeup of the South Florida/Caribbean I&M Network Board of Directors and Science and Technical Committee

Board of Directors

Dan Kimball (*Chair*)	Superintendent, EVER/DRTO
Pedro Ramos	Acting Superintendent, BICY
Mark Lewis	Superintendent, BISC
Joel Tutein	Superintendent, BUIS/SARI/CHRI
Mark Hardgrove	Superintendent, VIIS/VICR
Matt Patterson	I&M Coordinator, SFCN
Larry West	I&M Branch Chief, SERO

Science and Technical Committee

Ron Clark	Chief of Resource Management, BICY
Elsa Alvear	Chief of Resource Management, BISC
Zandy Hillis-Starr	Chief of Resource Management, BUIS/SARI
Robert Johnson	Director, South Florida Natural Resources Center
Rafe Boulon	Chief of Resource Management, VIIS/VICR
Carol Daniels	NPS Research Coordinator SFC CESU
Matt Patterson (*Chair*)	I&M Coordinator, SFCN

- *always been considered to be a primary function of monitoring networks. However, lower priority is justified in those instances in which the collaboration and coordination efforts do not directly contribute to accomplishing the network's core mission.*
- *Organizing and cataloging data collected by others – The task of collecting, organizing, and cataloging data collected by others (i.e. non-network) should be considered to be a core function of the network, to the extent that the data are applicable to the high-priority vital signs being monitored by the network."*

Other activities that the network may play an assisting or secondary role (but not lead) include: assisting in occasional resource assessments, reporting to GPRA and Land Health Goals, defining desired resource conditions based on current status and trend, and providing materials to interpreters, educators, and the general public.

8.3 Administration

The SFCN charter, created in 2001, describes the process used to plan, manage, and evaluate the inventory and monitoring program within the Network. Significant management and budgeting decisions are made by the Network Board of Directors, comprised of the Superintendents of the Network parks, together with the regional and Network I&M Coordinators. A Science and Technical Committee, which includes Network and park resource management staff, provide technical assistance and advice to the Board of Directors (Figure 8-A). The NPS Southeast Region provides program quality assurance, oversight and other technical assistance, as requested from the Board of Directors. This management structure is designed to foster the development of an I&M program which is responsive to the unique set of long-term resource issues and threats within the Network parks.

8.4 Staffing Plan

In accordance with national I&M goals, and SFCN park priorities, Network activities revolve around five broad program functions (Figure 8-B). The Network staffing plan is designed to support these functions, and to provide park managers with the professional expertise they need to implement a scientifically credible I&M program addressing the parks' most critical long-term resource issues. These issues,

Five Broad Program Functions

- **CONDUCTING BASELINE INVENTORIES** of natural resources in the parks, including those currently underway (vascular plant and vertebrate surveys, vegetation mapping, soils mapping), as well as other critical inventory needs of Network parks;
- **DEVELOPING AN INTEGRATED, SCIENTIFICALLY CREDIBLE, LONG-TERM ECOLOGICAL MONITORING PROGRAM** to efficiently and effectively monitor status and trends of selected vital signs;
- **DEVELOPING DATA MANAGEMENT AND DECISION SUPPORT SYSTEMS** (including GIS and other tools) to aid park managers in identifying, implementing, and evaluating management options;
- **INTEGRATING INVENTORY AND MONITORING** programs with park planning, maintenance, interpretation and visitor protection activities to help the parks in their efforts to make natural resource protection even more of an integral part of overall park management, and;
- **COOPERATING WITH OTHER AGENCIES AND ORGANIZATIONS** to share resources, achieve common goals, and avoid unnecessary duplication of effort and expense.

Figure 8-B. Five broad program functions encompassing SFCN activities

reflected in Chapter 1, Section 1.3.1 are discussed as well as the Network Vital Signs, detailed in Chapter 3.

In order to meet the Network's need for broad subject matter expertise in these areas, to institutionalize professional data management practices, to meet the need for qualified field personnel, and to properly administer the I&M program, the Network has created a staffing plan made up of a Coordinator, Administrative Assistant, and three branches; the Community Ecology Branch, the Marine Ecology Branch, and the Data Management Branch. The Community Ecology Branch is led by the Community Ecologist, with assistance from three biological technicians, one who specializes in vegetation, one specializing in wildlife, and a third assisting the group as a field assistant. The Marine Ecology Branch is lead by the Marine Ecologist, with assistance from the Fisheries Biologist, and three marine biological technicians. This team is split with the marine ecologist and two technicians based in Palmetto Bay, and with the Fisheries Biologist and other technician based in St. John, U.S. Virgin Islands. The Data Management branch is lead by the Quantitative Ecologist (Statistician), with assistance from the Data Manager, GIS/Data Management technician, and Data Management/Outreach technician (Figure 8-C). Each branch will be assisted by a wide variety of interns, post-doctoral positions, and contract help as necessary and dependent upon availability and resources. Brief descriptions of each position's primary duties is described in Table 8-A.

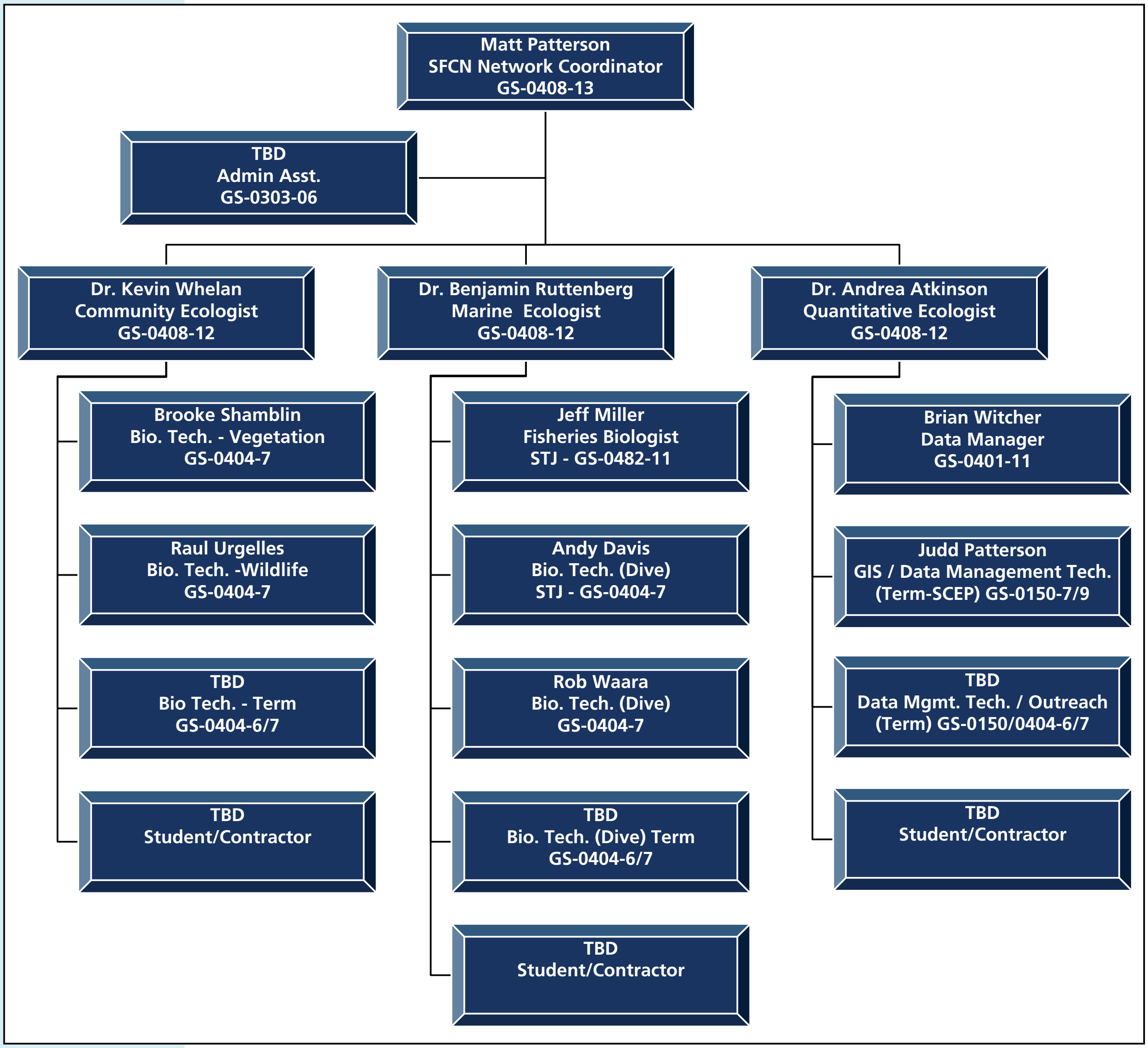

Figure 8-C. South Florida/Caribbean Network Organizational Chart.

Table 8-A. Short descriptions of SFCN positions and their primary functions.

POSITION	PRIMARY DUTIES	% OF TIME
Coordinator	Provides direction, and manages overall planning and implementation of the Network I&M program	35%
	Coordinates project-specific acquisition, data analysis, summary, and reporting	30%
	Ensures information is provided to parks and partners in useful formats	15%
	Coordinates I&M partnerships	5%
	Provides program oversight and supervision	10%
	Provides field assistance as needed	5%
Community Ecologist	Provides guidance, oversight and management of vegetation Vital Signs. Helps implement basic analysis and reports.	35%
	Provides guidance, oversight and management of fish, amphibian, and bird Vital Signs. Helps implement basic analysis and reports.	40%
	Provides guidance, oversight and management of exotic plant & animal Vital Signs. Helps implement basic analysis and reports.	10%
	Works with program professionals to provide information to parks and partners in useful formats Coordinates I&M partnerships	10%
	Provides supervision for community ecological I&M projects and staff	5%
Marine Ecologist	Provides guidance, oversight and management of benthic community and fisheries Vital Signs. Helps implement basic analysis and reports.	80%
	Provides guidance, oversight and management of marine invertebrate Vital Signs. Helps implement basic analysis and reports.	10%
	Works with program professionals to provide information to parks and partners in useful formats	5%
	Provides supervision for marine ecological I&M projects and staff	5%
Quantitative Ecologist	Provides guidance, oversight and management of statistical design and sampling	30%
	Conducts complicated analyses and assists Community and Marine Ecologists with conducting basic summaries and analyses.	25%
	In cooperation with Community and Marine Ecologists, works to gather and summarize reports and, as necessary, conduct supplemental analyses on data from other groups to report on Vital Signs being monitored by park staff, other agencies, and NGO's.	10%
	Works with data manager to develop automated data processing procedures and improved data visualization and outreach tools.	10%
	Provides field assistance as needed	5%
	Provides guidance, oversight, management and implementation of geospatial Vital Signs, in cooperation with Marine and Community ecologists.	15%
	Provides supervision for data management I&M projects and staff	5%
Data Manager	Conducts data validation, dissemination and archiving, database development, overall QA/QC for the I&M program	50%
	Works with ecologists to ensure information is provided to parks and partners in useful formats	20%
	Implements data management partnerships	20%
	Ensures SFCN program meets regional and national data management policies	10%
Fisheries Biologist (St. John)	Coordinates I&M Field Activities for USVI Parks	30%
	Works with Marine Ecologist to ensure I&M activities are properly planned and executed	50%
	Works with and supervises Biological Technician and other USVI I&M staff	5%
	Develops reports, graphics, and other data products based on new information	15%

Table 8-A. Short descriptions of SFCN positions and their primary functions (cont.).

POSITION	PRIMARY DUTIES	% OF TIME
Marine Biological Technicians (South Florida)	Works with program ecologists/biologists to collect field data, and document methods, procedures and anomalies	60%
	Conducts data entry and verification	40%
Marine Biological Technician (St. John)	Works with program ecologists/fisheries biologist to collect field data, and document methods, procedures and anomalies	60%
	Conducts data entry and verification	40%
Community Biological Technicians (South Florida)	Works with program ecologists to collect field data, and document methods, procedures and anomalies	60%
	Conduct data entry and verification	40%
GIS/Data Management Technician (Term)	Designs Network web pages and functions	10%
	Develops databases, including forms, queries, and reports, conducts data entry and verification	30%
	Develops GIS and map products for program. Creates summary graphics, report summaries, and outreach information.	60%
Data Management / Outreach Technician	Designs Network web pages and functions, edits reports and creates outreach materials	40%
	Provides general assistance to Data Management Branch regarding development of databases, GIS, map products, data entry and verification, and report creation	60%
Administrative Assistant	Tracks budget, contracts, agreements and property inventory	50%
	Maintains Network Website	10%
	Coordinates procurement	20%
	Coordinates travel	20%

Coordinator

The Coordinator provides overall direction for the SFCN I&M program. The Coordinator works with network parks, the Network Science and Technical Committee, Board of Directors, and the SERO I&M Coordinator, to develop inventory and monitoring strategies, and recommend implementation schedules for funding and staffing consideration. This position coordinates project-specific data analysis and reporting, and ensures that information is provided to park managers in useful formats. The Coordinator supervises the SFCN branch leads and administrative assistant, and provides general oversight and accountability for the Network program.

Community Ecologist

The Community Ecologist serves as the primary Network subject matter expert for community ecology which includes birds, fish, vegetation and coastal change dynamics. The Community Ecologist coordinates all aspects of community ecology inventory and monitoring projects, including protocol design and pilot testing; data collection, whether it is oriented toward field data collection, or gathering existing data from other sources; data quality during all phases of a project, including the QA/QC process, and the creation of project documentation and metadata; and the preparation and dissemination of project analyses and reports. The Community Ecologist also provides oversight and supervision for biological technicians and other staff/interns working on SFCN projects. In addition, this position serves as the primary Network technical contact for potential Network partners working on community ecology resource issues.

Marine Ecologist

The Marine Ecologist serves as the primary Network subject matter expert for marine resource issues. The Marine Ecologist coordinates all aspects of marine inventory and monitoring projects, including protocol design and pilot testing; data collection, whether it is oriented toward field data collection, or gathering existing data from other sources; data quality during all phases of a project, including, the QA/QC process, and the creation of project documentation and metadata; and the preparation and dissemination of project analyses and reports. The Marine Ecologist also provides oversight and supervision for biological technicians and other staff/interns working on SFCN projects. In addition, this position serves as the primary network technical contact for potential network partners working on marine resource issues.

Quantitative Ecologist

The Quantitative Ecologist provides statistical support to network ecologists and other partners and leads the data management branch of the SFCN program. The Marine, Community and Quantitative Ecologists work collaboratively to ensure programs complement one another, looking for linkages between the two systems. The Quantitative Ecologist explores multiple data sets to help better inform resource managers on how the parks resources function as an ecosystem and reviews partner monitoring programs for statistical robustness and availability for comparative analysis.

Data Manager

The Science Information & Data Manager has a central role in ensuring that project data conforms with program standards, designing project databases, disseminating data, and ensuring long-term data integrity, security, and availability. In order to maintain high data quality standards, and promote ready use of project data, the Data Manager collaborates with the project manager to develop data entry forms, QA/QC procedures, and automated reports. The SFCN Data Manager maintains spatial data themes associated with Network inventory and monitoring projects, and incorporates spatial data into the Network GIS. The Data Manager maintains standards for this data and the associated metadata, and develops procedures for sharing and disseminating GIS data to Network parks and partners. Coordinates web page updates with administrative assistant to ensure content meets NPS policy and is current and accurate.

Fisheries Biologist

The Fisheries Biologist serves as the U.S. Virgin Islands team leader for marine resource issues. The Fisheries Biologist assists with all aspects of marine inventory and monitoring projects, including protocol design and pilot testing; data collection, whether it is oriented toward field data collection, or gathering existing data from other sources; data quality during all phases of a project, including, the QA/QC process, and the creation of project documentation and metadata; and the preparation and dissemination of project analyses and reports. The Fisheries Biologist also provides oversight and supervision for biological technicians working on SFCN projects. In addition, this position is the primary Network technical contact for potential Network partners working on U.S. Virgin Islands projects. The Fisheries Biologist works collaboratively with the ecologists to ensure programs complement one another, looking for linkages across the whole ecosystem.

Marine Biological Technicians (South Florida)

The Marine Biological Technicians in South Florida assist the Senior Marine Ecologist with day to day inventory and monitoring activities. These technicians assist with data collection, data entry, preliminary data analysis, equipment maintenance, Quality Assurance/Quality Control (QA/QC), and other duties as assigned. The technicians will be responsible for care and preventive maintenance of SFCN boats and SCUBA equipment for South Florida.

Marine Biological Technician (U.S. Virgin Islands)

The Marine Biological Technician in the U.S. Virgin Islands assists the Fisheries Biologist with day to day inventory and monitoring activities. This technician assists with data collection, data entry, preliminary data analysis, equipment maintenance, Quality Assurance/Quality Control (QA/QC), and other duties as assigned. The technician will be responsible for care and preventive maintenance of SFCN boats and SCUBA equipment for U.S. Virgin Islands operations.

Biological Technicians (South Florida)

The three Biological Technicians in South Florida assist the Community Ecologist with day to day inventory and monitoring activities. These technicians assist with data collection, data entry, preliminary data analysis, equipment maintenance, Quality Assurance/Quality Control (QA/QC), and other duties as assigned. These technicians will be responsible for care and preventive maintenance of SFCN field equipment for use across the network.

Geographic Information System/Data Management Technician (TERM) (South Florida)

The Geographic Information System (GIS)/Data Management Technician assists with information requests, both internal and external. Core duties will be focused on database development, web page development, and GIS data management and manipulation. This position will help with digital data collection and transfer, data manipulation, data visualization, data archiving and storage. This position was envisioned as a term position to ensure new technologies would be applied to existing inventory and monitoring programs as software and hardware advanced. Having this position rotate over time will provide experience transfer from those trained with the latest and most innovative software and hardware to the institutional knowledge built on the core staff. This position will not only provide GIS support, but will be an integral member of the data management team.

Data Management / Outreach Technician

The Data Management / Outreach Technician provides general support to the day-to-day operations of the Data Management Branch as needed including assistance with upkeep of the computer network, database design, web design, creation of outreach materials, GIS support and map creation, data entry and verification, data archiving and storage, and report creation.

Administrative Assistant (South Florida)

The administrative assistant assists with the day-to-day operations of the network. This position will track budgets, assist with the preparation and tracking of travel, track property, manage personnel actions, track central files, and ensure network calendar is kept up to date. The administrative assistant will track contractual deliverable status and other products received. The administrative assistant will assist with website content updates. The administrative assistant works directly for the coordinator, but assists all network staff and interns with supplies and basic support.

8.5 Program Integration

I&M data will be made available to all other park operations, including interpretation, law enforcement and maintenance. The SFCN team is looking forward to developing a relationship with each park's interpretation division, since they are the major conduit of natural resource information from the parks to the public. The SFCN staff has been co-located with the Florida & Caribbean

Exotic Plant Management Team (EPMT) at the NPS Florida & Caribbean Office (FLACO) in Palmetto Bay, Florida since 2005. This office is conveniently located along the western boundary of Biscayne National Park, as well as a short distance from Miami Universities and other partners. Both EPMT and I&M data are shared on FLACO servers, so that exotic plant and animal treatment information can be tracked while assessing changes across the landscape. The office location provides for a better opportunity to attract student assistance from local universities.

The Fisheries Biologist and USVI Marine Biological Technician are duty stationed in the Biosphere Reserve offices in Virgin Islands National Park in St. John, U. S. Virgin Islands. This remote office works closely with all divisions of VIIS/VICR, as well as the network parks in St. Croix, U.S. Virgin Islands.

I&M natural resource information is helpful to maintenance and planning divisions, with the ability to easily retrieve information on the park's natural resources in place on the Internet and Intranet. I&M information has been used in the SFCN for General Management Plans, Watershed Condition Assessments, and other types of compliance reviews of proposed projects inside the parks. Integration with law enforcement and administration divisions is also a goal of the SFCN, and will be developed as the program matures.

8.6 Partnerships

The SFCN prides itself in its development of productive and sustainable partnerships with other federal, state, local agencies, NGO's, and the public. With the vast amounts of natural resource efforts undertaken in both South Florida and the USVI, the SFCN cannot accomplish its goals without strong partners. This can be very challenging with the various uncertainties of relying on others for long term data collection, since there can be future problems with funding, methodologies, and whether or not the data meets NPS standards for QA/QC and sampling design robustness. Below highlight just some of our key partners and cooperative agreements:

- US Geological Survey, Center for Coastal and Watershed Studies: interagency agreements for assistance with Light Detection and Ranging (LIDAR) data collection and mapping. USGS has provided funding for the past two years to hire a research assistant based in the FLACO office to create LIDAR map DVD's of multiple coastal parks and associated areas. (Dr. John Brock)
- US Geological Survey, Center for Coastal and Watershed Studies: Collaborative effort between NPS, USGS, and Nova Southeastern National Coral Reef Institute to examine the feasibility of mapping submerged aquatic vegetation along the west coast of Everglades National Park. (Dr. Ilsa Kaufner)
- NOAA Biogeography Program: The SFCN works closely with the Biogeography group to conduct benthic habitat mapping in USVI parks, fish and benthic habitat assessments in St. John and St. Croix, and fish telemetry research around St. John. (Dr. Mark Monaco)
- Florida Fish and Wildlife Conservation Commission, Florida Wildlife Research Institute: a cooperative agreement to assist the NPS with inventories, monitoring, or research activities. This agreement was written so all Florida networks were included, and has provided a way to cost share many projects including coral monitoring, aerial photography collection, and benthic habitat mapping.
- Florida Fish and Wildlife Conservation Commission, Florida Wildlife Research Institute: two task orders under a cooperative agreement to produce benthic habitat maps for offshore BISC and DRTO based on NOAA collected satellite imagery and LIDAR data to

help identify benthic resources. (Dr. David Palandro)

- South Florida/Caribbean CESU (host: University of Miami): cooperative agreement between multiple federal agencies and multiple university and non-profit entities to provide research, technical assistance and education.
  - University of Florida and USGS – Small and Medium sized mammal inventory for Everglades National Park and Big Cypress National Preserve. This 3 year project will determine presence/absence of small and medium sized mammals using a suite of methods to include IR triggered digital camera stations, live traps, aerial surveys of muskrat dens, and road kill information. These findings will help with a Presence of Area Occupied analysis based on major habitat classifications where the animals were detected. (Dr. Frank Mazotti and Dr. Ken Rice)
  - University of Miami: Development of Post Doctoral position to assist with marine community vital sign development including power analysis of existing data, data integration and protocol development for marine benthic and fish communities. This position is envisioned to assist over a two year period with many of the high priority vital signs. (Dr. Jerald Ault)
  - Florida International University: Development of Post Doctoral position to assist with community ecology vital sign development, including collection and analysis of existing data and reports, data integration and protocol development for wetland and upland communities. This position is envisioned to assist over a two year period with many of the high priority vital signs. (Dr. Jenny Richards)
  - Florida International University: develop a data driven vegetation classification based on the multiple vegetation data sets for South Florida to evaluate where the vegetation classification is supported by field data and where it lacks field data that could be collected in the future, or identify categories that may not occur across the landscape.(Dr. Mike Ross)
  - Florida International University: develop a vegetation map for Biscayne National Park based on the classification developed for South Florida Vegetation mapping. This map is being created from aerial photography. (Dr. Mike Ross)
  - Florida International University: develop a Resource Management Intern (ReMI) through the university to select a part time undergraduate senior with a natural resource academic background to assist with SFCN activities, with a full time internship for 1 year after graduation to allow the recent graduate to better understand Natural Resource management from a National Park Service perspective. (Dr. James Fourqurean)
  - Audubon of Florida: cooperative agreement for South Florida freshwater fish inventories and SFCN bird certification. (Dr. Jerome Lorenz)
- The Institute for Regional Conservation: Cooperative agreements to conduct vascular plant inventories and data certification, voucher collection of current species assemblage, and performance of an accuracy assessment for the Big Cypress National Preserve vegetation map (non-CERP) (George Gann and Keith Bradley)

- Fairchild Tropical Botanic Garden: cooperative agreement to mount, label, repair, annotate, scan, post to secure NPS Virtual Herbarium, and curate. The NPS Virtual Herbarium provides a web based secure portal for park resource managers and researchers to view herbarium specimens online through a searchable database. Each herbarium specimen has been scanned, and the high resolution digital image is available to help with species identification. This agreement has been written to assist other I&M networks, and provides a digital backup in case of catastrophic events that could damage or destroy the originals.

The SFCN realizes that these existing partnerships are very valuable, but there are many more we hope to develop in the coming years as we identify how best to leverage monitoring activities already in place throughout the SFCN landscape.

8.7 Review and Revisions

Periodic reviews of the Network's monitoring program and protocols are critical to ensure that the program is on the right course, or if course corrections are needed, that they are accomplished quickly to save unnecessary expenditures of resources and time. The SFCN will undergo a "Start-up Review" by the National Inventory and Monitoring Program WASO office within three years after the monitoring plan is accepted and implemented. The review will focus on the operational and administrative aspects of the network's monitoring program (this is not a technical review), and will ask the basic question "Is the network set up to succeed?" The review will allow Network and park staff to step back and evaluate their initial progress against the objectives and schedule set forth in the Network's monitoring plan, to develop a "road map" for completing and implementing the first set of protocols, and to make adjustments if needed. Thereafter the program will be reviewed formally, at least once every five years, by WASO. From this periodic review a formal report is generated, making specific suggestions for changes and revisions in the monitoring program. Also, network staff will be analyzing and presenting data on a regular basis to subject the Network's methodologies to ongoing peer review.

Eric Sudalter, a SFCN Student Conservation Association intern, helps gathers GPS points to assist vegetation map development in BISC. Interns have been a valuable asset to the SFCN program.

Chapter 9: Schedule

9.1 Startup schedule is phased

This chapter describes the startup schedule for implementing the SFCN Vital Signs Monitoring program. Not all monitoring activities will begin immediately upon completion of this monitoring plan. For some vital signs implementation may simply entail some coordination with an existing program already collecting data (e.g., alligators). But for others implementation will require a more detailed scoping of the vital sign, pilot data collection efforts, and/or determining analysis methods for the data (e.g., Spiny Lobsters). The design and pilot phase of protocol development frequently takes more time of higher-graded staff than final protocol implementation and can take up to 3 years. Thus, development of the SFCN Vital Signs program is phased to allow a balanced workload for both the marine and community ecology portions of the program. The assigned target year for protocol completion attempts to account for both time needed for completion and realistic workloads.

For the protocols under development in the next five years, Table 9-A shows the protocols to be completed by December 31 of each year. Table 9-B gives a schedule for development and implementation of each vital sign through 2012.

While additional protocols are being developed, SFCN monitoring protocols that were developed as part of the Prototype will continue: Marine Benthic Communities (including Coral – Index sites, Marine Invertebrates-Rare, Threatened, Endangered – *Diadema*, and Coral – Temperature monitoring) as will SFCN joint monitoring of Marine Fish Communities in cooperation with NOAA using established protocols in BUIS, DRTO, VIIS and coastal shelf of BISC.

In general schedules for the marine vital signs (fish, seagrass, lobster, coral, etc) monitoring will focus on sampling March– October as winter months tend to have poorer water clarity although some coral sampling in VIIS does take place in the winter months. In contrast the main months for sampling the freshwater/terrestrial vital signs are expected to be September – May. Table 9-C shows the general times of the year that the field sampling for the core vital signs is expected to occur.

Episodic monitoring may disrupt schedules in which increased monitoring is triggered by events such as coral bleaching, hurricanes and severe landscape-altering fires. In such cases, where additional sampling will greatly assist explanation of change to park managers or resolve critical uncertainties, other monitoring may be postponed (e.g., increased sampling during coral bleaching showed the critical part coral disease played in subsequent coral losses as well as the duration of bleaching and timing and severity of mortality that occurred; Hurricane Wilma deposited the equivalent of 16 years normal sediment accretion in 1 storm event).

In addition, with so many vital signs being monitored in part or completely by other entities, successful reporting of results is dependent upon cooperator willingness to collaborate and their own internal schedules. Outreach and collaboration with the CERP RECOVER Assessment Team reporting process will be an important part of this process.

Reporting of monitoring results also will be phased in over time. As SFCN collects data or begins coordination with existing programs, the network will prepare annual reports of activities and findings for each vital sign as well as posting summaries and reports to the network website. Comprehensive analysis and synthesis reports can begin immediately for some vital signs (e.g., coral at index sites, *Diadema*) but may await several years of data collection for other indicators (e.g., lobsters, vegetation, coastal geomorphology). Details of planned reports are in Chapter 7.

9.2 Programmatic reviews

The 3-year start-up review by the WASO office is anticipated in 2011 with periodic programmatic reviews every 5 years thereafter.

Table 9-A. Target completion years for each protocol or Vital Sign component reporting coupled with main task that will be completed (Completion by December 31of given year). Vital signs will continue to be monitored in subsequent years but are not mentioned further.

Year complete	Main task for completion	Protocol or Vital Sign component
2007	Submit Protocol Components	Marine Benthic Communities: Coral - Index sites, Diadema, Temperature
2008	Submit Protocol Components	Marine Benthic Communities: Coral – Extensive design, 2-20m deep
	Summarize/post reports for Vital Signs	Florida panther
		Protected Marine mammals
		Sawfish
2009	Submit Protocol or protocol components	Colonial Nesting Birds
		Invasive/Exotic Plants: Corridors of Invasiveness
		Land Use Change
		Marine Benthic Communities: Seagrass, Conch
		Marine Fish Communities
		Soil Elevation
	Complete SOP	Surface Water Hydrology: Weather stations – BUIS, SARI
		Surface Water Hydrology: Hydrology - SARI - Adding crest gage
	Assist Park/EPMT to develop Protocol/SOP	Fire Return Interval Departure
		Invasive/Exotic Plants: SRF-Digital Sketch Mapping
	Complete Supplemental Analysis SOP	Estuarine salinity patterns
		Marine Exploited Invertebrates: harvest data for Lobster, Pink shrimp, Crabs (Stone, blue, others), Sponges
		Nutrient Dynamics -BICY, BISC, DRTO, EVER
		Sea Turtles
		Surface Water Hydrology: Hydrology - BISC
		Water Chemistry-BICY, BISC, DRTO, EVER
	Summarize/post reports	American Alligator
		American crocodile
		Focal fish species
		Marine Benthic Communities: Seagrass - Florida Bay & Biscayne Bay
		Marine Exploited Invertebrates: Pink shrimp
		Surface Water Hydrology: Hydrology - Everglades, Big Cypress
2010	Submit Protocol	Forest Ecotones and Community Structure
		Freshwater fish, invertebrates, and periphyton
		Invasive/Exotic Animals in Canals - EVER, BICY
		Mangrove-Marsh Ecotone
		Spiny lobster
	Complete Mapping	Vegetation Communities Extent & Distribution: BISC, DRTO, BUIS, VIIS, SARI, 1/3 BICY

Table 9-A. Target completion years for each protocol or Vital Sign component reporting coupled with main task that will be completed (cont.).

Year complete	Main task for completion	Protocol or Vital Sign component
2010 (cont.)	Supplemental Analysis SOP	Surface Water Hydrology: Hydrology - VIIS
		Nutrient Dynamics: VIIS
		Visitor Use
		Water Chemistry: VIIS
	Summarize/post Reports	Coastal Geomorphology: Fl Bay - Mapping mud banks, berms
		Freshwater fish and large macro-invertebrates: EVER + NE BICY
		Periphyton (Freshwater): EVER + NE BICY
		Wetland Ecotones and Community Structures
2011	Complete Protocol Component	Marine Benthic Communities: Black Coral Feasibility Assessment
	Supplemental Analysis SOP	Air Quality
	Summarize/post reports	Marine Benthic Communities: *Acropora spp.*
2012	Submit Protocol	Amphibians
	Summarize/post reports	Contaminants
		Phytoplankton
		Vegetation Communities Extent & Distribution: EVER, 2/3 BICY
2013	Complete Mapping	Benthic Communities Extent & Distribution
2014	Complete Protocol Component	Marine Benthic Communities: Coral - Deep Coral >20m Feasibility Assessment

SFCN staff Kevin Whelan testing new airboat.

Table 9-B. Development schedule for each protocol. Grey boxes = development. Dark boxes = protocol/reporting implementation

Protocol	Component	FTE	2008	2009	2010	2011	2012	2013	Frequency	Lead Agency
Marine Benthic Communities	Coral - Index sites	3							Annual, 1-2 yr rotation	SFCN
	Coral - Extensive design,2-20m deep								Annual, rotation TBD	SFCN
	Coral - Deep Coral >20m Feasibility Assessment								TBD	SFCN
	Coral - Temperature Monitoring								Continuous	SFCN
	Seagrass-BISC,DRTO,BUIS,SARI,VIIS								Annual, 5 yr rotation	SFCN/NOAA
	Seagrass-Florida Bay & Biscayne Bay								Annual, 5 yr rotation	FHAP-SF, DERM
	Diadema								Annual? rotation	SFCN
	Conch				?	?	?	?	Annual, 5 yr rotation	SFCN with others
Colonial Nesting Birds	BISC- Colony monitoring	0.5							Annual	SFCN
	BICY - Colony monitoring, SRF flights								Annual	UF with asst. from SFCN
	EVER - Colony monitoring, SRF flights								Annual	Park staff
	DRTO, BUIS,VIIS - Colony monitoring								Annual or biennial	Park staff
	SARI - Colony monitoring								Annual or biennial	USFWS, VIDFW, park staff
Invasive/Exotic Plants-Corridors of Invasiveness	Corridors of Invasiveness	0.2							3-5 yr rotation	EPMT & SFCN
Land-use Change	Land-use change	0.5							Annual, 5 yr rotation	SFCN/WASO I&M
	Permiting/zoning changes next 1-3 yrs								Annual	SFCN
Marine Fish Communities	BISC (Coastal Shelf), DRTO	1							Annual or biennial	NOAA, FWRI
	BUIS, VIIS, SARI								Annual or biennial	NOAA/SFCN?
	Florida Bay & Biscayne Bay								Annual or biennial	SFCN with others
Soil Elevation	Soil Elevation Tables(SETs)	0.3							Annual	SFCN, USGS
Forest Ecotones & Community Structure	BISC, BICY, BUIS, EVER, VIIS	1.7							5-10 yr rotation	SFCN, park staff, other pgms
Mangrove-Marsh Ecotone	All parks								5-10 yr rotation	SFCN,USGS,CERP,FIU,FAU,other pgm
Freshwater fish, invertebrates, & periphyton	BICY NW corner	0.6							2x annually	SFCN
Invasive/Exotic Fish-Canals	Canals - EVER, BICY	0.2							Annual or bi-annual	SFCN/Park staff
Spiny lobster	Network-wide	0.5							Annual	SFCN
Amphibians	BICY, EVER, VIIS	0.6							Annual or bi-annual, 3x per sampling year	SFCN

Table 9-C. General estimate of months during which data collection could occur for SFCN protocols.

Group	Protocol	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Marine	Marine Benthic Communities	■	■	■	■	■	■	■	■	■	■	■	■
	Marine Fish Communities					■	■	■	■	■			
	Spiny Lobster					■	■	■					
Intertidal and above	Invasive/exotic plants –Corridors of Invasiveness	■	■	■	■	■	■	■	■	■	■	■	■
	Forest Ecotones and Community Structure	■	■	■	■	■	■	■	■	■	■	■	■
	Mangrove-marsh ecotone	■	■	■	■	■	■	■	■	■	■	■	■
	Soil Elevation	■	■	■	■	■	■	■	■	■	■	■	■
	Freshwater fish, invertebrates, and periphyton	■	■								■		
	Invasive/exotic Fish - Canals	■	■								■		
	Colonial Nesting Birds		■	■	■								
	Amphibians		■	■	■					■	■	■	
	Land-use Change	■	■	■	■	■	■	■	■	■	■	■	■

Chapter 10: Budget

The South Florida/Caribbean Inventory and Monitoring Network is funded from the WASO Vital Signs Monitoring Program and the Water Resources Division. The FY09 Vital Signs funding is expected to be $1,534,300 and Water Resource Division funding is expected to be $142,120, totaling $1,676,420. The SFCN is expecting additional project funding from the NPS vegetation mapping program in FY09 for ongoing vegetation map projects.

Natural Resource Challenge funds for the program are held in Washington Office base accounts and transferred annually through the Southeast Regional Office. All funds are managed by the network coordinator under the oversight of the Board of Directors (BOD). Funds are used solely for purposes of operating the program in a way consistent with NPS policies, rules, and regulations.

An annual work plan is developed with input from the Network Science and Technical Committee (STC) and approved by the BOD that directs expenditure of funds to salary, operations, and projects. All I&M program funds must be strictly accounted for and disclosed in an Annual Administrative Report.

The South Florida/Caribbean Inventory and Monitoring Network merged with the South Florida/USVI prototype program in 2004 which shifted the prototype funding and FTE's from Virgin Islands National Park to the network in order to more efficiently monitor marine resources across the network, and take advantage of the experience of prototype staff as the network continued to grow. In 2007, the SFCN was fully funded and was provided an additional $250,000 to augment the budget based on decreased prototype funding in the past. In FY09, WASO has agreed to 'loan' 3 FTE for term technician positions; one data management/outreach technician, one community ecology technician, and one marine ecology technician.

The SFCN was unable to find office space for the network at one of the network parks, and made the decision to locate the primary office in Palmetto Bay, Florida. This location borders Biscayne National Park, and is situated between Miami and Homestead. The SFCN has leased office space totaling approximately 4,000 sq. feet as well as a 1,730 sq. foot storage facility that will protect the SFCN catamaran and airboat, as well as provide a locker room and lab space for field equipment and analysis. Office and storage space construction completion is currently scheduled for Winter 2008. Office spaces are shared with members of the Florida/Caribbean Exotic Plant Management Team, as is IT infrastructure. This integration allows both groups to coordinate with one another's field activities, minimizes duplicative equipment, and increases operational efficiency of both programs. The SFCN uses an onsite IT company to provide both Internet connectivity and Local Area Network service. Both rent and IT support are considered fixed costs from a core operations standpoint. Table 10-A provides an overview of how the budget is divided by major categories.

Guidance provided to the networks recommends budgeting at least 33% of the budget towards data management. The SFCN staffing plan has three primary groups of scientists; community ecology, marine ecology, and data management. Although the majority of the data management salary would be considered as part of this 33%, the ecologists and biologists in both the community ecology and marine ecology groups will also spend a considerable amount of their time ensuring good quality data is being collected, entered, verified, and reported on as routine parts of their workplan.

With the estimated contribution of salaries towards data management exceeding $553,000 and IT services costing approximately $30,000 annually, data management activities require more than 34% of the SFCN budget.

Table 10-A. Summary SFCN Vital Signs Monitoring Budget. Anticipated budget for the SFCN Vital Signs Monitoring Program in the first year of implementation after review and approval of the monitoring plan.

Income	Dollar Amount	
Vital Signs Monitoring	$1,534,420	
Water Resources Division	$142,000	
Regional I&M Branch Chief Salary	$25,000	
Total	$1,701,420	
Expenditures by budget category	**Dollar Amount**	**Percent of budget**
Personnel	$1,012,400	60%
Cooperative Agreements	$169,000	10%
Contracts	$223,600	13%
Operations/Equipment	$172,900	10%
Travel	$90,000	5%
Other	$33,500	2%
Total	$1,701,420	

Chapter 11: Literature Cited

Acosta , A., J. Hunt, and F. Wilmot, editors. 2007. Coral Reef Monitoring Workshop: Examining underwater visual census techniques for the assessment of reef fish populations in South Florida. Marathon, FL, Florida Fish & Wildlife Conservation Commission/ Florida Fish and Wildlife Research Institute and the Florida Wildlife Legacy Initiative. Workshop summary. April 2007.

Amstrup, S.C., T. L. McDonald, and B. F. J. Manly. 2005. Handbook of capture-recapture analysis. Princeton University Press. Princeton, NJ.

Anderson, D. R. 2001. The need to get the basics right in wildlife field studies. Wildlife Society Bulletin. **29**:1294-1297.

Askins, R.A., D.N. Ewert, and R.L. Norton. 1989. Abundance of wintering migrants in fragmented and continuous forests in the U.S. Virgin Islands. Pages 197-206 *in* Proceedings of Manomet Symposium, Smithsonian Institution Press, Washington, D.C.

Atkinson, A. J., C. M. Marn, and B. Fong. 2002. Terrestrial and amphibious monitoring plan for the CALFED Bay-Delta Program. Technical Report. U.S. Geological Survey Western Ecological Research Center, Sacramento, CA. (http://www.werc.usgs.gov/sandiego/tamp2002.html).

Atkinson, A. J., P. C. Trenham, R. N. Fisher, S. A. Hathaway, B. S. Johnson, S. G. Torres, and Y. C. Moore. 2004. Designing monitoring programs in an adaptive management context for regional multiple species conservation plans. Technical Report. U.S. Geological Survey Western Ecological Research Center, Sacramento, CA. (http://www.dfg.ca.gov/nccp/pubs/monframewk10-04.pdf).

Beacon Council. 2003. Demographic Data. (http://www.beaconcouncil.com/0102.asp). Accessed 08/16/2006.

Bennett, A. J., W. L. Thompson, and D. C. Mortenson. 2006. Vital signs monitoring plan, Southwest Alaska Network. Department of the Interior, National Park Service, Southwest Alaska Network, Anchorage, AK.

Bertram, P., and N. Stadler-Salt. 2000. Selection of indicators for Great Lakes Basin ecosystem health, version 4. State of the Lakes Ecosystem Conference. Buffalo, NY, Environmental Protection Agency. March 2000. (http://www.on.ec.gc.ca/solec/indicators2000-e.html)

Blake, E. S., J. D. Jarrell, M. Mayfield, and E. N. Rappaport. 2005. The deadliest, costliest, and most intense United States tropical cyclones from 1851 to 2004 (and other frequently requested hurricane facts). NOAA Technical Memorandum NWS TPC-1. (http://www.nhc.noaa.gov/pastcost.shtml). Accessed 16 August 2006.

Browder, J., R. Alleman, P. Ortner, and S. Markley. 2004. CERP monitoring and assessment plan, part 1: Monitoring and supporting research, Appendix A.6 Biscayne Bay conceptual ecological model. Restoration Coordination and Verification (RECOVER) Program. January, 2004. Pages A-53 to A-78. (http://www.evergladesplan.org/pm/recover/recover_map_2004.cfm).

Buckland, S. T., D. R. Anderson, K. P. Burnham, J. L. Laake, D. L. Borchers, and L. Thomas. 2001. Introduction to distance sampling: Estimating abundance of biological populations. Oxford University Press, Oxford, UK.

CALFED Bay-Delta Program. 2000a. Ecosystem restoration program plan strategic plan for ecosystem restoration, final programmatic EIS/EIR technical appendix. CALFED Bay-Delta Program, Sacramento, CA. July 2000. (http://calwater.ca.gov/Programs/EcosystemRestoration/EcosystemVol3RestorationPlan.shtml).

CALFED Bay-Delta Program. 2000b. Recommendations for the implementation and continued refinement of a comprehensive monitoring, assessment, and research program, final programmatic EIS/EIR technical appendix. CALFED Bay-Delta Program, Sacramento, CA. July 2000. (http://calwater.ca.gov/CALFEDDocuments/Final_EIS_EIR.shtml).

California Resources Agency. 2002. Environmental protection indicators for California. (http://www.oehha.ca.gov/multimedia/epic/Epicreport.html).

CERP. 2006. Quality Assurance Systems Requirements (QASR) manual for the comprehensive Everglades restoration plan. South Florida Water Management District and Army Corps of Engineers. (http://www.evergladesplan.org/pm/program_docs/qasr.aspx).

CH2M Hill, Inc. 1979. A sediment reduction program, prepared for Department of Conservation and Cultural Affairs, Government of the U.S. Virgin Islands.

Croze, H. 1982. Monitoring within and outside protected areas. Pages 628-633 *in* J.A. McNeely and K.R. Miller, editors. National Parks, conservation and development: The role of protected areas in sustaining society. Proceedings of the World Congress on National Parks. Bali, Indonesia. Smithsonian Institution Press, Washington DC. 11-22 Oct, 1982.

CVMSHCP. 2004. Coachella Valley Multiple Species Habitat Conservation Plan/Natural Community Conservation Plan (CVMSHCP/NCCP), public review draft. Coachella Valley Association of Governments (CVAG). (http://www.cvmshcp.org/).

Davey, C. A., K. T. Redmond, and D. B. Simeral. 2007. Weather and climate inventory, National Park Service, South Florida / Caribbean Network. National Park Service, Fort Collins, CO. Natural Resource Technical Report NPS/SFCN/NRTR—2007/037.

Davis, G. E. 1989. Design of a long-term ecological monitoring program for Channel Islands. National Park, California. Natural Areas Journal **9**:80-89.

Davis, S. M. 2004a. CERP monitoring and assessment plan, part 1: Monitoring and supporting research, appendix A.3 Southern Marl Prairies conceptual ecological model. Restoration Coordination and Verification (RECOVER) Program, January, 2004. Pages A-53 to A-78.

Davis, S. M. 2004b. CERP monitoring and assessment plan, part 1: Monitoring and supporting research, appendix A.3 Everglades mangrove estuaries conceptual ecological model. Restoration Coordination and Verification (RECOVER) Program, January, 2004. Pages A-53 to A-78. (http://www.evergladesplan.org/pm/recover/recover_map_2004.cfm).

Deuver, M. 2004. CERP monitoring and assessment plan, part 1: Monitoring and supporting research, appendix A.4. Big Cypress Regional Ecosystem Conceptual Ecological Model. Restoration Coordination and Verification (RECOVER) Program, January, 2004. pp. A-53 to A-78. (http://www.evergladesplan.org/pm/recover/recover_map_2004.cfm).

Deuver, M., J. E. Carlson, J. F. Meeder, L. C. Duever, L. H. Gunderson, L. A. Riopelle, T. R. Alexander, R. L. Myers, and D. P. Spangler. 1979. The Big Cypress National Preserve, Research Report No. 8. National Audubon Society, New York.

Drayton, N., C. Rogers, and B. Devine. 2004. The State of the Coral Reefs of the U. S. Virgin Islands. The Ocean Conservancy, St. John, USVI.

Elzinga, C. L., D. W. Salzer, and J. W. Willoughby. 1998. Measuring and monitoring plant populations. Bureau of Land Management, Denver. BLM Technical Reference 1730- 1. BLM/RS/ST-98/005+1730.

Elzinga, C. L., D. W. Salzer, J. W. Willoughby, and J. P. Gibbs. 2001. Monitoring plant and animal populations. Blackwell Science, Inc., Malden, MA.

Gibbs, J. P., H. L. Snell, and C. E. Causton. 1999. Effective monitoring for adaptive wildlife management: Lessons from the Galapagos Islands. Journal of Wildlife Management **63**:1055-1065.

Hubbard, D. K. 1991. Geologic development of Buck Island Reef National Monument: A West Indies laboratory report to the National Park Service. March 1, 1991.

Jenkins, K., A. Woodward, and E. Schreiner. 2002. A framework for long-term ecological monitoring in Olympic National Park: Prototype for the coniferous forest biome. U.S. Geological Survey. Port Angeles, WA.

Johnson, W. C. and S. P. Bratton. 1978. Biological monitoring in UNESCO biosphere reserves with special reference to the Great Smoky Mountains National Park. Biological Conservation **13**:105-115.

Jones, K. B. 1986. The inventory and monitoring process. Pages 1-9 *in* A.Y. Cooperrider, R. J. Boyd, and H. R. Steward, editors. Inventory and Monitoring of Wildlife Habitat. U.S. Department of the Interior, Bureau of Land Management. Denver.

Lee, T. N., E. Williams, E. Johns, D. Wilson, and N. P. Smith. 2002. Transport processes linking South Florida coastal ecosystems. *in* J. W. Porter and K. G. Porter, editors. The Everglades, Florida Bay, and Coral Reefs of the Florida Keys: An Ecosystem Sourcebook. CRC Press. Boca Raton, FL.

Liston, S. E., J. J. Lorenz, W. F. Loftus, and C. 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 U.S. Geological Survey.

Lodge, T. E. 2005. The Everglades handbook: Understanding the ecosystem, 2nd edition. CRC Press, Boca Raton, FL.

Lundgren, I., and Z. M. Hillis-Starr. 2008. Variation in *Acropora palmata* bleaching across benthic zones at Buck Island Reef National Monument (St. Croix, USVI) during the 2005 bleaching event. Bulletin of Marine Science, *in press*.

MacCluskie, M., K. Oakley, T. McDonald, and D. Wilder. 2005. Central Alaska Network vital signs monitoring plan. National Park Service. (http://science.nature.nps.gov/im/monitor/plans/CAKN_MonitoringPlan.pdf).

MacDonald, L. H. and A. Smart. 1993. Beyond the guidelines: Practical lessons for monitoring. Environmental Monitoring and Assessment **26**: 203-218.

MacKenzie, D. I., J. D. Nichols, G. B. Lachman, S. Droege, J. A. Royle and C. A. Langtimm. 2002. Estimating site occupancy when detection probabilities are less than one. Ecology. **83**: 2248-2255.

Margoluis, R. and N. Salafsky. 1998. Measures of success: Designing, managing, and monitoring conservation and development projects. Island Press. Washington, D. C.

McDonald, T. L. 2003. Review of environmental monitoring methods: Survey designs. Environmental Monitoring and Assessment. **85**:277-292.

Menza, C., J. Aula, J. Beets, J. Bohnsack, C. Caldow, J. Christensen, A. Friedlander, C. Jeffrey, M. Kendall, J. Luo, and others. 2006. A guide to monitoring reef fish in the National park Service's South Florida / Caribbean Network. NOAA Technical Memorandum NOS NCCOS 39.

MHCP. 2003. Final multiple habitat conservation plan, vol. III: MHCP biological monitoring and management plan. California Department of Fish and Game, U. S. Fish and Wildlife Service, Conservation Biology Institute for the Multiple Habitat Conservation Program (MHCP) and SANDAG. March 2003. (http://www.sandag.org/index.asp?projectid=97&fuseaction=projects.detail).

Miller W. J, Muller E., Rogers C. S. Waara R. J., Atkinson A, Whelan K. R. T., Patterson M. E., Witcher B. D. *Submitted manuscript.* Coral disease following massive bleaching in 2005 causes 60% decline in coral cover on reefs in the US Virgin Islands.

Mora, C. and P. F. Sale. 2002. Are populations of coral reef fish open or closed? Trends in Ecology & Evolution. **17**(9): 422-428.

Morrison, M. L., W. M. Block, M. D. Strickland, and W. L. Kendall. 2001. Wildlife study design. Springer-Verlag New York, Inc. New York.

National Park Service. 2001. Management policies. U.S. Department of the Interior, National Park Service, Denver.

National Research Council. 1990. Managing troubled waters: The role of marine environmental monitoring. National Academic Press. Washington D.C.

New Zealand Ministry for the Environment. 1997. The state of New Zealand's environment 1997. (http://www.environment.govt.nz/reports/ser.html).

Nichols, J. D., J. E. Hines, J. R. Sauer, F. W. Fallon, J. E. Fallon, and P. J. Heglund. 2000. A double-observer approach for estimating detection probability and abundance from point counts. The Auk **117**:393-408.

NOAA. 2001. Benthic habitats of Puerto Rico and the U.S. Virgin Islands. Map. National Centers for Coastal Ocean Science Biogeography Program, National Oceanic and Atmospheric Administration (NOAA). Silver Spring, MD.

Noon, B. R. 2003. Conceptual issues in monitoring ecological resources. *In* D.E. Busch and J.C. Trexler, editors. Monitoring Ecosystems: Interdisciplinary Approaches for Evaluating Ecoregional Initiatives. Island Press, Washington, D.C.

Oakley, K. L. 2004. Quest for the "perfect" monitoring report.

Oakley, K. L., L. P. Thomas, and S. G. Fancy. 2003. Guidelines for long-term monitoring protocols. Wildlife Society Bulletin. **31**:1000-1003. Online. (http://science.nature.nps.gov/im/monitor/protocols/protocolguidelines.pdf).

Ogden, J. C. 2004. CERP monitoring and assessment plan, part 1: Monitoring and supporting research, appendix A.3 Everglades ridge and slough conceptual ecological model. Restoration Coordination and Verification (RECOVER) Program, January, 2004. Pages A-53 to A-78. (http://www.evergladesplan.org/pm/recover/recover_map_2004.cfm).

Ogden, J. C., S. M. Davis, and L. A. Brandt. 2003. Science strategy for a regional ecosystem monitoring and assessment program: The Florida Everglades example. *in* D. E. Busch and J. C. Trexler, editors. Monitoring ecosystems: Interdisciplinary approaches for evaluating ecoregional initiatives. Island Press, Washington, D.C.

Olsen, A. R., J. Sedransk, D. Edwards, C. A. Gotway, W. Liggett, S. Rathbun, K. H. Reckhow, and L. J. Young. 1999. Statistical issues for monitoring ecological and natural resources in the United States. Environmental Monitoring and Assessment. **54**:1-45.

Philippi, T. 2003. Final report- CERP monitoring and assessment plan: Stratified random sampling plan, SFWMD agreement C-C20304A September 24, 2003.

Philippi, T. 2005. Final report- CERP monitoring and assessment plan implementation: Transect and sentinel site sampling design, SFWMD agreement CP040131, April 28, 2005, Revised 10 June 2005.

Quinn, J.F. and C. van Riper. 1990. Design considerations for national park inventory databases. Pages 5-14 *in* C. van Riper III, T. J. Stohlgren, S. D. Veirs, Jr., and S. C. Hillyer, editors. Examples of Resource Inventory and Monitoring in National Parks of California. Proceedings of the Third Biennial Conference on Research in California's National Parks, September 13-15, 1990. University of California, Davis, CA.

RECOVER. 2004. CERP monitoring and assessment plan, part 1: Monitoring and supporting research. Technical report. U.S. Army Corps of Engineers, Jacksonville District, Jacksonville, FL and South Florida Water Management District, West Palm Beach FL. (http://www.evergladesplan.org/pm/recover/recover_map_2004.cfm#2004).

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, FL.

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, FL.

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, FL.

Rogers, C. S. and G. Garrison, 2001. The Windspirit incident; 10 years after the crime. Bulletin of Marine Science. **62**(2):793-8.

Roman, C. T. and N. E. Barrett. 1999. Conceptual framework for the development of longterm monitoring protocols at Cape Cod National Seashore. USGS Patuxent Wildlife Research Center, Cooperative National Park Studies Unit, Narragansett, RI.

Rudnick, D. 2004. CERP monitoring and assessment plan, part 1: Monitoring and supporting research, appendix A.5. Florida Bay. Restoration Coordination and Verification (RECOVER) Program, January, 2004. pp. A-53 to A-78. (http://www.evergladesplan.org/pm/recover/recover_map_2004.cfm).

Sasso, C. R. and M. Patterson, 2000. A study plan to the inventory of vascular plants and vertebrates in the South Florida/Caribbean Network of the National Park Service.

SFNRC and FWC. 2007. Assessing the conservation efficacy of the Dry Tortugas National Park Research Natural Area. South Florida Natural Resources Center, Everglades and Dry Tortugas National Parks, Homestead, FL, and the Florida Fish and Wildlife Conservation Commission, Tallahassee, FL. (http://www.nps.gov/ever/naturescience/upload/DRTOSciencePlanSmall.pdf).

Sobel, J. and C. Dahlgren. 2004. Marine reserves: A guide to science, design, and use. Island Press. Washington, D.C.

Stevens, D. L., Jr., and A. R. Olsen. 2004. Spatially balanced sampling of natural resources. Journal of the American Statistical Association. **99**:262-278.

Stevens, L. E., and B. D. Gold. 2003. Monitoring for adaptive management of the Colorado River ecosystem in Glen and Grand Canyons. Pages 101-134 *in* D. E. Busch and J. C. Trexler, editors. Monitoring ecosystems: Interdisciplinary approaches for evaluating ecoregional initiatives. Island Press, Washington, D.C.

Thompson, S. K. 2002. Sampling, 2nd edition. John Wiley & sons, Inc. New York.

Thompson, W. L., G. C. White, and C. Gowan, 1998. Monitoring vertebrate populations. Academic Press, San Diego.

Thornberry-Ehrlich, T. L. 2005a. Biscayne National Park geologic resource management issues scoping summary. Colorado State University – Geologic Resource Evaluation. February 9, 2005.

Thornberry-Ehrlich, T. L. 2005b. Dry Tortugas National Park Geologic Resource Management Issues Scoping Summary. Colorado State University – Geologic Resource Evaluation. February 9, 2005.

Thornberry-Ehrlich, T. L. 2005c. Everglades National Park Geologic Resource Management Issues Scoping Summary. Colorado State University – Geologic Resource Evaluation. February 4, 2005.

U.S. Fish and Wildlife Service. 1999. South Florida multi-species recovery plan. Atlanta, GA. (http://www.fws.gov/verobeach/index.cfm?Method=programs&NavProgramCategoryID=3&programID=107&ProgramCategoryID=3l).

Waddell, J. E., editor. 2005. The state of coral reef ecosystems of the United States and pacific freely associated states: 2005. NOAA/NCCOS Center for Coastal Monitoring and Assessment's Biogeography Team. Silver Spring, MD. NOAA Technical Memorandum NOS NCCOS 11. (http://ccma.nos.noaa.gov/ecosystems/coralreef/coral_report_2005/CoralReport2005_C.pdf).

White, P. S. and S. P. Bratton. 1980. After preservation: The philosophical and practical problems of change. Biological Conservation. **18**:241-255.

Wiersma, G. B. 1984. Integrated global background monitoring network. Proceedings of the symposium on research and monitoring in circumpolar biosphere reserves. Waterton Biosphere Reserve, Waterton Lakes, Alberta, Canada. August 27-31.

Williams, B. K., J. D. Nichols, and M. J. Conroy. 2002. Analysis and management of animal populations. Academic Press, San Diego.

Woodley, S. 1993. Monitoring and measuring ecosystem integrity in Canadian National Parks. *In* J. Kay and G. Francis, editors. Ecological Integrity and the Management of Ecosystems. St. Lucie Press, Delray Beach, FL.

Woodward, A., K. J. Jenkins, and E.G. Schreiner. 1999. The role of ecological theory in longterm ecological monitoring: Report on a workshop. Natural Areas Journal. **19**:223-233.

Yoccoz, N. G., J. D. Nichols, and T. Boulinier. 2001. Monitoring of biological diversity in space and time. Trends in Ecology & Evolution. **16**:446-453.

The U.S. Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives and affiliated Island Communities.

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