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Vital Signs Monitoring in the Southeast Coast Inventory & Monitoring Network

Natural Resource Report NPS/SECN/NRR—2008/061

ON THE COVER
Sandhill Cranes migrating from Chattahoochee River National Recreation Area.
Photograph by: Joe DeVivo

Vital Signs Monitoring in the Southeast Coast Inventory & Monitoring Network

Natural Resource Report NPS/SECN/NRR—2008/061

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Contents

Page

Figures vi

Tables viii

Executive Summary xi

Chapter 1. Introduction and Background 1

Program Purpose and Scope 1

Environmental Setting of the Southeast Coast Network 7

Analysis of SECN Natural Resource Issues 29

Summary of Existing Monitoring Programs 33

Chapter 2. Conceptual Ecological Models 35

Introduction & Approach 35

The Southeast Coast Network General Ecosystem Model 36

System-Specific Models within the Southeast Coast Network 43

Common Elements 63

Chapter 3. Vital Signs 69

Scoping and Vital Signs Selection Process 69

Vital Signs Selected for Implementation 73

Relationship of Vital Signs to Conceptual Models and Justifications 73

Chapter 4. Sampling Design 79

Monitoring Across Space 80

Monitoring Across Time 81

Measurement Approaches 83

Integration 83

Chapter 5. Sampling Protocols 87

Overview 87
Coastal Shoreline Change 90
Stream Habitat Assessment 91
Salt Marsh Elevation 92
Marine Water Quality 92
Fixed-Station Water Quality 93
Amphibians 94
Breeding Forest Birds 95
Plant Communities 96
Migratory & Wintering Shorebirds 97
Landscape Change Detection 98
Chapter 6. Data Management and Archiving 101
Information Management Goals 102
Information Management Strategy 104
Data Stewardship Roles and Responsibilities 105
Information Technology Infrastructure and System Architecture 107
Data Acquisition and Lifecycle 108
Quality Assurance and Quality Control 110
Data Documentation 111
Data Summary and Analysis 111
Data Dissemination 112
Data Maintenance, Storage and Archiving 114
Natural History Archiving, Curation and Records Management 114
Implementation 115
Database Development and Implementation Schedule 115

Chapter 7. Data Analysis and Reporting 119
Data Analysis 119
Data Reporting 122
Data Dissemination 123
Chapter 8. Administration / Implementation of the Monitoring Program 127
Coordination among Network Parks 127
Core Job Functions for Network Staff 130
Integration with Park Operations 131
Partnerships 132
Programmatic Reviews 132
Chapter 9. Schedule 135
Protocol Implementation Schedule 135
Annual Sampling Schedule 137
Chapter 10. Budget 139
Fixed Costs 141
Data Management 141
Operations 142
Chapter 11. Literature Cited 143
Glossary 161

Figures

Page

Figure 1-1. Location of parks within the Southeast Coast Network. 9

Figure 1-2. 303(d) water bodies (displayed in red) upstream or adjacent to SECN parks (2002 data). 28

Figure 2-1. General Ecosystem Model of the Southeast Coast Network. 36

Figure 2-2. The six primary ecosystems within Southeast Coast Network Parks. 44

Figure 2-3. Relationship among plant community types as a function of historic fire regime within longleaf pine ecosystems. 48

Figure 2-4. Conceptual model of ecosystem dynamics in upland forests of Southeast Coast Network Parks..... 48

Figure 2-5. Conceptual model of ecosystem dynamics in bottomland hardwood forests of Southeast Coast Network Parks. 50

Figure 2-6. General ecosystem model for river and stream systems within the Southeast Coast Network. 51

Figure 2-7. Location of the six river parks within the Southeast Coast Network along an elevation gradient. 52

Figure 2-8. Conceptual model of ecosystem dynamics in rivers and streams of Southeast Coast Network Parks. 53

Figure 2-9. Conceptual model of ecosystem dynamics in salt marshes and coastal wetlands of Southeast Coast Network Parks. 55

Figure 2-10. Conceptual model of ecosystem dynamics in estuaries and nearshore marine systems of Southeast Coast Network Parks. 57

Figure 2-11. Successional relationships of plant communities on barrier islands. 59

Figure 2-12. Relationship of the natural plant communities and historical land use practices on barrier islands. 60

Figure 2-13. Conceptual model of ecosystem dynamics in barrier islands of Southeast Coast Network Parks. 61

Figure 3-1. Implementation process used by the Southeast Coast Network for developing options for a Vital Signs Monitoring Program. 71

Figure 3-2. General Ecosystem Conceptual Model for the Southeast Coast Network with associated Vital Signs. 78

Figure 4-1. Sampling tours for probabilistic estuarine- and freshwater-quality monitoring protocols. 82

Figure 4-2. Sampling tours for wildlife and plant community monitoring protocols based on a 3-year (left) and 5-year (right) revisit schedule. 82

Figure 6-1. The object model is the strategic foundation for future information management efforts. 105

Figure 6-2. Core project data stewardship responsibilities of project leaders and data managers. 107

Figure 6-3. Information technology connectivity diagram. 108

Figure 8-1. Organization and staffing plan for the Southeast Coast Network as of 09 September 2008. 128

Figure 8-2. Operational organizational Chart for the Southeast Coast Network. 129

Figure 9-1. Annual protocol implementation schedule for Southeast Coast Network Vital Signs monitoring protocols that require field work. 136

Tables

Page

Table 1-1. Performance management goals for which monitoring data will be relevant within the Southeast Coast Network (based on NPS strategic planning guidance for 2007-2011). 5

Table 1-2. Preliminary SECN monitoring objectives, organized in the Inventory and Monitoring Program Ecological Monitoring Framework. 7

Table 1-3. Parks of the Southeast Coast Network. 8

Table 1-4. Summary of air quality issues in Southeast Coast Network Parks. 29

Table 1-5. Matrix of key natural resource issues and ecosystem types of concern within Southeast Coast Network Parks. 30

Table 1-6. Existing and historical monitoring programs relevant to Southeast Coast Network parks. 34

Table 2-1. Ecosystems present in each of the SECN parks. 45

Table 3-1. Criteria for prioritizing monitoring objectives based on the relative importance for meeting each monitoring objective. 72

Table 3-2. Vital Signs to be monitored by the Southeast Coast Inventory & Monitoring Network. 74

Table 3-3. Vital Signs to be monitored by the Southeast Coast Inventory & Monitoring Network and the ecosystems in which they are relevant. 76

Table 4-1. Site-selection methods used by the Southeast Coast Network. 81

Table 4-2. Site selection strategy, measurement approaches, and re-visitation schedules for Vital Signs monitoring in Southeast Coast Network. 84

Table 5-1. Monitoring protocols and associated Vital Signs to be implemented by the Southeast Coast Network, with the parties responsible for data collection indicated. 88

Table 5-2. Vital Signs to be implemented through the use of data collected by partnering parks, agencies, or other organizations. 89

Table 6-1. Data that are provided on national Inventory & Monitoring Program web sites. 103

Table 6-2. SECN roles and responsibilities for data stewardship. 106

Table 6-3. Database development schedule for all field protocols and data acquisition SOPs to be implemented by the SECN. 117

Table 7-1. Categories of analyses for SECN Vital Signs. 120

Table 7-2. Summary of proposed analyses for SECN Vital Signs. 123

Table 9-1. Deployment schedule of monitoring protocols to be implemented by the Southeast Coast Network. 135

Table 10-1. Anticipated budget for the Southeast Coast Network Vital Signs monitoring program in the first year of implementation after review and approval of the monitoring plan. 139

Table 10-2. Detailed budget for the Southeast Coast Network Vital Signs monitoring program in the first year of implementation after review and approval of the monitoring plan, showing the estimated expenditure on information management..... 140

Executive Summary

Chapter 1 – Introduction and Background. The Southeast Coast Network (SECN) is one of 32 National Park Service (NPS) Networks established to implement an integrated monitoring program under the Natural Resource Challenge. The SECN contains twenty parks, seventeen of which contain significant and diverse natural resources. In total, SECN parks encompass more than 184,000 acres of federally-managed land across North Carolina, South Carolina, Georgia, Alabama, and Florida. The parks span a wide diversity of cultural missions, including four National Seashores, two National Historic Sites, two National Memorials, seven National Monuments, two National Military Parks, a National Recreation Area, National Battlefield, and Ecological and Historic Preserve. The parks range in size from slightly more than 20 to nearly 60,000 acres, and when considered with non-federal lands jointly managed with SECN parks the Network encompasses more than 253,000 acres.

Three general properties broadly affect the integrity of ecosystems and natural resources in SECN parks: (a) parks are generally surrounded by altered landscapes; (b) the ecosystems of the Southeast Coast Network are driven to a large extent by natural disturbance process such as hurricanes, flooding, and fire; and (c) the Southeast Coast region is increasingly subject to human development, resulting in diverse anthropogenic effects on park resources.

The following major objectives of the SECN monitoring program are associated with the landscape-scale issues that many of our parks have in common:

- 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, and

- Provide a means of measuring progress towards performance goals.

Chapter 2 – Conceptual Ecological Models. The SECN has developed a suite of conceptual models to support and guide the development of the monitoring program. The General Ecosystem Model was constructed to serve as a template for specific models that depict the six dominant ecosystem types in SECN parks: Upland Forests, Bottomland Hardwoods, Rivers & Streams, Salt Marshes & Coastal Wetlands, Estuaries & Nearshore Marine Systems, and Barrier Islands. Each model depicts a set of system drivers, local drivers, and park resources. Each system model is applicable to multiple network parks, and several parks contain examples of multiple ecosystems represented by different system models. Detailed conceptual models are available in Appendix 7.

Chapter 3 – Vital Signs. The SECN identified 25 Vital Signs to be monitored as a part of the Inventory & Monitoring Program. Vital Signs span all categories of the Ecological Monitoring Framework (Air & Climate, Geology & Soils, Water, Biological Integrity, Human Use, and Ecosystem Pattern & Processes).

Chapter 4. – Sampling Framework and Design. An overall sampling framework has been proposed for the SECN. The SECN will use a design-based approach to monitoring that relies on a combination of probabilistic sampling, sentinel station sampling, censuses, and opportunistic sampling to assess natural resource conditions across parks. Measurement approaches range from direct measures of ecological parameters to conducting multimetric assessments of resource conditions based on suites of parameters.

The overall sampling framework is designed to allow for rapid utility of data to assess resource condition while preserving the flexibility to integrate monitoring data in efforts to model both long term trends and relationships among Vital Signs.

Chapter 5 – Sampling Protocols. The Southeast Coast Network will be developing and implementing 10 monitoring protocols. Additionally, the SECN is developing 10 data acquisition SOPs to obtain Vital Sign data from external sources. In most cases, the SECN is implementing sampling methods from published protocols with minimal changes. Protocol Development Summaries for all SECN protocols are located in Appendix 13. Each summary explains which Vital Signs are addressed by the protocol, the reasons why the Vital Sign was selected, sets forth specific monitoring objectives, and describes how the network plans to monitor the Vital Sign.

Chapter 6. Information Management and Archiving. The Information Management and Archiving Plan for the SECN serves as the overarching strategy to ensure that monitoring data meet rigorous quality assurance and control standards and that these data are available to others for decision making, research, and education. The plan also refers to other guidance documents, standard operating procedures, and detailed monitoring protocols that convey more specific standards and steps for achieving our data management goals for specific Vital Signs monitoring. The plan acts as a foundation to build upon as new protocols are developed, advances in technology are adopted, and new concepts in data management philosophy are accepted.

Table E-1.
Vital Signs to be monitored by the Southeast Coast Inventory & Monitoring Network. [✚ - Vital 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 monitored by a network park, another NPS program, or by another federal or state agency using other funding; ◈ - Monitoring deferred].

Ecological Monitoring Framework			Network Vital Sign	Measures	KEMO	CHAT	HOBE	OCMU	CONG	MOCR	CAHA	CALO	FOSU	FOPU	FOFR	CUIS	**TIMU / FOCA**	**CASA / FOMA**	**CANA**
Air and Climate	Air Quality	Ozone	Ozone	Atmospheric ozone concentration, damage to sensitive vegetation.	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
		Wet and Dry Deposition	Wet and Dry Deposition	Wet and dry sulfate and nitrate deposition.	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
		Visibility and Particulate Matter	Visibility and Particulate Matter	IMPROVE suite for visibility and fine particulates, particle size analyses: pm 10, pm 2.5, haze index.	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
		Air Contaminants	Air Contaminants	Concentration of mercury, semi-volatile organic compounds, acidic components of contaminants.	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	Weather and Climate	Weather and Climate	Weather and Climate	Air temperature, precipitation, relative humidity, tides, location and magnitude of extreme weather events.	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Geology and Soils	Geomorphology	Coastal / Oceanographic Features and Processes	Coastal Shoreline Change	Shoreline position.							✚	✚	✚	✚	✚	✚	✚	✚	✚
			Salt Marsh Elevation	Sediment elevation, salinity.							✚	✚		✚	✚	✚	✚	✚	✚
		Stream / River Channel Characteristics	Stream / River Channel Characteristics	Percent cover of coarse woody debris, detritus, distribution and extent of geomorphic features (runs, riffles, pools); grain size distribution; distribution, extent, and rate of change of erosion features.	✚	✚	✚	✚	✚	✚									
Water	Hydrology	Groundwater Dynamics	Groundwater Dynamics	Water Table levels for freshwater and saltwater.	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
		Surface Water Dynamics	Surface Water Dynamics	Discharge, magnitude and duration of flooding events.	●	●	●	●	●	●							●		
	Water Quality	Water Chemistry	Marine Water Quality	pH, temperature, dissolved oxygen, turbidity, salinity, concentrations of chlorophyll a, TDN, TIN, TDP, TIP, metals, and volatile organic compounds.							✚	✚	◈	✚	◈	✚	✚	◈	✚
			Riverine Water Quality	pH, temperature, dissolved oxygen, specific conductance, turbidity, trace ions, nutrient concentrations.	✚	✚	✚	✚	✚	✚									
Biological Integrity	Invasive Species	Invasive / Exotic Plants	Invasive / Exotic Plants	Occurrence of invasive plant species.	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚
	Focal Species or Communities	Marine Invertebrates	Marine Invertebrates	Occurrence of selected marine invertebrate species.							◈	◈	◈	◈	◈	◈	◈	◈	◈
		Fishes	Fish Communities	Fish community diversity, relative abundance, Index of Biotic Integrity, percentage of non-native species, number of crevice spawner species.	◈	◈	◈	◈	◈	◈	◈	◈	◈	◈	◈	◈	◈	◈	◈

Ecological Monitoring Framework			Network Vital Sign	Measures	KEMO	CHAT	HOBE	OCMU	CONG	MOCR	CAHA	CALO	FOSU	FOPU	FOFR	CUIS	**TIMU / FOCA**	**CASA / FOMA**	**CANA**
		Amphibians and Reptiles	Amphibians	Species occurrence, diversity, percent area occupied, disease incidence.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
		Birds	Breeding Forest Birds	Species occurrence, diversity, relative abundance.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
		Mammals	Small Mammals	Species occurrence, diversity, percent area occupied, relative abundance.	◈	◈	◈	◈	◈	◈	◈	◈	◈	◈	◈	◈	◈	◈	◈
		Vegetation Complex	Plant Communities	Plant species occurrence, diversity; percent cover by herbaceous, shrub and overstory; rooting by feral hogs and armadillos; occurrence of disease, occurrence of insect outbreaks, occurrence of non-native species; NVCS class.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	At-risk Biota	T&E Species and communities	Shorebirds	Number and location of piping plover, red knot, Wilson's plover, American oystercatcher.							●	◈	◈	◈	◈	◈	◈	◈	◈
		T&E Species and communities	T&E Species	Abundance, distribution, and recruitment of rare species such as sea beach amaranth, beach mouse, sea turtles, red-cockaded woodpeckers.	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Human Use	Consumptive Use	Consumptive Use	Fisheries Take	Species occurrence, weight, size based on compilation of existing data from State and other sources.							●	●	●	●	●	●	●	●	●
Human Use	Visitor and Recreation Use	Visitor Usage	Visitor Use	Monthly and annual visitor attendance compiled from existing Park and other sources.	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Landscapes	Fire and Fuel Dynamics	Fire and Fuel Dynamics	Fire and Fuel Dynamics	Burn area and extent, down woody debris, duff depth.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Landscapes	Landscape Dynamics	Landscape Dynamics	Land Cover and Use	Extent and distribution of land cover and use types, fragmentation, extent and distribution of management actions (compiled from park records).	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

Chapter 7 – Data Analysis and Reporting. The SECN approach to the analysis, interpretation, and reporting of monitoring data is based upon three factors that contribute to the success of the program: 1) quality and timeliness of information, 2) careful data analysis, and 3) effective communication to address different audiences with diverse information needs. Formal reports and publications that will be produced include, but are not limited to, annual administrative reports and work plans; annual monitoring reports or specific project reports to the parks; analysis and synthesis of long-term data and trends, including management recommendations; interpretive highlights of interest to visitors; technical and scientific papers and presentations; periodic program reviews; and web-based data availability, newsletters, and summaries. The network will host an annual Technical Committee meeting to present and discuss monitoring data. This will be an opportunity for the park resource managers to "compare notes," present monitoring data and analyses, and discuss resource issues of concern with other managers in the network.

Chapter 8 – Administration and Implementation. The network has developed a near-term (three to five year) plan under which monitoring will begin, and the development of all protocols will be initiated. This plan includes a staffing plan, key partnerships, relationship between the Network staff and member parks, and the periodic review process for the program. The network is planning to rely on key partnerships with federal and state agencies, and universities for both planning and implementation of the program.

Chapter 9 – Schedule. A proposed schedule for the development and implementation of each protocol is presented. All protocols will be implemented by 2011.

Chapter 10 – Budget. Annual funding from the National Park Service's Vital Signs Monitoring Program for SECN is $1,272,300 with an additional $116,300 coming from the National Park Service Water Resources Division for water quality monitoring. During the first year of implementation (FY2009), we expect that 62% of the budget will be spent on personnel. Data management expenditures (including salary costs) exceed the recommended 30%.

Chapter 1. Introduction and Background

Program Purpose and Scope

In 1992, the National Academy of Sciences (1992) reviewed the natural resource management program of the National Park Service (NPS) and concluded, “If this agency is to meet the scientific and resource management challenges of the twenty-first century, a fundamental metamorphosis must occur.” Indeed, that metamorphosis materialized when the National Park Service implemented a strategy to standardize inventories and monitoring of natural resources on a programmatic basis throughout the agency. The effort was undertaken to ensure that the approximately 270 park units with significant natural resources possessed the resource information needed for effective, science-based, managerial decision-making and resource protection. The national strategy consists of a framework having three major components:

1. Completion of basic natural resource inventories in support of future monitoring efforts,

2. Creation of experimental Prototype Monitoring Programs to evaluate alternative monitoring designs and strategies, and

3. Implementation of operational Vital Signs monitoring in all natural resource parks.

Knowing the condition 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.

Natural resource *monitoring* offers site-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. Monitoring data help to define the normal limits of natural variation in park resources and provide a basis for understanding observed changes; monitoring results can also be used to determine what constitutes impairment and to identify the need for change in management practices. Understanding the dynamic nature of park ecosystems and the consequences of human activities is essential for management decision-making aimed to maintain, enhance, or restore the ecological integrity of park ecosystems and to avoid, minimize, or mitigate threats to these systems (Roman and Barrett 1999).

In this plan, we define integrated monitoring as “systematic, consistent, and simultaneous measurements of physical, chemical, biological, and human-effects variables through time and at specified locations in a manner that is designed to effectively inform adaptive management decisions.” In theory, by monitoring a wide range of variables at long-term sites, it is possible to gain an understanding of how ecosystems function and respond to change (Bricker and Ruggiero 1998). Coupling monitoring with research and modeling might make it possible to predict what

will happen in the future and, if necessary, devise appropriate response strategies. Ecological monitoring is vital to park management for a variety of reasons:

- Ecological monitoring provides understanding and insight into long-term ecological phenomena and the function of complex ecosystems across park and network boundaries.

- Ecological monitoring provides the basis for evaluating whether NPS is achieving mandates and policies of protecting park natural resources. One of the major shortcomings of most of natural resource management and conservation plans has been the absence of a comprehensive ecological monitoring program (Kremen et al. 1993).

- Ecological monitoring allows for detection of long-term adverse effects of human activities on park ecosystems. Because of the delay between a human disturbance and a subsequent response, long-term ecological monitoring provides significant data.

- Ecological monitoring provides information to inform stakeholders, park visitors, and the public about the status and threats to park ecosystems, organisms, and ecological processes.

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. Vital Signs might occur at any level of organization including landscape, community, population, or genetic level, and might be compositional (referring to the variety of elements in the system), structural (referring to the organization or pattern of the system), or functional (referring to ecological processes).

Because of the need to maximize the use and relevance of monitoring results for making management decisions, Vital Signs selected by parks might include those that have important human values (e.g., harvested or charismatic species) or those with a known or hypothesized threat or stressor/ response relationship within a particular park resource. 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.

Monitoring is a central component of natural resource stewardship in the NPS, and in conjunction with natural resource inventories, management, and research, provides the information needed for effective, science-based managerial decision-making and resource protection. 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.

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 might trigger a management action or 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 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.

Legislative Mandates Linking Monitoring to Natural Resources Management

The enabling legislation establishing the National Park Service and its individual park units clearly mandates as the primary objective, the “*protection, preservation, and conservation of park resources, in perpetuity for the use and enjoyment of future generations*” (16 USC 1). National Park Service policy and recent legislation (National Parks Omnibus Management Act of 1998) require that park managers know the condition of natural resources under their stewardship and monitor long-term trends in those resources in order to fulfill the NPS mission of conserving parks unimpaired. The laws and management policies that follow provide the mandate for inventorying and monitoring in national parks.

National park managers are directed by federal law and National Park Service policies and guidance to know the status and trends in the condition of natural resources under their stewardship in order to fulfill the NPS mission to conserve parks unimpaired (see Appendix 2: Legislation Relevant to SECN Vital Signs Monitoring). The mission of the National Park Service (National Park Service Organic Act, 1916) is:

> *“...to promote and regulate the use of the Federal areas known as national parks, monuments, and reservations hereinafter specified by such means and measures as conform to the fundamental purposes of the said parks, monuments, and 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 strengthened the National Park Service's protective function, and provided language important to recent decisions about resource impairment, when it amended the Organic Act in 1978 to state that

> *“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….”*

More recently, the National Parks Omnibus Management Act of 1998 established the framework for fully integrating natural resource monitoring and other science activities into the management processes of the national park system. The act charges the secretary of the interior to

"continually improve the ability of the National Park Service to provide state-of-the-art management, protection, and interpretation of and research on the resources of the National Park System," and to "assure the full and proper utilization of the results of scientific studies for park management decisions."

Section 5934 of the act requires the secretary of the interior to develop a program of

"inventory and monitoring of National Park System resources to establish baseline information and to provide information on the long-term trends in the condition of National Park System resources."

Congress reinforced the message of the National Parks Omnibus Management Act of 1998 in its text of the FY 2000 Appropriations bill:

"The Committee applauds the Service for recognizing that the preservation of the diverse natural elements and the great scenic beauty of America's national parks and other units should be as high a priority in the Service as providing visitor services. A major part of protecting those resources is knowing what they are, where they are, how they interact with their environment and what condition they are in. This involves a serious commitment from the leadership of the National Park Service to insist that the superintendents carry out a systematic, consistent, professional inventory and monitoring program, along with other scientific activities, that is regularly updated to ensure that the Service makes sound resource decisions based on sound scientific data."

The 2006 NPS Management Policies updated previous policy and specifically directed the service to inventory and monitor natural systems:

"Natural systems in the national park system, and the human influences upon them, will be monitored to detect change. The Service will evaluate possible causes and effects of changes that might cause impacts on park resources and values. The Service will use the results of monitoring and research to understand the detected change and to develop appropriate management actions."

Further,

"The Service will:

identify, acquire, and interpret needed inventory, monitoring, and research, including applicable traditional knowledge, to obtain information and data that will help park managers accomplish park management objectives provided for in law and planning documents;

define, assemble, and synthesize comprehensive baseline inventory data describing the natural resources under NPS stewardship, and identify the processes that influence those resources;

use qualitative and quantitative techniques to monitor key aspects of resources and processes at regular intervals;

analyze the resulting information to detect or predict changes (including interrelationships with visitor carrying capacities) that may require management intervention and provide reference points for comparison with other environments and time frames; and

use the resulting information to maintain—and where necessary restore—the integrity of natural systems" (2006 NPS Management Policies).

Additional statutes that provide legal direction for expending funds to determine the condition of natural resources in parks and specifically guide the natural resource management of network parks are summarized in Appendix 2.

The Vital Signs monitoring program will allow the SECN and its parks to report on several goals related to the NPS strategic plan (Table 1-1). It is expected that performance of the Vital Signs monitoring program will eventually be measured by its ability to contribute to the measurement of park performance in attaining these goals.

Table 1-1.
Performance management goals for which monitoring data will be relevant within the Southeast Coast Network (based on NPS strategic planning guidance for 2007-2011). Not all goals are relevant for all Network parks.

GPRA Goal	Goal Description	Desired National Trend
Ia1A	Number of disturbed parkland acres restored.	Increase
Ia1B	Number of acres infested with invasive plant species controlled.	Increase
Ia1D	Number of NPS managed riparian (stream / shoreline) miles in desired condition.	Increase
Ia1J	Riparian (stream / shoreline) miles being restored.	Increase
Ia1H	Number of NPS acres in desired condition.	Increase
Ia2A	Number of federally-listed species making progress toward recovery.	Increase
Ia2B	Number of populations of species of management concern managed to desired condition.	Increase
Ia2C	Number of known invasive animal species populations controlled.	Increase
Ia4A	Number of surface water streams /shoreline miles that meet State water quality standards.	Increase
Ia4B	Number of surface water acres that meet State water quality standards.	Increase
1a4C	Complete work products and management outcomes that protect or restore water quantity conditions in NPS managed or influenced surface and ground-water systems.	All
1a4D	Protect and/or restore surface and ground waters directly managed or influenced by DOI, as specified in management plans and consistent with applicable Federal and State law, by working with State and local resource managers, as appropriate, to meet human and ecological needs.	Increase
1a6A	Percentage of collections in NPS inventory in good condition.	Increase
1a10	Number of wilderness acres that meet wilderness character objectives.	Increase

Goals of the Vital Signs Monitoring Program

The overarching purpose of natural resource monitoring in parks is to develop 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 monitoring program of the Southeast Coast Network will be designed around the five broad, service-wide goals common to all networks within the Vital Signs Monitoring Program:

- 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, and
- Provide a means of measuring progress towards performance goals.

In addition to the national goals presented above, each Vital Sign (and its associated protocol) has its own set of specific monitoring objectives (Table 1-2, and presented in greater detail in Chapter 5).

Because the majority of parks within the SECN network have limited (or no) natural resource management staff, it will be incumbent upon the Network to work closely with park mangers to integrate Network and Park operations. To this end, the SECN monitoring program is designed to (a) serve as the scientific basis for adaptive management of park resources, (b) provide clear insights on causes (and therefore possible solutions) to identified issues, and (c) assess park resources in the context of patterns across the region or larger landscape. Ultimately, Vital Signs data are intended to be useful for deciding where and how to manage resources as well as measuring success toward meeting each park's management goals.

Table 1-2.
Preliminary SECN monitoring objectives, organized in the Inventory and Monitoring Program Ecological Monitoring Framework.

Level 1	Level 2	Monitoring Objective
Air and Climate	Air Quality	Determine spatial and temporal patterns and trends in atmospheric particulates, gases and deposition.
	Weather and Climate	Determine the status and trends in the amount and frequency of precipitation in SECN parks.
Geology and Soils	Geomorphology	Determine the location and movement of shorelines in SECN coastal parks.
		Determine the status and trends of sediment elevation in SECN salt marshes.
		Determine the status and trends of the condition of habitats in SECN streams and rivers.
Water	Hydrology	Determine the status and trends in the amount of water flowing into and through SECN river systems and the magnitude, frequency and duration of flooding events.
		Determine the status and trends of freshwater and saltwater table levels inside and around SECN parks.
	Water Quality	Determine the spatial and temporal patterns and variation in water quality in freshwater and marine systems.
Biological Integrity	Invasive Species	Use monitoring data to inform managers of areas for treatment based on field observations and predictive modeling.
	Focal Species or Communities	Determine status and trends of population and community structure, function and composition within SECN parks.
	At-risk Biota	Determine status and trends of population measures and requisite habitats for target species.
Human Use	Consumptive Use	Determine magnitude and trends in harvest of biological resources such as finfish and shellfish.
	Visitor and Recreation Use	Determine spatial and temporal patterns of visitor use of park resources.
Landscapes	Fire and Fuel Dynamics	Determine the status and trends of measures of fire effects and risk.
	Landscape Dynamics	Determine spatial and temporal patterns in land use and land cover inside and surrounding SECN parks.

Environmental Setting of the Southeast Coast Network

Overview of the Southeast Coast Network

The Southeast Coast Network contains twenty parks, seventeen of which contain significant and diverse natural resources (Figure 1-1, Table 1-3). In total, SECN parks encompass more than 184,000 acres of federally-managed land across North Carolina, South Carolina, Georgia, Alabama, and Florida. The parks span a wide diversity of cultural missions also, including four national seashores, two national historic Sites, two national memorials, seven national monuments, two national military parks, as well as a national recreation area, national battlefield, and an ecological and historic preserve. The parks range in size from slightly more than 20 to nearly 60,000 acres, and when considered with non-federal lands jointly managed with SECN parks the Network encompasses more than 253,000 acres. Park descriptions are presented in two groups – inland riverine parks and coastal parks.

Table 1-3.
Parks of the Southeast Coast Network [Park codes in italics are administered by the nearest non-italicized entry above].

Park Code	Park	Significant Natural Resources?	Federal Acres	Non-Federal Acres	Total Acres
Riverine Parks					
KEMO	Kennesaw Mountain National Battlefield Park	Yes	2,880	5	2,884
CHAT	Chattahoochee River National Recreation Area	Yes	5,462	5,438	10,900
HOBE	Horseshoe Bend National Military Park	Yes	2,040	--	2,040
OCMU	Ocmulgee National Monument	Yes	702	--	702
CONG	Congaree National Park	Yes	21,769	4,663	26,432
MOCR	Moores Creek National Battlefield	Yes	88	--	88
Coastal Parks					
CAHA	Cape Hatteras National Seashore	Yes	34,500	--	34,500
FORA	Fort Raleigh National Historic Site	No	355	--	355
WRBR	Wright Brothers National Memorial	No	421	--	421
CALO	Cape Lookout National Seashore	Yes	25,174	3,070	28,243
FOSU	Fort Sumter National Monument	Yes	194	<1	195
CHPI	Charles Pinckney National Historic Site	No	28	--	28
FOPU	Fort Pulaski National Monument	Yes	5,365	258	5,623
FOFR	Fort Frederica National Monument	Yes	239	2	241
CUIS	Cumberland Island National Seashore	Yes	18,849	17,567	36,416
TIMU	Timucuan Ecological and Historic Preserve	Yes	8,417	37,583	46,000
FOCA	Fort Caroline National Memorial	Yes	133	5	138
CASA	Castillo de San Marcos National Monument	Yes	20	<1	21
FOMA	Fort Matanzas National Monument	Yes	298	--	298
CANA	Canaveral National Seashore	Yes	57,648	14	57,662
	Total		**184,581**	**68,605**	**253,187**

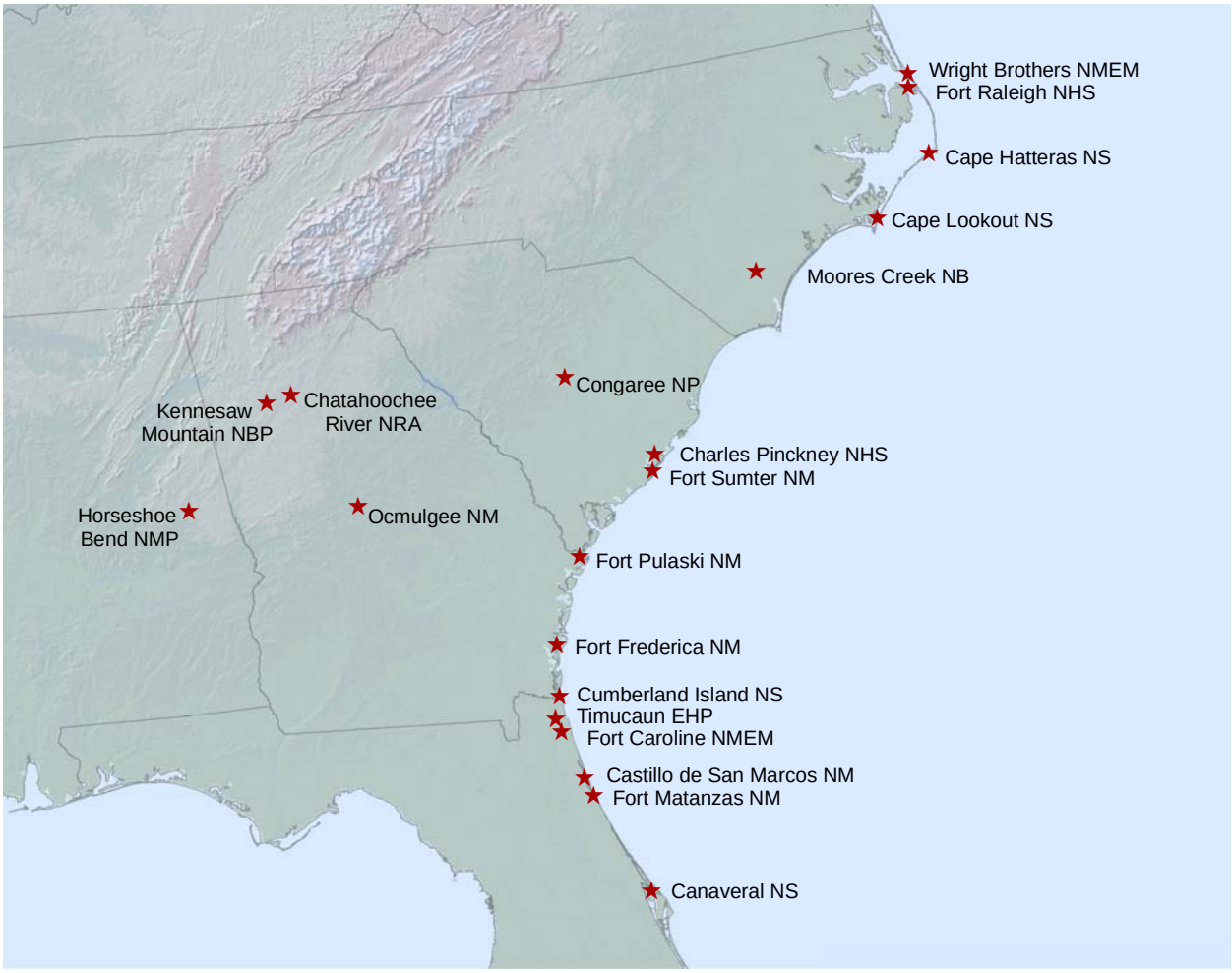
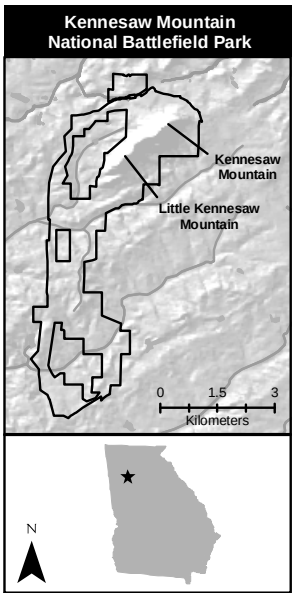


Figure 1-1. Location of parks within the Southeast Coast Network.

Riverine Parks

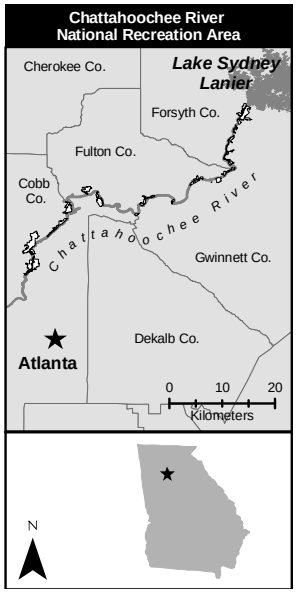
Kennesaw Mountain National Battlefield Park (KEMO), a 2,884-acre park in the metropolitan Atlanta area, includes the 1,808-foot peak of Kennesaw Mountain, Little Kennesaw Mountain and hundreds of acres of mixed hardwood/pine forests intermixed with a number of grassy fields. Included are more than 16 miles of designated hiking trails that attract hundreds of recreational visitors daily. The Park's location in the metropolitan Atlanta area makes it the second-most visited battlefield in the National Park System and has earned it a position on the Secretary of Interior's list of twenty-five most threatened parks.



Largely because of its proximity to Atlanta, major natural resource threats exist at KEMO. The development of Cobb County and greater metro Atlanta makes the lands within Kennesaw Mountain relatively valuable for natural habitats of localized plant and animal communities. Cobb County has plans to expand roads and highways that traverse the park and pose a potential threat to both cultural and natural resources.

Air pollution poses a major threat to the Park, which is located in a designated ozone nonattainment area. Vegetation in KEMO is considered at high risk of injury from ozone.

Also, there are minor threats from encroachment of adjacent landowners, exotic plant species, and industrial air and water pollution. Since 1993, pine beetle infestations have killed off thousands of pine trees throughout the park and the resulting increase in fuels laying on the forest floor pose an increased fire risk. Natural succession to hardwood forest is expected. There appears to be an increase in the beaver population. As beavers create dams, distribution and water quality is altered. The mitigation of encroachments and the removal of exotic plants are ongoing programs. A formal water quality monitoring program is ongoing and data indicate an extremely high fecal coliform level.



Chattahoochee River National Recreation Area (CHAT) extends for 48 miles along the Chattahoochee River within the Piedmont Plateau, between the city of Atlanta and the Appalachian Mountains further to the north. The park contains mesic hardwood and pine uplands, scattered cliffs, floodplains, and riparian, aquatic and shoal habitats. The park also contains significant cultural resources, for the river corridor has attracted humans for thousands of years and the remaining features have recorded their passage and story. These natural habitats and cultural resources adjacent to, and partly surrounded by, the growing greater Atlanta metropolitan area, provide a unique opportunity for environmental education and resource-based outreach programs.

The park's entire 48-mile length runs along the Brevard Fault Zone, which forms the Chattahoochee River channel, one of the oldest river channels in the United States. The Brevard Fault is a major 320+ mile long geological feature that, in part, forms the dividing line between two physiographic provinces, the Appalachian Mountains, and the Piedmont Plateau. The steep and rocky Palisades section of the park is generally considered to be the best location along the entire Brevard Fault Zone to view and study this major geologic feature.

The combination of mixed habitat types and the old and stable Chattahoochee River channel forms a biological link/ corridor with the Appalachian Mountains, which has resulted in a high biodiversity within Chattahoochee River National Recreation Area. These diverse habitats support numerous rare and protected aquatic and terrestrial species.

The park constitutes an important outdoor recreation resource to more than 3.7 million people located in a major southeastern metropolitan area. The park's green space and the river significantly improve the quality of life by serving as a sanctuary as well as providing a variety of outdoor recreation opportunities such as hiking, nature viewing, paddling, boating and fishing. The Chattahoochee River is inhabited by 22 species of game fish, including the largest stocked trout fishery in Georgia.

At the upstream terminus of the park is Buford Dam, which is operated by the Corps of Engineers. Buford Dam generates electricity and the impoundment, Lake Lanier, provides water

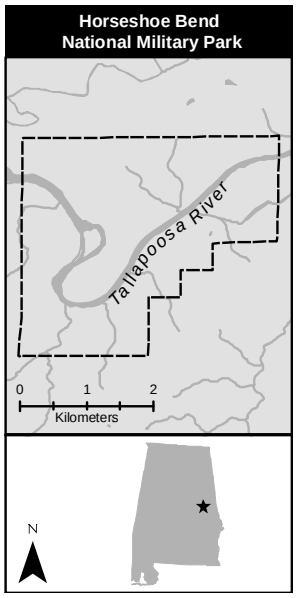
to the greater Atlanta metropolitan region. The operation of the dam dramatically alters river flows and water temperatures within the park.

CHAT consists of 15 separate units, however the park is currently acquiring additional land which will eventually link many of these units. The lands surrounding the park units, especially closer to Atlanta, are experiencing rapid development and urban sprawl. This urbanization of adjacent lands has resulted in significant impacts to the river and viewshed, and has taxed the region's sewer utility capacity. As a consequence, heavy rains and associated storm water runoff routinely cause sewer spills which flow directly into the Chattahoochee River. Additionally, siltation is a consistent problem. Currently there are five permitted commercial sand and gravel mining operations within the park. All utilize suction dredging barges along with an upland dewatering plant.

Although there is a high diversity of native plant species, impacts from exotic species are extensive and pervasive.

CHAT runs through or near several counties (including Forsyth, Fulton, Gwinnett, Dekalb, and Cobb) that are designated nonattainment for the national standard for ozone, a pollutant that affects both human health and vegetation. Vegetation in CHAT is considered at high risk for injury from ozone.

Existing baseline data on park resources and impacts are minimal at best. Historically, management has focused primarily upon the park's recreational opportunities. It is only lately that the park has begun to address its long overdue natural and cultural resource stewardship responsibilities. The park has recently begun the development of a long-term water quality monitoring program and is increasing resource staff to address many of the challenges facing Chattahoochee River NRA. Because the park contains a rich assemblage of natural and cultural resources, and is located so close to a large metropolitan region and institutions of higher education, Chattahoochee River NRA provides a great opportunity for resource-based environmental educational outdoor lab "facility."



Horseshoe Bend National Military Park (HOBE) is comprised of 2,040 acres. The park is situated near the southern end of the Piedmont Plateau. It contains low rolling hills, which reach elevations from 600 feet to 711 feet above sea level. The park not only contains many species of plants endemic to the Piedmont region, but also species associated with the Southeastern and Southern Coastal Plains. River bottomland borders each side of the Tallapoosa River. This land, which was extensively cultivated from 1832 until the establishment of the park in 1959, is in various stages of ecological succession.

The land has undergone some minor changes in the intervening 175 years since the battle. In many places pines have displaced the climax hardwoods that existed in 1814. The vegetation has been altered by human settlement, logging, and by the introduction of exotic species. The timbered lands that once gave way to agricultural crops have now given way to natural reforestation or open fields. "Forest type is mesic

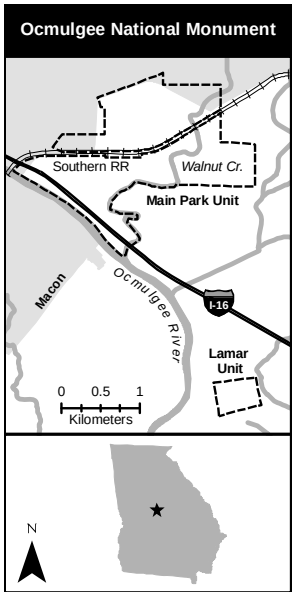
beech-oak-hickory with some loblolly pine. Drier areas and ridge tops are dominated by loblolly pine. The understory is relatively open and dominated by sapling elms, blueberries, silver bells, muscadines and ferns." The condition of wildlife species was basically unknown upon acquisition of the park. It was found that all wildlife species had been indiscriminately hunted and preyed upon by feral dogs and cats until many species barely continued to exist. Enforcement of resource laws concerning flora and fauna has allowed a diversity of wildlife species to be re-established upon the varied habitats of the park.

The hydrologic regime of the Tallapoosa River, three and one-half (3 ½) miles of which are within the park boundary, is dam-controlled upstream of the Park by Alabama Power Company. The release schedule is determined by hydroelectric needs and bears no relationship to natural flows, more resembling a "trickle or torrent" that impacts both natural resources and the cultural landscape. The U.S. Fish and Wildlife Service is currently seeking to accelerate reauthorization of the dam in order to negotiate a flow regime less detrimental to river ecology.

Pine forests at HOBE have been impacted heavily in recent years. Southern Pine Beetle infestations are growing and rapidly spreading in many areas of the park. In some cases infestations are moving toward park boundaries and endangering private lands. A heavy accumulation of slash and downed trees due to beetle kills and the aftermath of Hurricane Opal have resulted in potentially dangerous fire situations. Ladder fuels, heavy pine needle litter, and duff accumulation could substantially increase the difficulty of controlling wildfires. Ladder fuels, such as honeysuckle and other vines would assist a hot ground fire into a crowning fire.

Exotic species have impacted some areas within the park. Invading exotic plants such as ailanthus (*Altissima*), mimosa (*Albizia julibrissin*), chinaberry (*Melia azedarach*), Japanese honeysuckle (*Lonicera japonica*), kudzu (*Pueraria lobata*), and sandburs (*Cenchrus longispinas*) continue to expand and invade new areas.

The park is currently going through the General Management Plan (GMP) planning process. In this document, the stated purpose of Chattahoochee River National Recreation Area is to "lead the preservation and protection of the 48 mile Chattahoochee River corridor from Buford Dam to Peachtree Creek, and its associated natural and cultural resources, for the benefit and enjoyment of the people."



Ocmulgee National Monument (OCMU) sits on the "Fall Line," the transition between the rolling Piedmont and the flat Atlantic Coastal Plain. A portion of the monument is within the city limits of Macon, GA (shaded region of map). The Ocmulgee River comprises the boundary on one side of the monument.

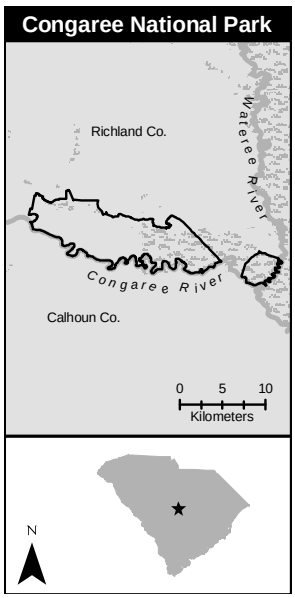
The natural resources of the park have been heavily impacted by human activities, including I-16 and its associated berm, which has essentially cut off the river from its floodplain and disrupted the natural flow of the area. Despite this, and its proximity to Macon, OCMU has a surprising amount of wildlife present. This is probably a result of a corridor, or what is known locally as the "Greenway," connecting the monument to other natural areas south of the monument. Numerous bird species are

present in the monument, either feeding or nesting or both. Migratory birds utilize the area as a stopover during spring and fall migrations. The endangered wood stork (*Mycteria americana*) feeds here during summer months. Numerous other wildlife live here, including deer, beaver, bobcat, alligators, and various reptiles and amphibians. Recreational fishing is allowed, with largemouth bass and bream being two common catches. Within the last eight years, coyotes have entered the monument. What effect this will have is unknown. Exotic species include nutria, fire ants, feral pigs, as well as domestic dogs and cats. Vegetative exotics include privet, Japanese honeysuckle, and kudzu.

The overall lack of knowledge of the natural resources in the monument has become both a problem and a frustration. Major changes have occurred, such as a 500-year flood associated with Tropical Storm Alberto in 1994, pressure from exotic species, particularly feral pig damage, as well as more subtle changes over time. Because there is no baseline data for the monument, there has been no way to track these changes or impacts over time.

Threats affecting the native plants and animals in the monument result mainly from human activities, and include exotic species, water quality, air quality, development, and the general proximity to the city of Macon. Exotic species are a disruptive influence in the monument. Disruptive and invasive species include privet, Japanese honeysuckle, and feral hogs. Feral pigs are responsible for a tremendous amount of resource damage in both the main unit and the detached Lamar unit. Fire ants are spreading through the park.

Human development has severely impacted the park. A railroad and I-16 bisect the park; a sewage lift station and its associated underground pipes are in the park. A once small stream now drains a large part of east Macon, bringing large amounts of trash, pollution, and occasionally raw sewage into the park. This has raised questions regarding water quality, groundwater quality, and where the pollution goes. The city of Macon and surrounding Bibb County, and part of adjacent Monroe County, have been designated nonattainment for the national ozone standard. In addition, vegetation in OCMU is considered at high risk of injury from ozone.



Congaree National Park (CONG) is situated immediately adjacent to the Congaree and Wateree Rivers in southeast Richland County, South Carolina, approximately 20 miles southeast of the capital city of Columbia. The park protects towering old-growth trees and diverse plant and animal life within the largest contiguous bottomland hardwood forest remaining in the United States. Periodic flood waters from the adjacent rivers sweep through the bottomland forest in winter and spring, carrying the nutrients and sediments that nourish and rejuvenate this unique floodplain ecosystem. Nearly 90 species of trees grow within the park, with many that are recognized as national and state champions for their size. Forested wetlands, oxbow lakes, and slow moving creeks and sloughs provide superb habitat for fish, birds, reptiles, mammals and other aquatic life. The diversity of flora and fauna, tall tree canopy and giant trees, and intact floodplain ecosystem earned the park the designation of an International Biosphere Reserve,

National Natural Landmark, Globally Important Bird Area, and congressionally designated Wilderness Area.

Congaree National Park encompasses a 26,800-acre bottomland hardwood forest in central South Carolina. Located 20 miles southeast of Columbia, it borders the northeast side of the Congaree River and the west side of the Wateree River. Densely forested, most of the Park is located within the river floodplain. A wide variety of forest communities are represented, with dominant tree species ranging from upland pines to wetland cypress (*Taxodium* spp.) and tupelo (*Nyssa* spp.). The Congaree River forest environment is characterized by silty clay soils, oxbow lakes, swales and sloughs, and meandering creeks. The Congaree and Wateree Rivers are the major source of floodwaters, sediment, and nutrients delivered to the Park, although several tributary creeks also flow through it. The significance of CONG lies in its: (a) unique old-growth bottomland hardwood forest community associated with the swamp-like floodplain, (b) remarkably large trees, including loblolly pine, bald cypress (*Taxodium distichum*), tupelo, sweet gum (*Liquidambar styraciflua*), American sycamore, cottonwood (*Populus* spp.), oak (*Quercus* spp.), and holly (*Ilex* spp.) trees; (c) the intact floodplain ecosystem, and (d) high biodiversity.

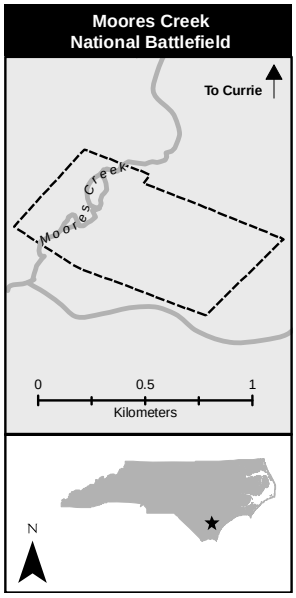
Congaree National Park's mission calls for accomplishing the long-term goal of "preserving, protecting, and perpetuating the bottomland hardwood ecosystem in a manner that promotes the natural function of the Congaree River floodplain by (a) managing and restoring designated wilderness areas and all-inclusive wetlands, so as to minimize disturbances to natural landforms, vegetation, and wildlife habitat, and (b) conserving the rich and abundant biodiversity within the Congaree and Wateree River alluvial floodplains by controlling, where necessary, the adverse effects caused by human activities.

Threats to the health and viability of the surface and ground water in the park include chemical runoff from agricultural fields, an Environmental Protection Agency Superfund Site located five miles from the park northwest boundary, aquaculture operations on the north boundary perimeter, highway treatment residues, and discharges and corporate expansion of two neighboring companies: a nuclear fuel production plant and a pulp and paper manufacturer. Also upstream from the park is the Teepak Company, a manufacturer of synthetic skins for meat products, and the Carolina Eastman Company, a manufacturer of synthetic filament products. The Congaree River receives effluent from many smaller manufacturing plants and from sewage-treatment facilities in Columbia and adjacent counties. All of these plants are monitored by the State Department of Health and Environmental Control and the State Water Resources Commission. Little is known about their operation or impacts, if any, on park resources. Air pollution from vehicles, industries, and powerplants also affects CONG. A portion of Richland County is designated nonattainment for the national standard for ozone.

Exotic species and past land use practices also pose threats to park resources. Although efforts are underway to control populations within the park, feral hog rooting and herbivory causes potentially severe impacts to forest community structure. The historical suppression of fire has altered successional processes in parts of the park, while forestry practices have led to the creation of species-poor pine plantations in some areas.

Moores Creek National Battlefield (MOCR) is an 88-acre park located in an area of second growth forest interspersed with small farms. Local woodlands are harvested for the pulp

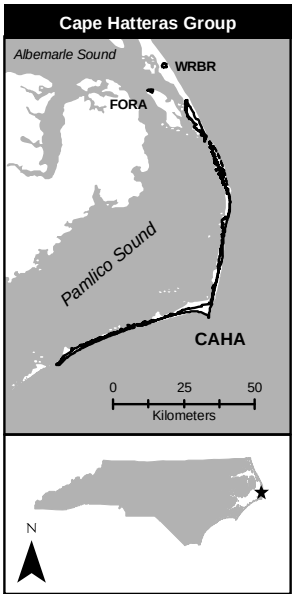
industry. At present, no significant industrial, commercial, or residential developments exist near the park. The topography of the region is relatively flat. A short distance within the park, the higher land characteristic of the inland Carolina coastal plain descends abruptly to the lowlands that comprise the greater portion of the park land, reaching to Moores Creek. This freshwater stream, averaging 30 feet in width, forms the western boundary of the park. Bordering the park are screens of dense second-growth vegetation, while the landscape at the center of the development consists of grass-covered meadows and slopes with scattered trees and brush. Habitats include: alluvial woods, old fields, ditches, sandy xeric woods, lawns, a pond, pinewoods, mixed wooded slopes, creek banks, roadside ditches and meadows.



Several potential threats to MOCR resources have been noted. Although the park is fairly isolated, residential development on adjacent lands has been increasing in recent years. Past landscape practices at the Battlefield have likely impacted several locally rare or state-listed plant species. Efforts to restore habitat for these species is currently underway, although long-term monitoring is necessary to fine-tune efforts and ensure their eventual success. Finally, the predominant tree species, loblolly pine, is greatly affected by pine bark beetle. Long-term efforts are underway to restore the beetle-resistant, native Longleaf pine across much of the Battlefield.

Coastal Parks

Cape Hatteras National Seashore (CAHA), Fort Raleigh National Historic Site (FORA), and Wright Brothers National Memorial (WRBR) are located within the east coast barrier island system. The Seashore contains 35,400 acres of land and 74 miles of virtually unspoiled beach. The U.S. Fish and Wildlife Service administers Pea Island National Wildlife Refuge within the boundary of the seashore. The intensely developed town of Nags Head borders the northern end of the Seashore and nine other villages border the seashore. Seashore marshes contribute heavily to primary estuarine productivity and provide habitat for numerous wildlife and aquatic species. Buxton Woods is located on the widest portion of the Seashore and is one of the largest maritime forests on the east coast. Approximately one-third of the forest, about 1,000 acres, lies within Park Service boundaries. Of the rest, about 800 acres are under state protection. The unique and varied habitats, mature broad-leafed evergreen forest and shrub, freshwater marsh, and bog support an unusual assemblage of aquatic, terrestrial, and avian species. Buxton Woods also overlies, protects, and provides for recharge of an important freshwater aquifer. The seashore has recently been designated a Globally Important Bird Area by the American Bird Conservancy because of the importance of the seashore habitats to avian breeding, migration, and wintering.



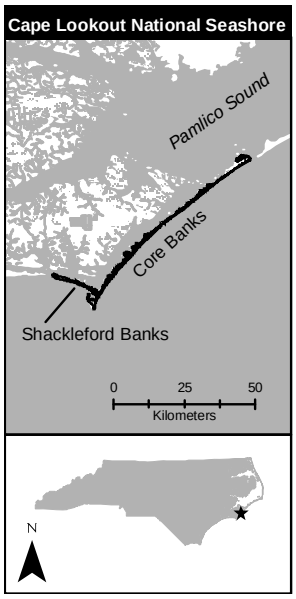
The ecological zonation of Cape Hatteras National Seashore is resultant in part on artificial alterations dating from the turn of the twentieth century. The most important perturbations were (a) early efforts at mosquito control and waterfowl management which involved excavation of

drainage ditches and construction of water control structures, and, (b) construction and vegetative stabilization of primary dunes along the length of the Seashore. Later changes were wrought when road construction included excavation of borrow ponds for road bed material. For the most part, these actions ended by the 1970's, save for localized projects designed to protect specific and discrete portions of infrastructure.

Fort Raleigh NHS is located on the north end of a forested island between the barrier islands and the mainland of coastal North Carolina. The site's 355 acres vary in elevation from sea level to 20 feet. Over half of Fort Raleigh is heavily forested with the remainder of the area supporting a visitor center, administrative and maintenance buildings, residences, the Waterside Theatre complex, and maintained open grassed areas. The maturing mixed deciduous and pine forest occurs on land that was previously disturbed, having been used for farming, grazing, transportation routes, and early settlement activities. Habitats include upland forests dominated by pines or a mixture of pine and hardwoods, brackish marsh, and swamp forests dominated by hardwoods. Species within the forest canopy include live oak, laurel oak, blackjack oak, American holly, dogwood, persimmon, and loblolly pine.

Wright Brothers NM covers over 421 acres in Kill Devil Hills, NC. The area's wind-blown sand flats and hills were the Wright brother's chosen practice field, and in 1903, the site of the first human flight. WRBR is situated on a barrier island within a rapidly developing residential and commercial community. The site has been transformed from its original relatively barren, dynamic state to a stabilized, dune and grass flat region. Grassed areas are vegetated with native and introduced grasses. Loblolly pine dominates the forested areas with laurel and live oak being the more predominant broad-leafed trees. Evergreen broad-leafed shrubs are interspersed within the forested area and between the forested and grassed areas. Much of the site is occupied by a visitor center, reconstructed buildings of the period, the monument itself, maintenance and residential structures, a paved airstrip, roads, walkways, and parking lots. Only limited vegetation and faunal inventories have been conducted at the site.

Developmental pressures outside the Park and visitor and recreational uses represent the major categories of threat to the integrity of natural resources on the CAHA Group parks. Adjacent property development has resulted in direct loss and fragmentation of habitat upon which numerous park wildlife species were partially dependent. Replacement of natural areas with impervious surfaces increases storm water runoff with its associated contaminants. Two potentially profound adverse impacts associated with adjacent development are contamination of ground and surface water by septic leachate and drawdown of the aquifer associated with excessive groundwater withdrawals. Other threats to natural resources include the introduction of exotic plants and animals, off-road vehicle use, and dredging of channels adjacent to the park.



Cape Lookout National Seashore (CALO), largely undeveloped and accessible only by boat, is made up of three barrier islands covering 56 miles of the central coast of North Carolina. Most of the seashore consists of North and South Core Banks, a 44-mile (71-km)-long barrier system oriented in a southwest to northeast direction and separated by

the infrequently maintained New Drum Inlet. CALO extends into the Atlantic Ocean from its southern end, and abandoned Portsmouth Village is located at its northern end. The other barrier system within the Seashore, Shackelford Banks, extends westward from Cape Lookout and, while smaller (13 km long), is considered ecologically more diverse than Core Banks.

Core Banks is a long, narrow expanse of low dunes, maritime grasslands, and extensive salt marshes. Shrub thickets border the grassland in many places, and a low maritime forest occupies small areas of higher ground, such as Guthries Hammock. The islands are generally about 1 to 2 meters in elevation and 1 to 2 kilometers in width. For the most part, they are open and treeless. Windblown salt spray is carried across the entire barrier.

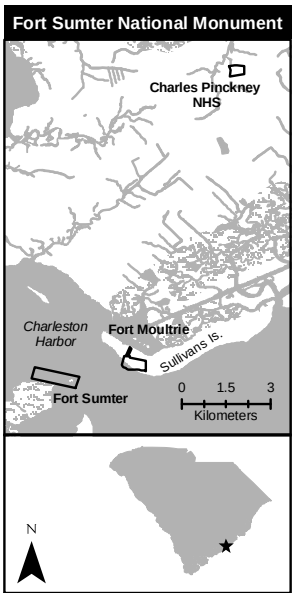
The wide berm and low, scattered dunes of Core Banks are characteristic of overwash-influenced barrier systems that have not been altered by man-made structures. When storms occur, the dunes here offer little resistance to flooding. Another process that has shaped these islands is the opening and closing of inlets. Dramatic changes in the position of inlets may take place in the period of a few years or even months. Many of the creeks in the marshes along Core Banks have probably been inlets in the past.

Although the physiography of Core Banks is more or less uniform along its length, the areas of Portsmouth Village and Cape Lookout are unique. Instead of exhibiting the typical zonation of a wide berm, low dunes, grasslands and shrub thickets, and salt marsh, the northern end of Portsmouth Island is characterized by vast tidal sand flats (averaging 1 km in width) located between the berm and the dunes of a series of marsh-fringed islands. At triangular Cape Lookout, continuous dunes similar to those on Shackleford Banks can be found on the southwest side, with several small freshwater marshes present in depressions between the dunes. With high dunes significantly reducing overwash, thickets have further stabilized the flats of the Cape's interior. A long spit extends from the western tip of Cape Lookout, where a jetty built in the early 1900s has encouraged accretion in this direction.

The dunes at the western end of Shackleford Banks are 10 to 13 meters (34 to 44 ft) above sea level and contain the highest elevations on Shackleford. The presence of high dunes on the western section may be due to the island's east-west orientation. Because the island faces the prevailing southwest winds rather than being parallel to them, sand is continually blown from the accreting beach into the dunes, where it is trapped and stabilized by the dune grass, *Uniola*. In the lee of this wall of rolling dune ridges, there is an impressive maritime forest, as well as several fresh and brackish marshes. On the side of the island that faces Back Sound, the beach is narrow and, in some places, the scarped bank is eroding away. Unlike most of the Outer Banks, the inner shore here is not fringed with salt marsh.

The western end of Shackleford is an accreting sand spit. Young dunes with *Spartina patens* and *Fimbristylis castanea* are forming along the edge of the curving berm, while areas of salt marsh are developing on the sound side of the spit. The eastern two-thirds of Shackleford Banks consists of low dunes, grassland, and salt marsh. In contrast to the western third, it is influenced by overwash. This part of the Island is characterized by dunes of less than 3 meters (10 ft) in height, open grassland (on overwash terraces), mesic meadows, and salt marsh. Shrub thickets occur in a few areas.

Specific issues of concern to CALO include off-road vehicle use and associated impacts to dunes, threatened and endangered species, commercial fishing, military overflights, and non-native species.



Fort Sumter National Monument (FOSU) consists of 200 acres of land located at the mouth of Charleston harbor and on nearby Sullivan's Island, South Carolina. The park's two major units are Fort Sumter, site of the Civil War's first engagement, and the somewhat older Fort Moultrie. Historic Fort Sumter is influenced dramatically by the surrounding natural elements. Of the 198 acres that comprise the park, 122 acres surrounding the Fort are submerged under the waters of Charleston Harbor. The remaining acreage is located on Sullivan's Island and in Charleston. Adjacent to the park, but outside its boundaries, are shoals, islands, and marshes important to the Fort Sumter scene. Two endangered species, the manatee and the loggerhead turtle, migrate through the waters adjacent to the park, but do not live or nest within the park itself.

The 28-acre Charles Pinckney National Historic Site (CHPI) was established under Public Law 100-421 and is a relatively new addition to the National Park Service. It is a rural vernacular landscape in use from 1695 until the 1980's, and was actually a working farm until the 1960's when nearly 700 acres were sold for development. The grounds include three acres of wetlands, eight acres in mixed hardwoods and pines, and ten acres of open pasture. The site, which fronts Long Point Road, a scenic highway, is surrounded by suburban housing developments.

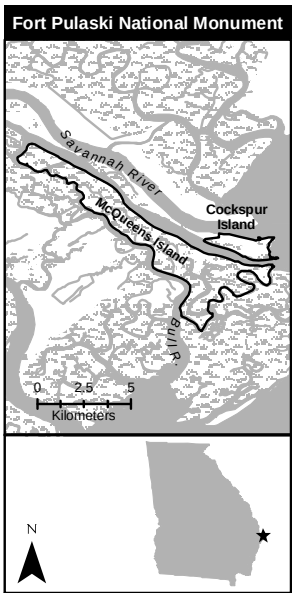
A Servicewide issue potentially threatening Fort Sumter is sea level rise. At present, sea level rise is approximately 1.3 millimeters per year, but many experts believe this rate may accelerate in coming decades. An annual increase in sea level, no matter how small, over a long period of time would upset coastal dynamics in the Charleston area and could eventually pose a direct threat to Fort Sumter and Fort Moultrie.

Harbor dredging is another major concern. Dredging is necessary in order to maintain Charleston as a viable seaport; however, it negatively impacts Fort Sumter's marine ecosystems as well as disturbing the historic viewshed by creating spoil banks on nearby barrier islands. The park staff continues to monitor dredging activities within the harbor, working with the Army Corps of Engineers and local authorities to mitigate the impact of dredging on the historic scene whenever possible.

Insect infestations present a natural resource management concern. Fire ants, termites, and other insects are unsightly to the visitor and can be harmful. As in the case of fire ants, they may bite visitors creating painful welts. The park's approved Integrated Pest Management Plan requires revision to incorporate the new facilities of Charles Pinckney NHS, Moores Creek NB and the Curatorial Storage Facility.

Fort Pulaski National Monument (FOPU) is located in Chatham County, Georgia along the Savannah River only a few miles from its junction with the Atlantic Ocean. The site consists of

two islands that were, before human intervention, primarily salt marsh. Judging from the composition of existing vegetation, Cockspur Island probably supported some coastal hammock forest or woodland. It was selected for fortification as early as the seventeen hundreds. In the eighteen hundreds, as part of the development of the site for defense, the island was modified by the installation of drainage canals and a dike system. In latter years, the site was also impacted by the deposition of spoil material. The addition of dredge material from the Savannah River to Cockspur Island continued until recent times. During the civil war period, the vegetation was removed to enhance visibility and kept in early successional stages. Since the abandonment of the fort in the late eighteen hundreds, a large portion of central Cockspur Island has reverted to maritime forest. Currently the upland portions of Cockspur (approximately 260 acres) support a mosaic of maritime forest, maritime shrub communities, maintained grasslands and successional spoil deposit areas. It also includes over 340 acres of tidal shrubland and tidal herbaceous marsh.

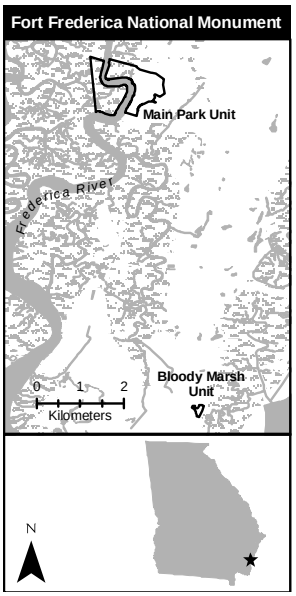


McQueens Island makes up the largest portion of land holdings for the National Monument (about 4,900 acres) and the majority of this consists of salt marsh. A railroad was constructed along the northern edge of the island in 1887 to connect the city of Savannah with Tybee Island and operated until 1933. In 1923, US Highway 80 was constructed, occupying a location across the central portion of the island and adjacent the old railroad grade along the eastern section. In 1994 Chatham County converted the abandoned railroad right-of-way to a multipurpose hiking trail. Both the highway and the converted rails-to-trails areas support ruderal habitat for a number of coastal plain herbaceous species. Other upland habitat on McQueens Island occurs in association with a public fishing and boat ramp on the eastern end of the island and an abandoned section of US 80 leading to the Bull River.

The natural resources at FOPU face a number of threats, primarily related to its proximity to the city of Savannah. Heavy industrial development on the Savannah River, as far upstream as the Savannah River Site near Aiken, SC, have been known to impact the water quality and ecological health in and around the park. Pollutant levels in water, sediment, and invertebrate tissue will be analyzed as part of an upcoming study. Shipping traffic and associated dredging are contributing to increased shoreline erosion along the north shore of Cockspur Island. Finally, Highway 80 between Savannah and Tybee Island is slated for widening in the near future, impacting park wetlands adjacent to the existing roadway. The Monument is currently working with the U.S. Fish and Wildlife Service, the Federal Highways Administration, and the Georgia Department of Transportation to develop a mitigation plan that complies with NPS Wetlands Policies.

Fort Frederica National Monument (FOFR) features stately oaks, exceptionally large grapevines, and Spanish moss that lend an air of antiquity unequaled on the coast. The monument is divided by the Frederica River, one of the primary salt marsh rivers in the Brunswick area, with 99 acres of marsh lands at the Frederica site on the west side of the river and approximately 137 acres of uplands adjoining the east side of the river. The Bloody Marsh

site consists of 8 acres of which approximately 5 acres are tidal marsh. Approximately 50% of park-owned lands are classified as wetlands.



Outside of the park, the vegetation is composed primarily of pine-hardwood and gum-bay assemblages. Dominant plants include loblolly pines, live oaks, water oaks, saw palmetto, cabbage palms, gums, bays, magnolias and myrtles. A large variety of under brush including several species of ferns and vines is also present. Inside FOFR, clearing and possibly selective cultivation has led to a different variety of plants, especially trees. These include large live oaks, loblolly pines, pecan, magnolia, cedars, sweet gum, and cabbage palm. Large muscadine vines, saw palmetto, and small bamboo are also common. Although the largest part of the marsh is dominated by smooth cord grass, a number of other species are common along the upland boundary. These include black rush, giant cord grass, sea ox-eye, marsh elder, salt myrtle, and *Distichlis*.

Sedimentary deposits composed primarily of sandstone, limestone and clay underlie Frederica. Surface deposits of sand are common to the upland area, while the marsh substrata are composed of unconsolidated clays containing high organic matter content and sand. In most areas the soils are well drained; however, poorly drained soils occur in the northeastern portion of the park.

The climate of the island area and coastal mainland is hot and humid in the summer and cool and wet in the winter with occasional very cold spells. Sub-freezing temperatures are relatively common at night from late November into early February. Spring and fall are marked by heavy concentration of pest insects. The summer months are characterized by frequent, locally severe, thunderstorms with high winds often interrupting commercial electricity.

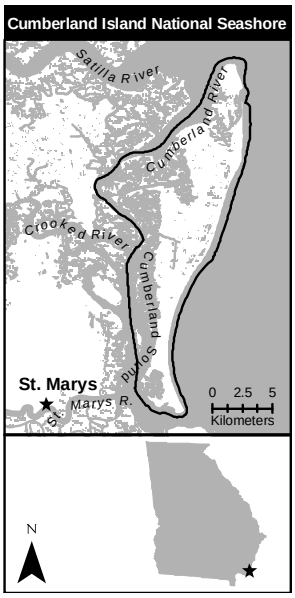
Specific threats to the resource include:

- *Water Quality.* Deterioration is a concern from industrial contaminants as well as the impact of the intensive recreational use of the Frederica River by boaters and fishermen. The wave action from watercraft presents possible damage to park wetlands and the cultural landscape through erosion by wave action. Several of the nearby industrial plants have buried or discharged, legally and otherwise, toxic wastes in the Brunswick, Georgia, community.

- *Pest Management.* Insect and animal pests at the park present human safety hazards and some natural resource concerns in the form of pine beetle and gypsy moth infestations.

- *Coastal Dynamics.* Any long-term change in coastal dynamics caused by global climate change and associated sea level rise would present a clear threat to the Monument's natural and cultural resources. Frederica's elevation is three feet above high tide.

Cumberland Island National Seashore (CUIS), a 17.5 ½ mile long sandy barrier island, is one of the larger and more diverse islands on the Atlantic Coast. It totals 36,415 acres, of which 16,850 are estuarine. A *Spartina* grass dominated salt-marsh, oyster mud flats, and six tidal creeks provide the habitat for a diverse marine-based fauna. The remaining acreage is terrestrial. A live oak-palmetto dominated forest backs an extensive dune system. As the elevation of the island rises on the northwest, a mixed pine-deciduous forest can be encountered. The island is known for nesting loggerhead sea turtles, abundant shore birds, undeveloped dune fields, maritime forest ecosystems, and the historic structures in five historic districts on the National Register of Historic Places. Cumberland Island and its surrounding waters provide habitat for at least thirteen federally listed threatened or endangered species.



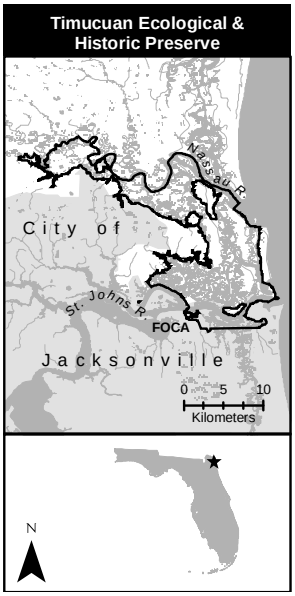
The National Seashore was established in 1972, to preserve the scenic, scientific, and historical values of the largest and most southerly island off the coast of Georgia. Cumberland Island is also part of the South Atlantic-Carolinian Biosphere Reserve and will be permanently protected in a primitive state. The northern half of the island has also been designated a wilderness area. This unspoiled environment, once prevalent on all the barrier islands, provides a unique opportunity to experience the flora and fauna of a natural coastal ecosystem.

Many of the resource issues at CUIS stem from either external development or past human uses of the island. The southeast Georgia coast is going through profound growth in new, residential communities, many of which incorporate marinas. Recreational pressure will in turn increase on the island, much of it uncontrolled, and the threat to resources and critical habitat will intensify. The dredging and maintenance of the adjacent Intracoastal Waterway and St. Marys Inlet complicate the natural processes of sand budgets and tidal flow, which are key components in the island's stability and ecology. Boat wakes might be contributing to erosion on the back-barrier (west) side of the island. The nearby urban centers of St. Marys, Fernandina Beach, Brunswick, and Jacksonville might contribute to a range of island issues, from air and water quality to light pollution. Regional industries, such as commercial fishing and paper mills, also have an impact on Cumberland Island's resources. Kings Bay Naval Submarine Base is located immediately across the Cumberland Sound from the park.

Past development and human use of the island has significantly changed landscapes and introduced destructive non-native species. Streams and wetlands were altered historically to accommodate agriculture uses. More recently, roads and causeways were constructed which now effect the island's hydrology where they cut across tidal streams, high salt marsh, freshwater sloughs, and wetlands. Non-native species were introduced for ornamental and agricultural purposes but, introductions have been both intentional and accidental. Their presence is significantly degrading the native flora and fauna on the island. Feral hogs present problems in virtually every type of Cumberland Island habitat and, although a management program is in place and the population decreasing, monitoring and actions must be long term. Feral horses also have a serious impact across the island, however; their management has been and will continue to be highly complex due to their public popularity. Multiple species of non-native

plants have established themselves on the island, with several of the most invasive in dense or expanding populations.

Global issues such as sea level rise from increased greenhouse gases in the atmosphere are also important resource issues. Changes in the shoreline and biota from flooding of lower elevations and changes in coastal dynamics may threaten nesting of threatened species and create ecosystem level perturbations.



Timucuan Ecological and Historic Preserve (TIMU) and Fort Caroline National Memorial (FOCA), situated entirely within Duval County and the city limits of Jacksonville, FL, encompasses approximately 46,000 acres between the St. Johns and Nassau rivers. The southern third of the preserve lies at the mouth of the extensive St. Johns River watershed, which includes parts of Duval and several other counties for approximately 300 miles to the south. The St. Johns River is heavily impacted by agricultural, industrial and urban pollution; however, marine tidal waters near its mouth serve to ameliorate pollution through dilution and flushing. Water quality is considered relatively good in the preserve due to this flushing action. The northern two thirds of the preserve lie within the Nassau River drainage basin, a small watershed that covers parts of Duval and Nassau counties. The Nassau River watershed has not yet experienced the concentrated urban and industrial growth found along the St. Johns River; still, portions of the watershed exhibit poor water quality. The area surrounding the preserve to the west and north is predominantly marsh and low uplands utilized for timbering, residential and agricultural uses.

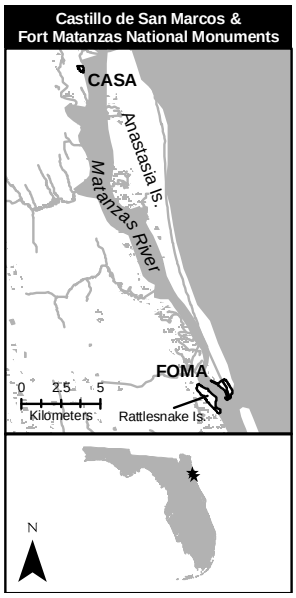
Several rare, threatened or endangered species are known to use the preserve, including the West Indian manatee (*Trichechus manatus*), colonial wood stork (*Mycteria americana*), least tern (*Sterna antillarum*), gopher tortoise (*Gopherus polyphemus*), arctic peregrine falcon (*Falco peregrinus*), and loggerhead sea turtle (*Caretta caretta*). Other rare, threatened or endangered species are suspected to occur within the preserve, such as the eastern indigo snake (*Drymarchon corais couperi*) and Atlantic sturgeon (*Acipenser oxyrhynchus*).

Timucuan and Fort Caroline National Memorial are administered as one park. Fort Caroline NM includes approximately 138 acres located along the St. Johns River within the city of Jacksonville and Duval County, Florida. Located primarily on a bluff overlooking the river that rises to a height of nearly 90 feet, the park consists of mixed species forest with fresh water wetlands, preserving an enclave of representative species native to the North Florida-South Georgia community.

Duval is one of the fastest growing counties in Florida. The preserve is located in an area that has historically experienced limited development and growth due to lack of easy and quick access. Development and recreational use pressures have increased, however, with the opening of a six-lane bridge in 1989 and ongoing construction of a major highway linking the bridge to the interstate highway system.

Throughout both watersheds, many residential homes operate private well and septic systems, the failure of which is a presently unquantified source of water pollution. An unknown amount of pesticide, herbicide, and fertilizers is transported by stormwater runoff to the marshes of the preserve. Contaminated sediments are known to occur in some areas of the preserve, but the extent of contamination and the effects of sediments resuspension are not known. This is of particular concern as several major dredging projects are proposed in the near future.

Exotic plants and animals are known to occur within the preserve, but information on species, locations and potential threats is lacking. The preserve presently has little information on vegetative and aquatic habitats, ecological processes, and current ecological conditions. Related to the issue of exotic species is the recent development of a prescriptive fire program, which is expected to be instrumental in returning native species to the numerous pine plantations within the preserve.



Castillo de San Marcos (CASA) and Fort Matanzas National Monuments (FOMA) are located 14 miles south of St. Augustine on the northeast Atlantic coast of Florida. Fort Matanzas encompasses of a total of 298 acres divided between the southern tip of Anastasia Island (108 acres) and the northern end of Rattlesnake Island (190 acres). Both are barrier islands separated from the Florida mainland by the Matanzas River and the Intracoastal Waterway.

Castillo de San Marcos National Monument was established to preserve the Spanish fortification (Castillo de San Marcos) and associated modifications. The masonry fort itself is significant for its military architecture. Being made primarily of coquina, it is potentially sensitive to changes in regional air quality (such as increased acid rain).

The Anastasia Island portion of FOMA consists of stabilized beach dunes rising as much as 7.6 meters above sea level. Predominant habitats in this portion of the park include beaches along both the Matanzas River and the Atlantic shore, stabilized sand dunes supporting maritime forest, secondary dunes further inland, and salt marsh.

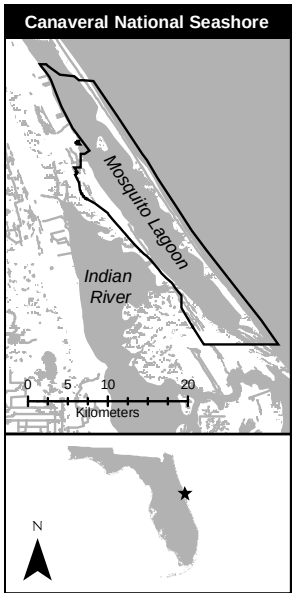
Most of Rattlesnake Island is less than 5 ft above sea level, though it rises to 15 ft at one point on its northern end. Much of northern portion of Rattlesnake Island consists of sandy fill pumped in from dredging operations that maintain the boat channels in the Intracoastal Waterway. In addition to the habitats found on Anastasia Island, Rattlesnake Island supports slash pine and red bay woodlands, oyster shell beaches, and developing hardwood forests typified by wax myrtle, cedar, and cabbage palm.

FOMA has actually increased in size by an estimated 13 acres over the past three decades. This continuing growth is evident in the expanding shoal banks inside and outside the Matanzas River inlet. Shoals inside currently allow fishermen on Rattlesnake Island to wade into the middle of the Matanzas River west of the inlet bridge, while shallow bars outside break Atlantic waves before they can roll into the mouth of the Matanzas River.

Moderate threats to sea turtle nests are due to the high level of vehicular traffic on the beach (it is legally a state highway), and the threat of human poaching of new nests. Beach mouse habitat, a small area (less than 5 acres) is located just behind the first barrier dunes on the beach and is also threatened by overwash from extreme weather conditions accelerated by the vehicular traffic. The park, in cooperation with the Florida DOT, will be installing two new parking lots and a dune crossover trail all just north of the bridge and improvement of the parking area at the beach access. This project will help reduce the number of vehicles on the beach and provide a hardened interpretive trail that will help keep visitors out of the delicate dune ecosystem. Unfortunately, a separate threat also exists from occasional illegal "dune busting" by four-wheel drive vehicles.

Minor threats include disturbance of a least tern rookery area by vehicles. Also, natural plant succession is decreasing the attractiveness of the area as a rookery for the least tern. Foot traffic into the dunes is a constant occurrence, creating blow-outs in the dunes, which reduce their ability to maintain plant life. The dunes directly protect the fort by reducing erosion of the barrier island that shields Fort Matanzas from damaging storms.

Introduced plants pose another minor threat, competing with native species in several disturbed areas of the park. They are beginning to threaten the survival of some species and habitat. Exotic animals such as house cats, both feral and free roaming pets, are a direct threat to the Anastasia Island beach mouse. House mice and European rats are considered a potential threat to the Beach mouse and other indigenous mammals.



Canaveral National Seashore. Canaveral National Seashore's (CANA) natural resources include a diverse assemblage of wildlife, plant communities, geophysical features and natural processes reflecting the complexity of the land/lagoon/sea interface of east central Florida. Throughout the park, the relationship of land and water is paramount. From ephemeral wetlands to Atlantic beaches, the natural processes shaping the coastal environment are present in full diversity where change is the only constant.

Unlike many barrier islands, CANA has only a single dune ridge, averaging 12 ft in height. For the vast majority of its length the dune is quite stable, backed by a dense growth of saw palmetto (*Serenoa repens*) and several other species of hardy shrubs and grasses.

Mosquito Lagoon, extending along the backside of Canaveral's barrier island, is the northernmost part of the Indian River Lagoon. Containing the most diverse assemblage of aquatic species on the entire Eastern Seaboard, this 155-mile long lagoon has been designated as an Estuary of National Significance by the Environmental Protection Agency and an Outstanding Florida Water by the State of Florida. It contains one of the last significant populations of oysters on the entire Atlantic Coast that has not been depleted by over harvesting or pollution. Commercial shell fishing is extremely important to the local economy; recreational fishing and shrimping in the lagoon support a multimillion-dollar tourist industry. The estuary also acts as an important nursery area for a number of commercially important ocean-going species such as flounder, mullet, black drum and shrimp.

The park is located along the "frost line," resulting in a unique combination of temperate and subtropical plants found nowhere else in the Western Hemisphere. Several temperate species extend no farther south than Canaveral, while a number of subtropical species occur no farther north. Signs of this unusual mixture include Canaveral's hammocks, which contain an overstory dominated by temperate species and an understory comprised of subtropical plants. Another sign is the significant shift in vegetation along the edge of the lagoon from salt marsh cordgrass (*Spartina alterniflora*), which predominates in areas north of Canaveral, to mangrove species that predominate to the south.

Wildlife resources are considerable, ranging from myriad terrestrial and aquatic species inhabiting estuarine systems to small endemic populations of mammals living in the dunes. Canaveral is second only to Everglades National Park in number of federally protected species with 14. These include such species as the highly endangered West Indian manatee (*Trichechus manatus*), right whale (*Balaena glacialis*) and little known Atlantic salt marsh snake (*Nerodia fasciata taeniata*), who's entire known range consists of a single county in Florida. Canaveral's 24 miles of beach provides a critical nesting area for sea turtles, harboring 3,000 to 4,000 nests each year. The majority are loggerhead (*Caretta caretta*), with a smaller number of green (*Chelonia mydas*) and an occasional leatherback (*Dermochelys coriacea*). Mosquito Lagoon provides an important nursery area for juvenile sea turtles.

Boaters are coming into Canaveral National Seashore in increasing numbers due to the growing popularity of fly-fishing for redfish. This increases the destruction of seagrass beds, impacts to fisheries are unknown and manatees are highly affected. One of the very controversial and volatile issues among boaters in Florida is the establishment of slow speed zones to protect the West Indian manatee. Canaveral has supplied sighting data and engaged in several discussions with Florida Department of Environmental Protection (FDEP) on the proper placement of slow speed zones in the vicinity of the park. The park also assisted FDEP with a boating survey to determine boating use patterns and areas that warrant speed restrictions.

Additionally, the park has long been concerned about the impact of commercial harvesting on hard clams (*Mercenaria* spp.) and eastern oysters (*Crassostrea virginica*). As shellfish have been depleted along other portions of the Atlantic coast, harvesting pressure has increased significantly in Mosquito Lagoon. Currently, the park requires all fishermen commercially harvesting shellfish to submit monthly catch logs. The accuracy of these logs is questionable and compliance has been poor.

Canaveral faces a number of complex issues regarding water quality in Mosquito Lagoon. These include septic tank, agricultural and industrial effluents, mosquito control activities, dredging of the Intracoastal Waterway, impacts of aquaculture, and increased boating activity. While water quality in Mosquito Lagoon is quite good overall, septic tank effluent and stormwater runoff from adjacent communities are threatening to degrade the lagoon. Currently park waters are closed to shellfishing when rainfall exceeds 1.5 inches in a 72-hour period, due to high fecal coliform levels. Another of the delicate issues with which Canaveral NS must grapple is mosquito control. In the designation of lands for NPS management, both NASA and the State of Florida stipulated that Canaveral NS must cooperate with the local mosquito control districts to control salt marsh mosquitoes. Canaveral and East Volusia Mosquito Control District have

tested several measures, including Open Marsh Water Management (OMWM) techniques, to reduce the use of chemicals and to restore lost salt marsh.

Canaveral's most extensive resource management program involves sea turtle nest protection. The park documents 3,000 to 4,000 sea turtle nests each year. In the early 1980's, more than 95 percent were destroyed by raccoons. In 1984, the park began a nest screening program and has reduced depredation to 20-30 percent. In the last three years, depradation has been reduced to as low as 5.6, 6.6, and 4.7% respectively.

Canaveral NS is located in one of the most active lightning strike areas in the country. This, combined with the volatile fuels (particularly saw palmetto) and the extremely high fuel loads that have been allowed to accumulate, makes wildfire or human-ignited fire a serious threat. In addition, a number of vegetative communities and the animals that they support are dependent on periodic light to moderate fires.

Like a number of other parks in the southeast, Canaveral faces a serious threat from the invasion of exotic plants, including Brazilian pepper (*Schinus terebinthifolius*), Australian pine (*Casuarina equisetifolia*) and century plant (*Agave* sp.). Brazilian pepper has spread throughout virtually all of the disturbed areas of Canaveral. A small number of *Melaleuca quinquenervia*, a species that has severely impacted the Everglades, have been found in MINWR, less than 5 miles from the park boundary.

Exotic animals are also a threat to park resources. The feral hog (*Sus scrofa*) has become established in the southern half of Canaveral NS, particularly in the joint management area, and is seriously disrupting native vegetation. A voracious snake eater, it may also be affecting native snakes, including the protected eastern indigo snake (*Drymarchon corais couperi*). Another exotic animal that might be impacting the park is the feral cat (*Felis catus*). During a two-year survey to determine the distribution of the southeastern beach mouse within Canaveral NS, no mice were captured in the northernmost section of the park (Stiner 1991; Stiner 1992). In addition, a number of potentially harmful amphibian and reptile species are expanding their ranges into Florida from tropical areas throughout the world. The park is attempting to detect these invaders through the long-term herpetofaunal monitoring program established by Southeastern Louisiana University in 1992.

Water Resources of the Southeast Coast Network

Water Bodies. Eight percent (23/274) of water resources within or adjacent to SECN Parks are 303(d)-listed waters, with 39% (9/23) of those occurring at CHAT (Figure 1-2; See Appendix 8 for more details). 303(d)-designated waters (waters designated by States as failing to meet water quality standards as defined by Section 303(d) of the federal Clean Water Act) are considered to be relevant to park managers if (a) they pass through, enter or are contained within Park boundaries as EPA-designated 303(d) waters or (b) they are designated 303(d) waters within the same 12- or 14-digit HUC boundaries as each respective Park. Twelve-digit HUC coverages were available for AL (i.e., in draft form), FL and GA; 14-digit HUC coverages were available for NC and SC. All 303(d) designations are based on (2002) EPA and state listings of impaired waters and GIS coverages (http://www.epa.gov/waters/data/downloads.html).

Various GIS coverages (e.g., National Hydrography Dataset, EPA 303(d) listed waters and existing Park narratives were reviewed for all available information regarding documented SECN Park water bodies. Special designations of Park waters were also noted (Tables A8-1-A8-9). CHPI, FOCA and WRBR have no documented water resources within Park boundaries.

Water Quality. Despite the Federal Water Pollution Control Act of 1956, subsequent amendments in 1972, the Federal Water Pollution Control Act of 1972, the Clean Water Act of 1977 and the Safe Drinking Water Act of 1977, the chemical, biological and physical integrity of the nation's waters remains threatened (Hermann et al. 1998). Compromised water quality is largely the result of management of chemical, biological, and physical discharge/ waste from urbanization/ population growth, agricultural, and industrial activities. Adverse effects of impeded water quality on biota include altered floral- and faunal- species composition, reduced fecundity, low fitness, and bioaccumulation. The Southeastern U.S. is one of the fastest growing areas in the nation; consequently, marine and freshwater water quality throughout Southeast Region Parks has been impacted (White et al. 1998). Despite the abundance of 303(d)-listed waters in the Southeast Region, only eight percent of SECN water resources are 303(d) listed. However, most of the SECN parks are downstream from multiple 303(d) listed waters outside NPS jurisdiction (Figure 1-2).

Water quality data in most SECN Parks, and adjacent lands, have been collected by a variety of governmental and private entities. Existing data were compiled and summarized by the Inventory and Monitoring Program and Water Resources Division of the DOI National Park Service (NPS) and Horizon Systems Corporation (HSC) into documents referred to as the Horizon Reports (National Park Service 1994a, National Park Service 1994b, National Park Service 1994c, National Park Service 1994d, National Park Service 1994e, National Park Service 1994f, National Park Service 1997, National Park Service 1998a, National Park Service 1998b, National Park Service 2001a, National Park Service 2002a, National Park Service 2002b). Although the Horizon Reports provide a very thorough summary of baseline water quality data in SECN Parks, the data compiled and summarized for this endeavor included data only as recently as 1990 and 1992 for FOFR and CAHA, respectively, or 1998 for FOMA, FOPU, and FOSU (Table A8-10). As a result, recent trends in water quality are unknown.

Thoroughness of water quality data varies from park to park, however data are adequate to establish trends in waterbodies adjacent to parks, and infer status in parks if data within park boundaries are limited, if not the parks themselves. However, gaps in the datasets, in terms of evaluations of all significant water resources in each park, do exist (e.g., no water-quality sampling has occurred on two freshwater ponds at FOPU that account for 67% of freshwater resources at the park) and attempts to rectify these issues will be incorporated into future water-quality sampling designs. Because many agencies, organizations, and individuals have contributed to existing long-term water-quality data (in regard to data collection and laboratory analyses), estimates of data accuracy, precision, and subsequent reliability are currently unknown.

Results from the Horizon reports were qualitatively summarized in order to determine potential "red flags," or parameters that consistently exceed established water quality criteria, in SECN park water resources and assist in determining focal points (i.e., water-quality parameters) for future water-quality sampling design (Appendix 8, Table A8-11). Total coliform measurements

commonly exceeded EPA standards in SECN parks, although fecal coliform, several forms of which are naturally occurring, was not consistently differentiated from total coliform. Although no other "red flags" are evident in existing Network-wide data, chloride and copper levels exceeded EPA standards in several parks, which can cause gastrointestinal irritation and kidney and liver damage, respectively, in humans. Current EPA guidelines for select water quality parameters are also presented (Tables A8-12 through A8-14).

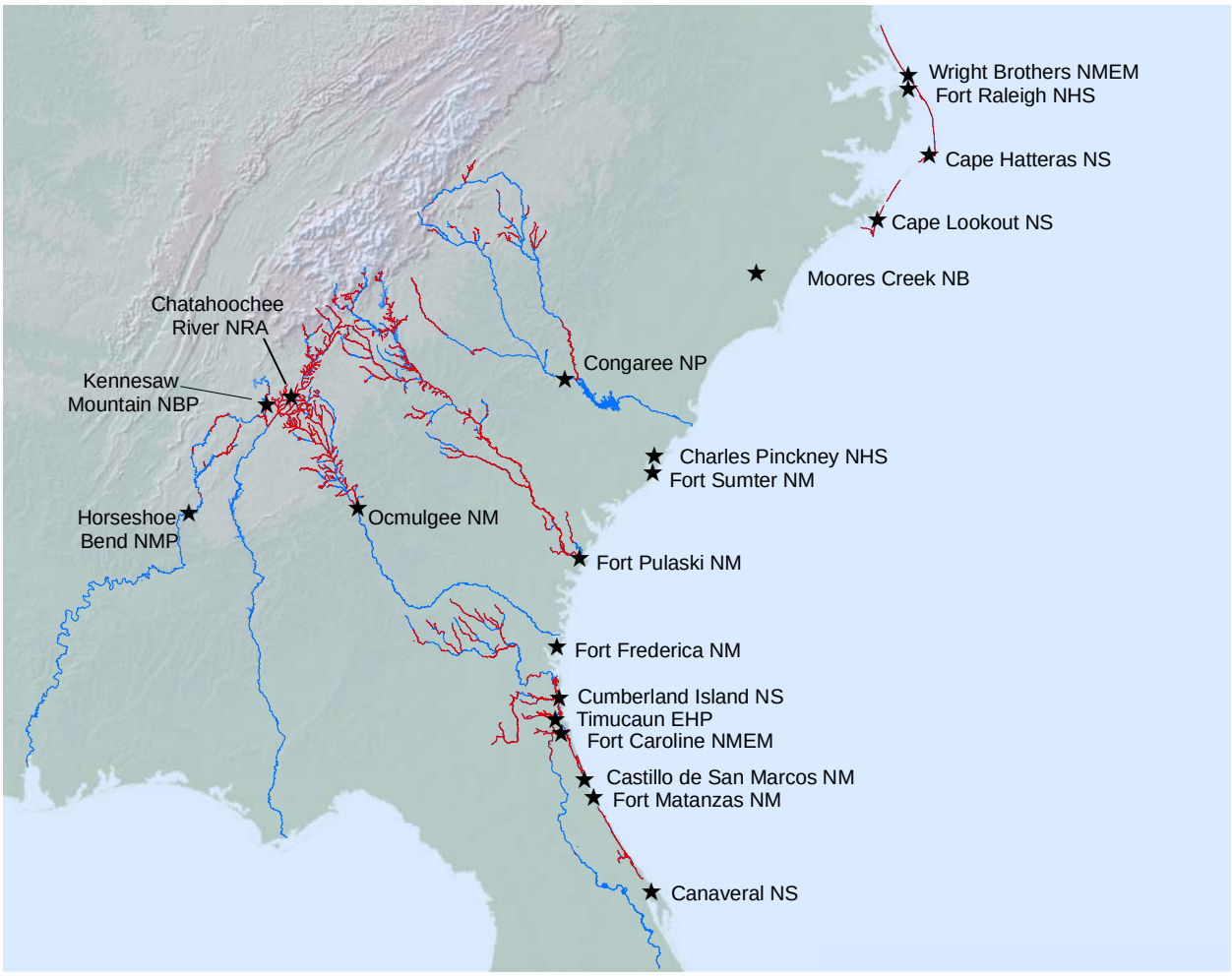


Figure 1-2. 303(d) water bodies (displayed in red) upstream or adjacent to SECN parks (2002 data). River systems within the region that do not pass through SECN Parks are not displayed.

Air Resources of the Southeast Coast Network

None of the Southeast Coast Network parks are within Class I airsheds. However, air quality is of concern at several parks within the network due to ozone exposure and atmospheric deposition of metals and nutrients (Table 1-4). Three parks within the network (CHAT, KEMO, and OCMU) are in areas where vegetation is at a high risk of damage due to ozone exposure (National Park Service 2004b). Four parks in the network (CHAT, CONG, KEMO, OCMU) are in counties designated nonattainment for the national ozone standard. Park water quality data were reviewed for fifteen Southeast Coast Network parks; surface waters at CONG and MOCR

are extremely sensitive to acidification from atmospheric deposition. Elevated concentrations of metals in surface waters indicate that atmospheric deposition of metals might be an issue for half of he Southeast Coast Network parks (T. Maniero, Air Resources Division, NPS, written communication, 2003).

Table 1-4.
Summary of air quality issues in Southeast Coast Network Parks ["↑", Increasing; "↓", Decreasing; "NT", No Trend; "Y", Yes; "N", No; "•", Frequently or consistently surpasses air quality thresholds; "○", surpasses or infrequently surpasses air quality thresholds; "-", either does not surpass air quality thresholds or no data are available; "L", Low; "M", Medium; "H", High]. From (National Park Service 2004a) and T. Maniero, written communication, 2003).

		KEMO	CHAT	HOBE	OCMU	CONG	MOCR	CAHA	CALO	FOSU / CHPI	FOPU	FOFR	CUIS	TIMU / FOCA	CASA / FOMA	CANA
Wet Deposition																
Ammonium	Deposition			NT	NT	↑	↑							NT	NT	↑
	Concentration			↑	NT	↑	↑							NT	NT	↑
Nitrate	Deposition			↑	NT		NT							NT	NT	↑
	Concentration			↑	NT		NT							NT	NT	↑
Sulfate	Deposition			↓	↑		↓							↓	↓	NT
	Concentration			↓	↑		↓							↓	↓	NT
Dry Deposition																
Nitrogen	Overall dry deposition			NT	↑		NT		NT							
	Percentage of total N that is dry			36	42		37		32							
Sulfur	Overall dry deposition			↓	↓		NT		NT							
	Percentage of total S that is dry			41	42		34		36							
Surface Water Chemistry																
Acidification	Concern for Park	N		N	N	Y	Y	N	N		N	N	N	N	N	N
Metals	Potential aerial deposition	Y		Y	Y	Y	Y				Y			Y		
Nutrients	Potential aerial deposition	N		N	N	N	N	N	N		N	N	N	N	N	N
Ozone																
Sum06	Frequency standard surpassed	•	•	•	•	○	•	•	•	○	○	○	○	○	•	○
W126	Frequency standard surpassed	•	•	•	•	○	○	○	○	-	-	-	-	-	-	-
Foliar Injury	Risk based on conditions	H	H	M	H	L	M	M	M	L	L	L	L	L	M/L	L

Analysis of SECN Natural Resource Issues

Monitoring program-related issues of highest importance to parks in the Southeast Coast Network fall into seven broad categories: exotic plant management & control, water quality, geology & geomorphology, water quantity, fire management, habitat management, and species management (Table 1-5). Detailed descriptions of park natural resource issues and relative monitoring priorities for each park can be found in Appendix 5 and Appendix 9.

Table 1-5.
Matrix of key natural resource issues and ecosystem types of concern within Southeast Coast Network Parks.

Natural Resource Issue	KEMO	CHAT	HOBE	OCMU	CONG	MOCR	CAHA	CALO	FOSU / CHPI	FOPU	FOFR	CUIS	TIMU / FOCA	CASA / FOMA	CANA
Exotic Plant Management & Control	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Water Quality															
Lagoonal															•
Coastal / Estuarine							•	•		•	•	•	•	•	•
Riverine	•	•	•	•	•	•									
Geology & Geomorphology															
Coastal Geomorphology							•	•	•			•	•	•	•
Stream Bank Erosion & Habitat	•	•	•	•	•	•									
Water Quantity															
Surface Water	•	•	•	•	•	•									
Groundwater	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Effects of hydrologic modification	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Fire Management	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
High Priority Ecosystems & Habitats															
Rivers	•	•	•	•	•	•									
Coastal Dunes							•	•				•		•	•
Wetlands	•	•	•	•	•	•	•	•		•	•	•	•	•	•
Intertidal Zones							•	•		•		•	•	•	•
Threatened and Endangered species & Species of Management Concern															
Feral Hogs				•								•	•		
Shorebirds							•	•				•	•	•	•
Marine Turtles							•	•				•	•	•	•
Feral Horses								•				•			

Exotic Plant Management and Control. Monitoring objectives related to exotic plant management were consistently of high priority across all parks within the Southeast Coast Network. Currently only parks within Florida are included in an operation exotic plant management program: CANA, TIMU, FOCA, CASA, and FOMA.

Water Quality. In general, objectives relating to water quality were high across all parks also, but the water bodies among the park vary substantially across the Network.

- *Estuarine / Lagoonal.* Nine parks within the network contain significant estuarine or marine waters: CAHA, CALO, FOSU, FOPU, FOFR, CUIS, TIMU, FOMA, and CANA. Mosquito Lagoon at CANA is another significant brackish water body. Water quality in these systems is almost entirely driven by upstream or up-shore factors outside National

Park Service boundaries or jurisdiction, and water quality monitoring is in general conducted by the various coastal states.

- *Coastal*. Six parks (CAHA, CALO, CUIS, TIMU, FOMA, and CANA) contain significant areas with access to marine / ocean waters. In all cases except CANA, NPS jurisdiction extends only to mean high tide; CANA's jurisdiction extends 0.5 mile east of the shore line. Threats to coastal water quality include non-point source chemical contaminants from up-shore as well as marine debris.

- *Riverine*. Six parks within the network contain or are bordered by significant river systems ranging from upland to coastal plain drainages: CHAT, KEMO, HOBE, OCMU, CONG, and MOCR. With the exception of the rivers contained within CONG, all other parks contain limited portions of the watersheds that the rivers drain. Adjacent land use and upstream development pressures are consistent threats to water quality among the river parks, but the types of land use and development pressures range widely from agriculture / animal husbandry operations, to extremely dense urban and suburban landscapes.

Geology and Geomorphology. Parks within the network are all in highly dynamic coastal or riverine ecosystems. Although changes in the landscape are a natural part of the evolution of the landscape, the degree to which observed processes can be considered "normal" are largely unknown. Coastal barrier islands and river systems are the two predominant systems with high rates of geomorphic change.

- *Coastal Geomorphology*. All coastal parks are experiencing geomorphic changes either through accretion or erosion. Though these processes are natural in barrier island ecosystems, the current rates and locations of accretional and erosional zones are likely outside natural norms. Non-natural factors that are suspected to influence erosion and deposition rates include dredging operations, jetty and pier construction / placement, and hardening of shorelines.

- *Stream Bank Erosion*. Stream bank erosion and stability is a major concern at CHAT, HOBE, KEMO, and OCMU where hydrologic modification resulting from upstream watershed development and hydropower facility management has resulted in altered riverine flow regimes.

Water Quantity. Water quantity issues in general are currently of concern, but will likely become larger during the next 10-20 years as water demands in the Southeast increase.

- *Surface Water*. River systems provide the majority of drinking water for the southeast. Major water supply reservoirs are located upstream of HOBE, CHAT, OCMU, and CONG, that serve the areas of Montgomery, AL, Atlanta, GA, Macon, GA, and Columbia, SC respectively. The amount of fresh water that reaches estuarine systems is likely one of the major drivers that influences estuarine and salt marsh ecosystem condition.

- *Groundwater*. The Floridan aquifer is the main water supply source for agricultural and industrial needs along the southeast coast. The degree to which withdrawals affect park

resources is not known, but as demand increases, the potential for impacts on park ecosystems could increase.

- *Effects of hydrologic modification.* In addition to the average amount of water available within parks, the timing and distribution of flooding events is also changing due to upstream or watershed land use activities. In general flooding frequency of major floods has decreased during the last twenty years, and hydropower "peaking" operations have introduced a flow regime in riverine ecosystems that is outside expectations in natural systems. Multiple other water diversion structures occur in or near parks for agricultural, pest control, or transportation purposes.

Fire Management (effects, risks, and planning). Twelve of the network parks currently have or are in the process of developing fire management programs. The activities that will be conducted at each park will vary widely from suppression to routine prescribed burning. In all cases, climatic data relating to fire risk will be useful for fire management planning and risk assessment. Programs implementing prescribed burning would benefit from fire effects monitoring.

High Priority Habitats. The Southeast Coast Network contains multiple habitat types. The following four habitats had the most commonality among Network parks, and (in part) are the basis for the network's conceptual ecosystem models presented in Chapter 2.

- *Rivers*. In addition to the six parks that contain large rivers, CAHA and CUIS contain smaller freshwater systems.

- *Coastal Dunes*. Coastal dunes are major habitat features at CAHA, CALO, CUIS, and CANA. Future land acquisitions at TIMU might result in the addition of dune habitats there as well. Coastal dunes are particularly important due to the fact that (a) they support a wide variety of sensitive or protected species, (b) they are fragile, (c) they are particularly threatened by visitor uses, and (d) they play a significant role in the overall stability of the island.

- *Wetlands*. Wetlands within SECN parks vary widely from intermittent interdunal pools to riparian floodplains to vast salt marshes. These systems are particularly sensitive to changes in water quantity.

- *Intertidal zones*. Intertidal zones, provide critical foraging and nesting habitats for many sensitive and protected species such as shorebirds and sea turtles. These areas are threatened by visitor uses, and predation from both native and non-native species.

Threatened, Endangered, and other Species of Management Concern. More than twenty species were identified for potential monitoring across the Network, though with very few exceptions, though the need for network-wide monitoring was small due limited species' ranges. In nearly all cases, floral and faunal differences among parks were large enough that few species' ranges span more than three parks. Exceptions include shorebirds, marine turtles, and multiple exotic plant and animal species. The following include species whose distribution occurs across six or more parks *or* whose impacts are large:

- *Feral hogs*. Eight parks in the network have current, historic, or potential infestations of feral hogs: CAHA, CANA, CASA, CONG, CUIS, FOFR, OCMU, TIMU. Active eradication programs are occurring at OCMU, and CUIS.

- *Shorebirds*. Plovers, oyster catchers, least terns, and wood storks are of large concern at all coastal beach parks. Active monitoring at various intensitieoccurs at CANA, CUIS, CAHA, CASA, and CALO, although these efforts are not currently coordinated among the parks.

- *Marine turtles*. Marine turtles are monitored and protected at seven Network parks (CAHA, CALO, CANA, CASA, CUIS, FOPU, and FOSU). These monitoring programs are currently coordinated with other state and federal agencies though not with one another. In addition to turtle monitoring, other related monitoring needs include predator, beach habitat, and light pollution monitoring.

- *Feral horses*. Feral horses are present at CUIS, CALO, and CAHA. In addition to the need to monitor aspects of horse populations (i.e., demography, disease incidence rates), the effects of the horses on other park resources.

Summary of Existing Monitoring Programs

At least 140 historical or ongoing monitoring programs are being conducted by various agencies within the Network (Table 1-6; Appendix 3). Only 34 of those are being conducted by the NPS. However, more than 100 historical and on-going monitoring programs are being conducted in or adjacent to Network parks by other State, Federal, or County agencies or one of many NGOs. The majority of NPS programs have centered on threatened and endangered species monitoring, primarily with reptiles and birds. Non-NPS monitoring programs span a wide variety of categories, but nearly a quarter of those programs deal with water resources monitoring. Although the breadth of resources being monitored throughout the region is large, most of these efforts are *not* conducted within SECN parks. However, data being collected by other programs are close enough in proximity to SECN parks to still be relevant (such as air quality, stream flow, and weather data).

As a general rule, the SECN has attempted to adopt or model its Vital Signs monitoring protocols after those in use by other agencies within the region to improve the Network's ability to leverage its efforts. Specific programs with which the SECN is coordinating are discussed in Chapter 5 and Appendix 13 (sampling protocols).

Table 1-6.
Existing and historical monitoring programs relevant to Southeast Coast Network parks. For a detailed description of programs, objectives, and the types of monitoring data being collected, see Appendix 3.

Category	NPS programs	Non-NPS programs	Total
Water Resources	1	24	25
Air Resources	3	5	8
Climate & Weather	0	5	5
Ecosystem Processes	1	2	3
Pest Species	0	3	3
Exotics – Invertebrates	1	3	4
Exotics – Vertebrates	1	1	2
Exotics – Plants	1	4	5
Forestry	0	4	4
Geology	1	5	6
Marine / Estuarine Systems	1	12	13
Recreational Use	0	2	2
Threatened & Endangered Species	0[1]	10	10
Vegetation	5	7	12
Vertebrate Disease	0	3	3
Waste Management	0	1	1
Wetlands	0	1	1
Wildlife – Birds	8	8	16
Wildlife – Fish	0	3	3
Wildlife – Mammals	4	1	5
Wildlife – Reptiles & Amphibians	7	2	9
Total	**34**	**106**	**140**

[1]Several NPS T&E species monitoring programs are included in the “wildlife” categories below

Chapter 2. Conceptual Ecological Models

Introduction & Approach

Lessons learned from the development of monitoring programs in other programs or agencies have demonstrated that every monitoring effort is based on some underlying understanding of how the ecosystem in question works. This underlying understanding forms a mental model, often not written for others to read and discuss. To ensure a successful monitoring effort, these underlying models need to be explicit and available for discussion, evaluation, and refinement (Maddox et al. 1999).

Models are purposeful representations of reality (Starfield et al. 1994). Conceptual models provide a mental picture of how something works, with the purpose of communicating that explanation to others. Models (of all types) work best when they include only the minimum amount of information needed to meet the model's purpose (Starfield 1997).

Conceptual models play several useful roles in monitoring program design, including:

- Formalizing current understanding of the context and scope of the ecological processes important in the area of interest.
- Expanding our consideration across traditional discipline boundaries, fostering integration of biotic and abiotic information.
- Facilitating communication among scientists from different disciplines, between scientists and managers, and between managers and the public.

The key point about conceptual models is their role in communication among people with different points of view (Abel et al. 1998). Conceptual models can take a variety of forms—from narrative descriptions to schematic diagrams or flowcharts with boxes and arrows. Regardless of form, the success of a model depends on its ability to share viewpoints and develop a common understanding based on multiple viewpoints.

Within the National Park Service Inventory & Monitoring program, the development of conceptual models has the specific purpose of guiding the process of identifying those *Vital Signs* that will be selected for long-term monitoring. With this purpose, a critical role of the conceptual models discussed below is to identify (a) key resources and functions, (b) natural and anthropogenic agents of change, and (c) expected ecosystem responses within Southeast Coast Network ecosystems. With the drivers of change identified, the types of ecological changes most important for park managers to detect can be evaluated.

Conceptual ecosystem models for the Southeast Coast Network are presented in two sections, with increasing levels of detail. In the first section, general models of SECN ecosystems are presented that provide the framework for more-detailed system-specific conceptual models. In the second section, a set of detailed conceptual models is introduced to describe relationships among system drivers, agents of change (both natural and anthropogenic), and park resources. Appendix 7 includes further details on key components of each of the ecosystems presented here.

The Southeast Coast Network General Ecosystem Model

The Network's general model (see Figure 2-1) focuses on four broad categories of natural System Drivers, five broad categories of Agents of Change, and the resources and management that occurs within SECN parks. System Drivers are major external forces that have large-scale influences on natural systems. System Drivers can be either natural or anthropogenic and include things such as climate, tidal processes, freshwater inputs, and current & historical land use that make up the mosaic of conditions in which SECN parks exist. Local Drivers include those processes or disturbances inside or adjacent to SECN park units that potentially alter the condition of resources within park boundaries. Within each Park's management sphere of influence are both the trust resources, and the management actions undertaken to manage those resources. Descriptions of model components that appear in all ecosystems follow below.

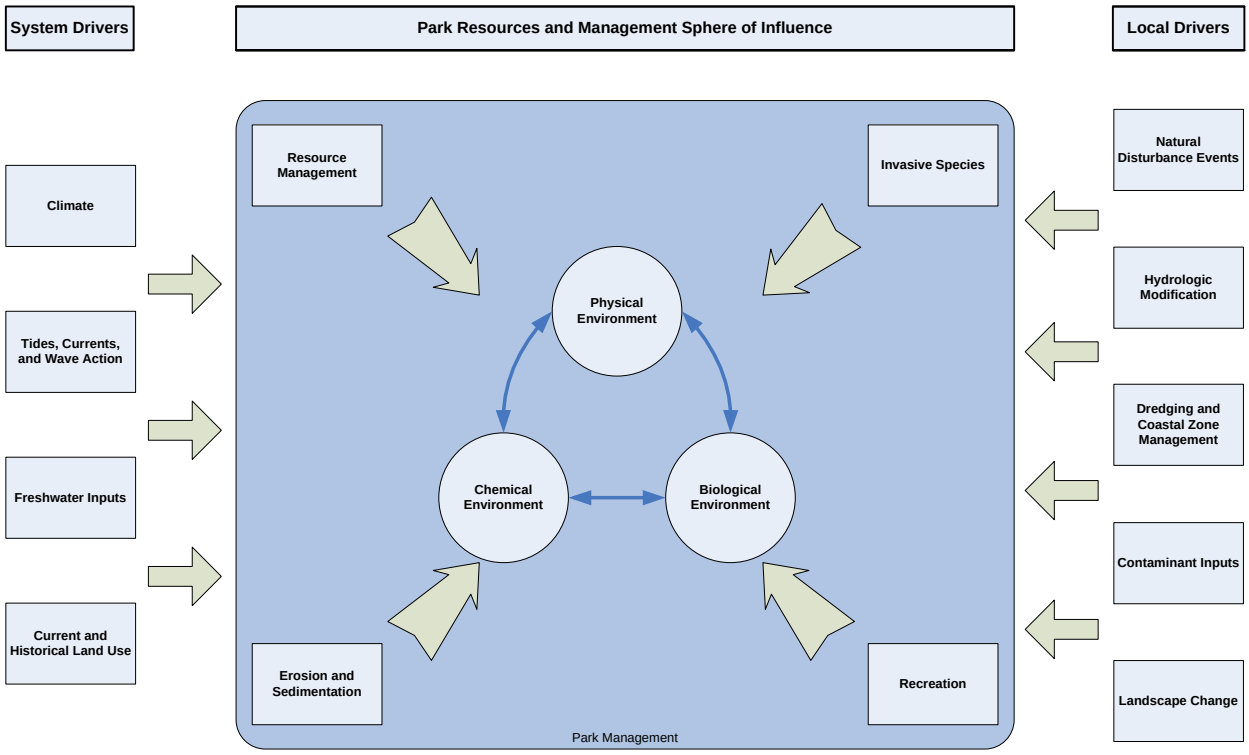


Figure 2-1. General Ecosystem Model of the Southeast Coast Network. Rectangles indicate predominant agents of change; circles represent major components of the ecosystem (detailed in supporting text). Large green arrows link agents of change to the entire ecosystem, including biotic, chemical, and physical components. The dark blue area includes those agents of change or resources that are currently / actively managed by NPS.

System Drivers

Climate. Southeastern climates are humid and warm-temperate to subtropical. Major variation in climate occurs with change in latitude and elevation. Longitude has a more subtle influence on climate than latitude, as a result of maritime influence to the south and east and continental influences to the north and west.

Latitudinal gradients in temperature are steeper in winter than in summer, producing a strong geographic pattern in freeze-free periods and cold temperatures. The gradient in average

minimum January temperature spans 22°C, whereas the gradient in average maximum July temperature spans only 4°C (Ruffner 1985, Martin and Boyce 1993). The freeze-free period decreases northward, from 365 days in the Florida Keys, which experienced freezing temperatures in fewer than half of the years on record, to 180 days in Arkansas and 150 days in northern Virginia. The freeze-free period also decreases with elevation, to 110 days at the highest elevations in the southern Appalachians. Canadian air masses bring the coldest winter temperatures, penetrating the Southeast from the continental interior and generally producing decreasing minimum temperatures westward at a given latitude. Annual snowfall shows the same steep gradients as cold winter temperatures, increasing from zero in south Florida to over 100 centimeters northward and to over 200 centimeters in the high mountains.

Precipitation occurs throughout the year but is generally lowest in fall and highest in summer, when convective thunderstorms develop. Thunderstorms in Florida occur an average of 80-130 days annually; the number of thunderstorms decreases northward, occurring an average of 40-60 days a year in Kentucky, Virginia, and interior regions.

Tides, Currents, and Wave Action. Several fundamental processes drive processes in coastal ecosystems, including the hydrographic conditions, sediment supply, and a suite of natural disturbance factors operating at local, regional, and global scales. Hydrographic conditions encompass a combination of physical and hydrologic features, such as the near shore system of bars, ridges, and shoals, and the continuous movement of water in the form of currents, waves, and tides. Collectively, these features and forces direct and control the movement of sediment and water through the near shore system.

Ultimately, the presence of Beach/Dune habitat depends upon the availability of appropriately sized sediments within near shore coastal environments. Finite in supply, especially along the mid-Atlantic coast, sediment availability serves as a limiting factor in the landform's response to the forces of wind and waves. Sediment supply is susceptible to human disturbance and interruptions. When subject to prolonged changes in sediment supply, landforms may disrupt the physical environment and associated biota.

Freshwater Inputs. Nearly all SECN parks border on or are at the end of major river systems in the Southeast. These systems not only drive the ecosystems within parks, but serve as the primary drinking water supply for the human population of the Southeast. The amount of water entering streams is therefore a factor of both extraction for human use and inputs from precipitation.

From 1950 to 1990, both the population and domestic water use in the United States increased steadily. Withdrawals of fresh and salt waters increased to a peak of 1.7 billion cubic meters per day in 1980, and by 1990 daily freshwater withdrawals were 1.5 billion cubic meters. Rural use of water for households and livestock increased from 1960 to 1990. Irrigation increased from 1950 to 1980, to a maximum of 570 million cubic meters per day, while per capita water use in the United States decreased from 6.8 million cubic meters per day in 1970 to 5.9 million cubic meters per day in 1990. Commercial and industrial uses of water, including self-supplied industrial use and withdrawals of water for mining, increased to a plateau in 1975-1980 before declining by 14%. The estimated use of fresh groundwater—fresh water drawn from below the ground—was 130 million cubic meters per day in 1950. Use of groundwater increased to 310

million cubic meters per day by 1975, decreased during the 1980's to 280 million cubic meters per day, and then increased again to 300 million cubic meters per day in 1990. The use of fresh surface water peaked in 1980 at 1.1 billion cubic meters per day and declined to 980 million cubic meters per day by 1990. Consumptive use—water that is withdrawn from a water source and does not eventually return to the water source—of fresh water followed the same patterns as withdrawals. The reduction of withdrawals during 1980-1985 reflected conservation but could also relate to climate or the economic slowdown (Solley and Pierce 1988, van der Leeden et al. van der Leeden et al. 1990, Solley et al. 1993).

Fresh water is now a limited ecological (physical and biological) and economical resource. The trend in the present use of water reflects its limited availability. Krusé (1969) estimated that by 1965, withdrawals of 1.3 billion cubic meters per day were exceeding the available dependable water supply by 13%. The deficit reflected the need for reusing water, the increased use of salt water, and the lack of new water development opportunities.

Current and Historical Land Use. Destructive logging and soil erosion in the Southeast were major stimuli to the conservation movement in the early twentieth century; this movement led to the creation of national forests, national parks, state parks, research stations, and other protected areas. In contrast to the western United States, the Southeast had little public land--less than 10%--and these areas had to be created by purchase of private lands. Today, public land is mostly in the mountains, with less public land in the Piedmont and Coastal Plain (Boyce and Martin 1993).

Data from 1987 show that although 55% of the land was forested then, the trend was downward, with a decline of 5% since 1960 (U.S. Forest Service 1988a, Martin and Boyce 1993). The rest of the land was used for crop and pasture (31%) and miscellaneous purposes (roads, towns, cities, airports; 14%). Urban areas are growing at the fastest rate, but the rate of growth varies by region. For example, in North Carolina, urbanization occurred three times faster in the Piedmont than in either the mountains or Coastal Plain (see review in Boyce and Martin 1993). Although the high total of forested land indicates potential for the survival of biological diversity, these forests are largely privately owned; less than 10% of the forested land is in federal ownership (U.S. Forest Service 1988b) and the remainder are not managed for biological diversity per se. Further, because these lands have almost all been disturbed by logging and agriculture, they have already lost communities and species.

Forestland has been predicted to decline by 15% over the next 50 years (with additional forestland converted from natural to plantation forests), agricultural land to decline slightly (with a continued shift from small to large farming operations), and urban areas to increase in area (see discussion in Boyce and Martin 1993), suggesting that further habitat loss and fragmentation will occur near human population centers. We know too little about the survival of biological diversity in human-dominated landscapes, but we do know that the biodiversity of these areas will generally decrease with habitat fragmentation (Harris 1984). Some human-dominated landscapes, however, have the potential to support the diversity of some groups. For example, some crop systems support bird diversity (Allen 1995) by cultivating marginal lands, including some wetlands.

Local Drivers

Natural Disturbance Events. Natural Disturbance events include localized, though potentially large, effects on communities through processes including storms, fire, insect outbreaks, and desease. The Southeast's frequent thunderstorms provide an ignition source for natural fires. In the past, Native Americans and European settlers also burned natural vegetation regularly. Regardless of ignition source, fire frequency and intensity have been dominant forces throughout the Southeast on all but the wettest and coldest (high mountain) sites. The mid- to late 1900's represent a period of reduced fire frequency, size, and intensity, a shift that is a major source of change in the region's ecosystems, leading to increases in mesic species (that is, species adapted to moister conditions), increased understory stem density, increased woody cover in formerly open habitats, and decreases in fire-dependent species and ecosystems.

Tropical storms are also a major recurrent disturbance, with much of the area experiencing about two damaging storms per decade. Between 1871 and 1981, 138 tropical storms affected south Florida (Davis and Ogden 1994). Although storm incidence declines from coastlines to the interior, tornadoes are more frequent in interior areas, where nearly 10 violent tornadoes per year have occurred over the last 100 years (Grazulis 1984, Martin and Boyce 1993).

The heavy rainfall that accompanies these and less violent storms is an important natural disturbance, especially in the Appalachian Mountains, where debris avalanches create open habitats in the forested matrix and flash floods scour stream banks and affect stream biota. Throughout the Southeast, the natural flooding and erosional dynamics of rivers were and are an important natural process for biological diversity; impoundments, changes in the quality and quantity of water, draining of bottomlands, and channelization of rivers are major causes of loss in the biological diversity dependent on dynamic stream and river systems.

The dynamics of flooding and meandering rivers are a major natural process in southeastern ecosystems. Many plant and animal species are dependent on the natural dynamics of water flow. The overall tendency is for human influence to make a dynamic environmental factor less variable. Succession favors the species best adapted to the more uniform conditions, and diversity decreases. In natural systems, however, extreme hydrological events are an important agent in the maintenance of species diversity.

Fire was and is important to many southeastern ecosystems, including many Coastal Plain and south Florida ecosystems, pine-dominated forests of the Coastal Plain and Appalachian Highlands, oak and oak-hickory forests, oak savannas, glades, barrens, and prairies. Because most natural communities in the Southeast are dependent on fire, more than 50% of the rarest plants in the region also possess this dependence. Fire may also explain the occurrence of canebrakes, dense stands of the Southeast's only native bamboo, which were frequently described by earlier travelers but which have vanished from the landscape except for small remnant patches (Noss et al. 1995). Although natural fires were quite important, Native Americans and European settlers also set fires frequently. When fire suppression became effective in the 1940's, dramatic changes in ecosystem composition and structure began.

Outbreaks of the native southern pine beetle can not only hasten the succession from pine to hardwoods but can also result in high fuel loads. On dry topographic sites and in drought years,

high-intensity fires can occur because of these fuel loads. Such hot summer fires are critical to pine regeneration.

Disease has long been recognized as one of the potentially limiting factors on wildlife populations. Now, the rapid spread of established diseases; the emergence of new diseases in humans, domestic animals, and wildlife; and the threats of bioterrorist attacks have attracted considerable public attention, as well as generated a call for action. In addition, convincing evidence has been presented advocating the usefulness of wildlife as sentinels for public and domestic animal health threats. Emerging zoonotic diseases (transmissible between animals and humans) have been identified as significant public health threats.

Hydrologic Modification. Alteration to the hydrological regime is a common disturbance in a variety of southeastern ecosystems: bottomland and floodplain forests, mountain bogs, rocky stream gorges, longleaf pine savanna, Carolina bays, pocosins, Atlantic white-cedar swamps, barrier-island communities, mangrove forests, rivers, streams, caves, lakes, and the Everglades mosaic of communities. Hydrological change has altered flood depth, duration, frequency, and seasonal timing in many of these systems, leading to a raising and lowering of the water table in specific cases.

Hydrological change is caused by sedimentation, construction of dams and other barriers, and channelization (Adams and Hackney 1992). Portions of almost all major southeastern rivers have been impounded during the last 75 years. For example, a 1974 stream survey in Maryland showed that all 14 drainages in 17 tidewater counties had dams (258) or other blockages (89; Lee et al. 1984). Other barriers include farm or mill pond dams, weirs, and raised culverts. Dams result in changes to water temperature and unpredictable releases of water. Channelization, which includes straightening the streambed, smoothing bottom contours, and removing logs, obstructions, and plants, alters the rate and timing of water flow (the local water table is lowered, resulting in increased flooding downstream), aquatic productivity, microhabitats within the channel, and food webs. Sedimentation, blockages, and channelization often occur within one river system, leading to decreases in native fishes and other aquatic species, a loss of species intolerant of such changes, and increases in tolerant species and nonindigenous species (Crumby et al. 1990).

Dredging and Coastal Zone Management. In coastal systems, anthropogenic activities also have the potential to substantively alter sedimentation and erosion processes. Most significant are shoreline stabilization activities (e.g. groins; jetties; bulkheads), beach “nourishment” (to artificially increase local sediment supply), and dredging activities. Each of these practices has the potential to alter existing hydrographic conditions and sediment supply, and influence natural patterns of erosion/deposition, overwash, inlet formation, and migration.

Contaminant Inputs. Pollution is impairing visibility in some of the nation’s parks and other protected areas. In 1999, average visibility for the worst days in the East was approximately 15 miles. In the West, average visibility for the worst days was approximately 50 miles in 1999 (U.S. Environmental Protection Agency 2002a). Particulate matter is the major contributor to reduced visibility, which can obscure natural vistas. Without the effects of pollution, the natural visibility in the U.S. is approximately 47 to 93 miles in the East and 124 to 186 miles in the West. The higher relative humidity levels in the East result in lower natural visibility.

Two of the key pollutants that contribute to the formation of particulate matter—SO_2 and NO_x—react in the atmosphere with water, oxygen, and oxidants to form acid droplets. Rain, snow, fog, and other forms of precipitation containing the mixture of sulfuric and nitric acids fall to the earth as acid rain (wet deposition). The particles also may be deposited without precipitation, known as “dry deposition.” Wet sulfate deposition has decreased substantially—20 to 30 percent—throughout the Midwest and Northeast, where acid rain has had its greatest impact, between the periods 1989-1991 and 1999-2001. During the same period, wet nitrogen deposition decreased slightly in some areas of the eastern U.S. but increased in other areas, including those with significant agricultural activity (U.S. Environmental Protection Agency 2002b).

In addition to the six criteria pollutants, the Clean Air Act identifies 188 toxic air pollutants to be regulated. Among those pollutants are benzene, found in gasoline; perchloroethylene, emitted from some dry cleaning facilities; and methylene chloride, used as a solvent by a number of industries. Often referred to as “air toxics,” these are pollutants that may cause cancer or other serious health effects—reproductive effects or birth defects, for example—and may also cause adverse ecological effects.

In recent years, the Clean Water Act has done much to reduce point sources of pollution by requiring water treatment. Nonpoint-source pollution and sedimentation are harder to control, though. Sedimentation is a serious problem for most aquatic organisms, particularly primary producers as well as benthic (bottom-dwelling) macroinvertebrates and fishes that require gravel or rock substrates. Medium-sized rivers are particularly vulnerable to alteration of substrate composition and texture (Etnier and Starnes 1991).

Other factors responsible for depletion of aquatic faunas are pollution (including chemical and thermal pollution) and introduction of non-indigenous fishes and aquatic plants. Invasive non-indigenous plants that are capable of altering function (for example, hydrology, amount of photosynthesis, and food webs) in aquatic systems in the Southeast include parrot feather watermilfoil (*Myriophyllum aquaticum*), Eurasian watermilfoil (*M. spicatum*), waterthyme (*Hydrilla verticulata*), curlyleaf pondweed (*Potamogeton crispus*), water hyacinth (*Eichhornia crassipes*), and water chestnut (*Trapa natans*) (Hotchkiss 1967, Lachner et al. 1970).

Landscape Change. The Southeast has one of the country's most rapidly growing human populations. Population growth was 20% from 1970 to 1980, 13.4% from 1980 to 1990, and an estimated 10%-19% for the 1990's (U.S. Bureau of the Census 1994). The continued growth of the human population and changes in the way humans interact with the natural landscape present a challenge to conservationists concerned with the survival of diversity in this biologically rich region. Most SECN parks located in or adjacent to major cities (such as Atlanta, GA, Columbia, SC, Jacksonville, FL) or areas undergoing rapid coastal development (such as Saint Mary’s, GA and the Outer Banks, NC).

As the coastal population grows and barriers become urbanized, valuable habitats are being destroyed, and associated negative impacts such as waste disposal, pollution, and changes in freshwater and fine-grained sediment dispersal are altering entire coastal marine and maritime ecosystems (Williams and Johnston 1995). Protecting all remaining undeveloped coastal barriers should be a national priority. Some protection occurs through the Coastal Barrier Resources

System, as well as other local, state, and federal programs, including acquisition, restoration, protection, and management programs.

Park Management Sphere of Influence

Invasive Species. Invasion by nonindigenous species is one of the most important issues in natural resource management and conservation biology today. The ability of nonindigenous species to alter population, community, and ecosystem structure and function is well documented (Elton 1958, Mooney and Drake 1986, Vitousek et al. 1987, Drake et al. Drake et al. 1989). Ecosystem-level changes that alter water, nutrient, and energy cycles; productivity; and biomass directly affect human society. Ecosystem-level consequences of invasive nonindigenous species have major ecological and economic implications and directly affect human health. Complex technology has addressed the cleanup of chemical pollutants and contaminants and has reversed some of the damage from physical alteration of the environment. However, little attention has been paid—and almost no progress has been made—in addressing the problem of nonindigenous species. In the SECN, invasive species of concern include feral hogs, feral cats, and many invasive plant speices.

Erosion & Sedimentation. Within parks, erosion and sedimentation affect natural habitats and cultural resources. Erosion within parks is caused by natural processes (cutbanks in rivers or storm overwashes on barrier islands) and by anthropogenic means (social trail creation for river access). Control or rehabilitation of erosion points within parks is often driven by the need to protect cultural resources, regardless of whether the rates of erosion are at or above historical norms.

Nonpoint-source sedimentation is hard to control, though it can be a serious problem for most aquatic organisms, particularly primary producers as well as benthic (bottom-dwelling) macroinvertebrates and fishes that require gravel or rock substrates. Medium-sized rivers are particularly vulnerable to alteration of substrate composition and texture (Etnier and Starnes 1991).

Recreation & Visitor Use. Visitor uses of natural resources, though appropriate within the Natural Park System, can cause a number of direct and indirect changes within the ecosystem. Use of natural areas has increased steadily since 1965 (Cole 1996) and will likely continue as protected lands become increasingly rare in the rapidly developing landscape within the Southeast. Most visitor use impacts are assumed to increase as visitation rates increase.

Of great concern within the SECN are the effects of off-road and recreational vehicles. Several parks allow access vehicular access (such as Cape Hatteras NS), and are potentially affected by increased mortality of sensitive species (sea turtles, ground-nesting shore birds). Also, vehicles can potentially cause changes in vegetation stability, and increased soil erodibility (Grantham et al. 2001). These impacts are potentially of highest concern in areas with loosely-consolidated soils such as coastal dunes. Additional visitor use impacts include degraded air quality (associated with vehicle and off-road vehicle use), litter, trampling, poaching, species introductions, and social trail creation. Also, visitor use impacts can cause changes in animal ranges, particularly large mammals through avoidance behaviors (Papouchis et al. 2001). Human-animal interactions might be of high importance in wilderness areas during breeding

times. Also, trails have been shown to be a vector for dispersion of exotic plant species (Patel and Rapport 2000).

Park Resources

Park resources within the Southeast Coast Network are very diverse and highly variable from park to park and ecosystem to ecosystem. For the purposes of these models, we have split these out into Physical, Chemical, and Biological components, but realize that these categories are not mutually exclusive. Details on the resources of interest in each of the six primary SECN ecosystems are included in the system-specific models that follow.

System-Specific Models within the Southeast Coast Network

Six dominant ecosystem types have been identified in the Southeast Coast Network: upland forests, riparian / bottomland hardwood forests, rivers & streams, salt marshes & coastal wetlands, barrier islands, and estuaries / nearshore marine systems (Figure 2-2). Each park in the SECN contains at least two of the described ecosystems (Table 2-1).

Each ecosystem below includes one or more "layers" of models to explain the key resources, stressors, and responses:

1. Ecosystem-specific generalized models that include the primary biotic and abiotic resources, and the relationships of those resources to one another,

2. Expanded models that include processes (natural and anthropogenic) that drive successional shifts among dominant community types, and

3. Environmental gradients known or suspected to explain trends among the parks within the network (or the region).

Each system is also discussed in both a regional and a network or park-specific context. For further explanatory information on components of each model, a literature review on the local drivers, system drivers, and park resources included within the models are contained Appendix 7.

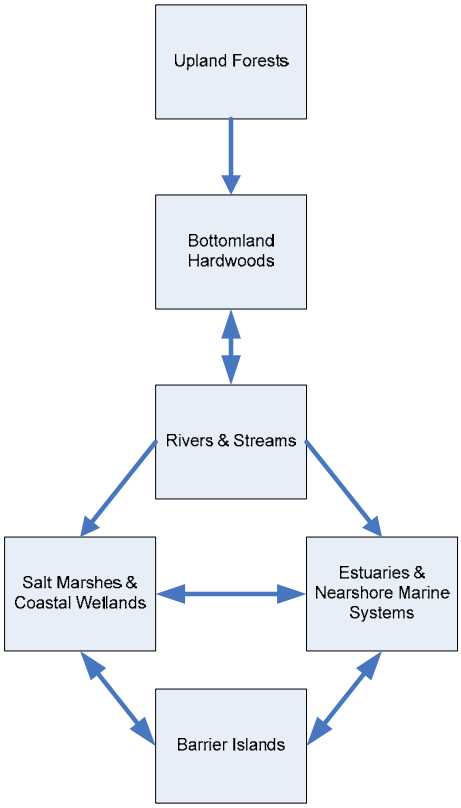


Figure 2-2. The six primary ecosystems within Southeast Coast Network Parks. Arrows indicate how processes and resources in each ecosystem relate to other ecosystems within the Network (i.e., processes or changes within rivers and streams can potentially drive processes or changes within salt marshes or estuarine systems).

Table 2-1.
Ecosystems present in each of the SECN parks.

	Upland Forests	Bottomland Hardwoods	Rivers and Streams	Salt Marshes and Coastal Wetlands	Estuaries and Nearshore Marine	Barrier Islands
KEMO	X	X	X			
CHAT	X	X	X			
HOBE	X	X	X			
OCMU	X	X	X			
CONG	X	X	X			
MOCR	X	X	X			
CAHA	X			X		X
CALO	X			X		X
FOSU	X				X	
FOPU	X			X	X	
FOFR	X			X		
CUIS	X			X	X	X
TIMU/FOCA	X			X	X	
CASA/FOMA	X			X	X	X
CANA	X			X	X	X

Upland Forests

The pinelands of the Coastal Plain once extended from the James River in southeastern Virginia to the Trinity River in eastern Texas and covered 24 to 35 million hectares (Frost et al. 1986, Stout and Marion 1993). Longleaf pine savanna was the most common community—the trees, which were thinly distributed, flat-topped, and had limbless lower trunks, occurred in a sea of grasses and diverse wildflowers and carnivorous plants. The historical distribution of pineland communities was determined by moisture supply and fire (Frost et al. 1986). Pines were dominant in habitats ranging from pine flatwoods and mesic savannas to the longleaf pine-turkey oak association in the dry Carolina Sandhills. Longleaf pine was the leading species, with slash pine increasing southward. Both species are now outnumbered by loblolly pine because of fire suppression, conversion to farmland, and commercial timber production (Ware et al. 1993).

The most widespread of the pineland communities, the longleaf pine savanna, occurred widely on the moisture gradient from wet areas and mesic savannas to the dry sandhills and turkey oak associations. The vast, parklike longleaf pine savanna had an herbaceous layer dominated by wiregrass in the southeastern states and by bluestems in Louisiana and eastern Texas. At small scales (1-100 square meters), this herb layer is one of the most diverse in the world; 40 to 75 species of vascular plants have been reported for a single 1-square-meter quadrat and 130 for a 0.1-hectare plot (Clewell 1989). Today, only 14% of the expansive longleaf pine forest remains, with just 3% surviving as old-growth habitat, a loss comparable with or exceeding that of many of the other unique communities in North America (Noss 1989). The dry longleaf pine-turkey oak stands of the sandhills are the most poorly protected areas of this endangered ecosystem (Stout and Marion 1993).

Species that inhabit longleaf pinelands exhibit a high incidence of rarity and endemism. The longleaf pine-wire-grass community includes 191 species of rare plants. Pine communities on the Atlantic Coastal Plain are more diverse and contain a greater number of rare plants. The southeastern pineland community harbors large numbers of federally listed species: 18 plants, 4 reptiles, 4 birds, and 1 mammal, as well as 100 candidates for federal listing (Noss et al. 1995). In addition, the pinelands serve as a major corridor for a large number of migratory birds that winter in the West Indies and South America (Stout and Marion 1993), and they support 170 species of reptiles and amphibians (Dodd, Jr. 1995b). High percentages of these reptile and amphibian species are imperiled (endangered, threatened, or declining): 22% of the salamanders, 15% of the frogs, 34% of the turtles, 31% of the lizards, and 19% of the snakes fall in this category (Dodd, Jr. 1995a).

Lightning fires, occurring at about 1- to 3-year intervals throughout the area, were carried over large areas by wire-grass and pine duff and were stopped only by excessive moisture or abrupt changes in topography. Historically, 10%-30% of the southeastern pinelands burned each year (Ferry et al. 1995); these frequent fires reduced litter accumulation and invasion by competing woody species. Pine seedlings and many of the grasses and forbs present in longleaf pine communities are shade-intolerant, and many require bare mineral soil and reduced competition for germination and early growth. Longleaf pine has several adaptations to minimize fire injury and a large annual needle cast that provides good fuel for future fires (Stout and Marion 1993). The reduction of litter accumulation is essential for the survival of small, rare herbaceous species such as the unique Venus flytrap.

By the time European explorers and settlers arrived in this region, Native Americans had already been augmenting the natural lightning-caused fire regime with annual burning. Set in fall and winter, these fires were used to drive game and improve browse. Early settlers also used fire in winter to improve forage for their livestock, which roamed freely in the forested land.

The longleaf pine forest remained largely intact until the mid-seventeenth century, when the Naval stores industry (that is, products such as turpentine or pitch, originally used to caulk the seams of wooden ships) started to develop in Virginia and then reached its full development in North Carolina in the mid-eighteenth century. Demand then turned to timberland, and despite warnings from late nineteenth-century foresters concerned with regeneration, much of the old-growth forest was cut by the 1920's (Ware et al. 1993).

With much of the timberland being converted to agriculture and much of the wiregrass understory disturbed and fragmented by logging roads and fields, the era of unrestricted ground fires ended. In the absence of fire, other species of pines and woody plants invaded, shading out the regenerating longleaf pine and the sun-loving herbaceous layer. The introduction of livestock also contributed to the end of regeneration by longleaf pine; the nonresinous, carbohydrate-rich meristems of longleaf pine seedlings became favorite livestock forage. In the mesic regions along the coast, extensive areas of longleaf pine were cut, drained, and converted to commercial pine plantations. Finally, the initiation of government-sponsored fire suppression in the 1920's completed the demise of fire-maintained longleaf pinelands in all but a few locations. By 1946 the range of longleaf pinelands had decreased to one-sixth of their former extent, and today only 14% of the original total remains (Frost et al. 1986).

Much of the remaining 2 million hectares of longleaf pine are fragmented and located near developed areas. Winter burning can actually promote woody invasion of the wiregrass understories, but summer burning (the natural fire regime) is considered hazardous near human property. Prescribed burning relies on firebreaks and roads, which further fragment the herbaceous understory and alter local hydrology (Noss 1989). Even though some rare native species respond to other types of disturbance, fire is the most universally important disturbance (Hardin and White 1989).

Of the animals dependent on longleaf pinelands, the best known is the red-cockaded woodpecker, a federally listed species unique for its use of live old-growth or mature second-growth pine trees for cavity excavation (Costa and Walker 1995). The red-cockaded woodpecker is the prime cavity builder in an environment largely free of snags and natural cavities. This species has declined with the loss of longleaf pine habitat; however, intensive management has stabilized several populations (Costa and Walker 1995). Bachman's sparrow, federally listed as threatened, nests in the wire-grass tussocks. The fox squirrel is dependent on the longleaf pine for forage in late summer (Ware et al. 1993). The gopher tortoise, a species whose populations have declined by 80% in the past 100 years (Auffenberg and Franz 1982), is a keystone species in longleaf pine savannahs--more than 300 species of invertebrates and 65 species of vertebrates use burrows dug by gopher tortoises, the only species that creates this microhabitat (Dodd, Jr. 1995a). Recent regional trends are not available for this species. A study in Florida showed that gopher tortoise populations had increased on one study site, decreased on another, and remained stable on three others (data from 1987 to 1988 compared with 1978 to 1979; Mccoy and Mushinsky 1992).

Pineland and Upland Forests in the SECN. In the SECN, nearly all parks have upland forest communities, though those community types vary widely across the Network. Natural systems within the network are marked by high levels of plant diversity, and more often than not historical dependence on fire as significant landscape-level drivers of ecosystem function. The elimination of natural burning processes, combined with a long history of agriculture and silviculture has resulted in forests (regionally) that are highly modified in nature (Figure 2-3).

The current status of upland forested ecosystems is largely driven by climatic drivers, and external processes linked to often rapidly changing landscape dynamics. Successful management of these lands and interpretation of monitoring data collected from them must be performed in the context not only of current, but historical land use practices (grazing, burning, etc.). The cumulative effects of these off-site drivers results in large influxes of invasive species (plant and animal) that interact with native communities (Figure 2-4).

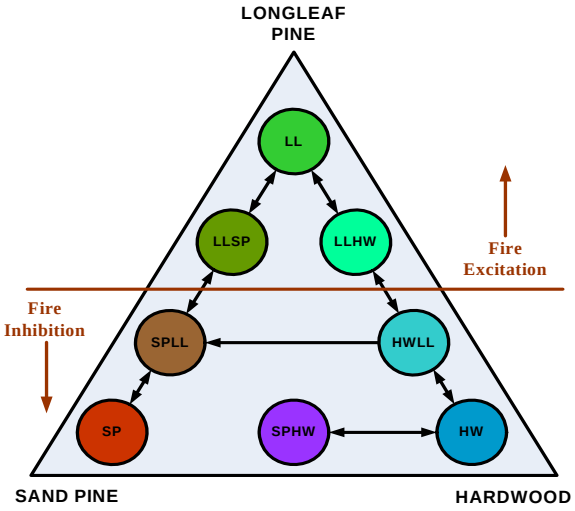


Figure 2-3. Relationship among plant community types as a function of historic fire regime within longleaf pine ecosystems. [SP – Sand Pine; LL – Longleaf Pine; HW - Hardwood]. From Peterson et al. 1998.

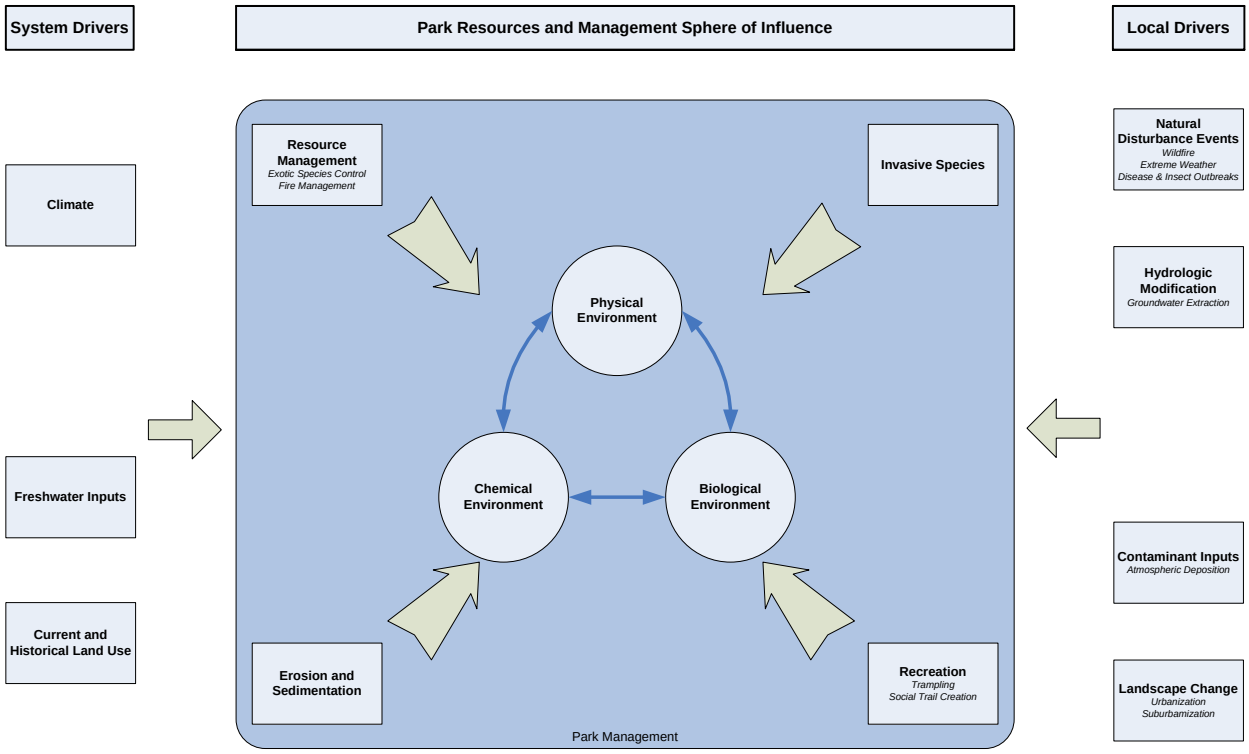


Figure 2-4. Conceptual model of ecosystem dynamics in upland forests of Southeast Coast Network Parks. Rectangles indicate predominant system drivers and agents of change; circles represent major components of the ecosystem (detailed in supporting text). Large green arrows link agents of change to the entire ecosystem, including biotic, chemical, and physical components. The dark blue area includes those agents of change or resources that are currently / actively managed by NPS.

Bottomland Hardwoods

The Southeast contains 36% of all wetlands and 65% of the forested wetlands of the conterminous United States, even though it makes up only 16% of this area (Keeland et al. 1995). Noss et al. (1995) estimated that 78% of southeastern wetlands were lost between settlement and 1980.

The forested wetlands of the Coastal Plain and Piedmont and the continental interior include bottomland hardwood forests and deepwater alluvial swamps (Sharitz and Mitsch 1993); twelve major forest types have been recognized. The vegetation of these forests varies in composition and structure according to flooding duration (Larson et al. 1981).

Harris (1989) listed characteristics of these ecosystems that are beneficial to wildlife: hard mast production and a phenology (that is, periodic biological phenomena, such as flowering and breeding, in relation to climate) that is not synchronous with surrounding upland communities, frequent cavity trees, high abundance and biomass of invertebrate wildlife, and a linear distribution throughout the landscape that aids local and regional movement of animals. The seasonal flooding of these habitats makes them less suitable for agriculture; thus, in agricultural landscapes, they are often the only forest refuges available for many mammals, birds, and other species. Bottomland forests were and are very important to many birds in the Southeast, and the extinction of one species, the Carolina parakeet, and the extirpation of another, the ivory-billed woodpecker, are partially the result of fragmentation of this habitat.

Southern floodplain forests may have the largest remaining area of any riparian habitat in the United States (Klopatek et al. 1979, Keeland et al. 1995). Estimates of extent vary widely, however, from 6,600,000 hectares (Klopatek et al. 1979) to 13,000,000 hectares (Abernathy and Turner 1987). This areal extent is decreasing (0.51% per year from 1954 to 1974; Harris and Gosselink 1990), with a total loss of about 63% (Klopatek et al. 1979) to 78% (Noss et al. 1995). These forests have been converted to farmland, industrial parks, and urban areas. Surviving stands are influenced by levee construction, channelization, agricultural runoff, cattle grazing, timber extraction, and invasions of nonindigenous species. Restoration has been attempted, with 65,000 hectares of bottomland forest replanted since 1985, but it is too early to tell if these efforts will be successful (Keeland et al. 1995).

Species and population losses accompany these trends in habitat loss. For example, in Louisiana, Burdick et al. (1989) showed that the number of forest bird species was 15% lower and the number of individual birds 33% lower on transects with 26% forest cover compared with those areas that had 46% forest cover.

Bottomland Hardwoods in the SECN. Bottomland hardwood forests are one of the dominant riparian ecosystem types in the United States (Mitsch and Gosselink 1993); Congaree National Park contains the largest contiguous tract of old-growth bottomland floodplain forest in the nation. These wetlands represent a transition zone between terrestrial and aquatic ecosystems. Ecosystem processes and distributions of both plant and animals are driven at least in part by gradients of flooding frequency, duration and timing (Figure 2-5). Like upland forest communities, bottomland hardwood and riparian forests within network parks are influenced by exotic invasive species, historical land use, and (to a lesser extent) visitor uses. However, SECN

bottomland hardwood forests and riparian zones within the network are much more sensitive to landscape dynamics within their watersheds that alter hydrology or water quality.

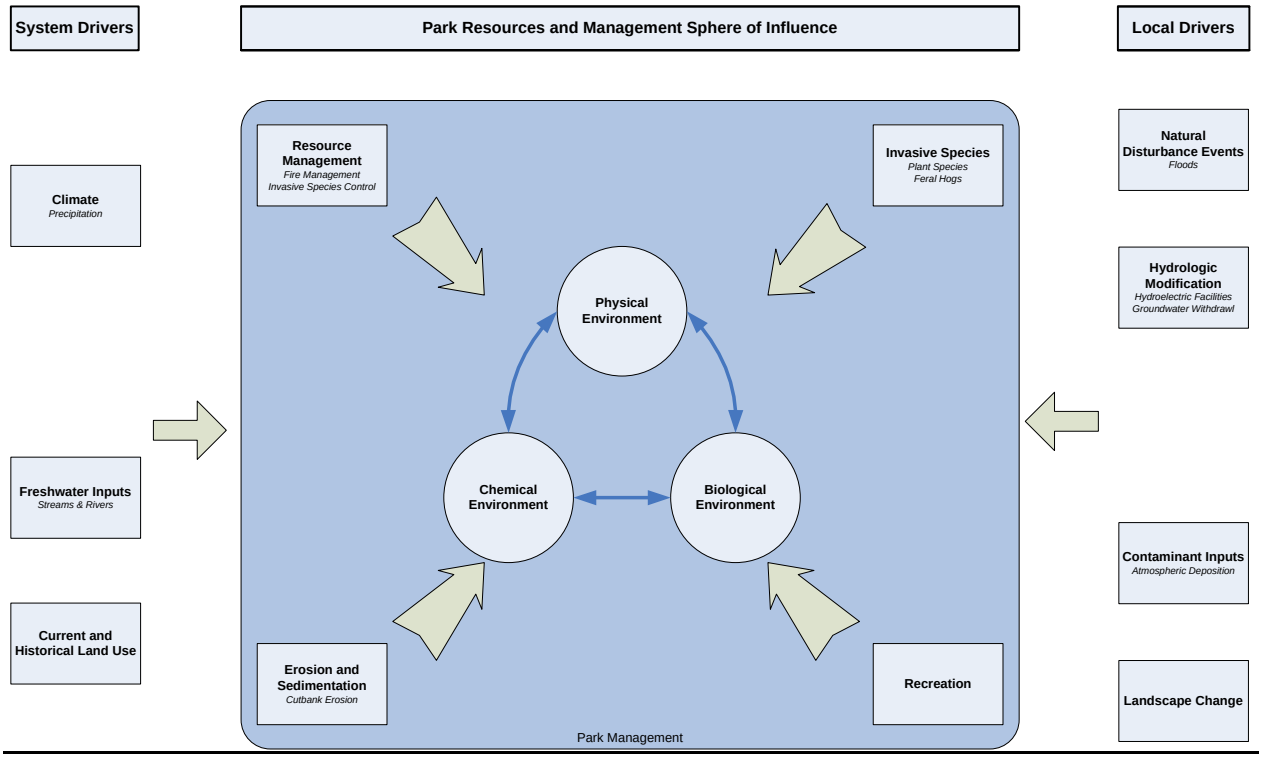


Figure 2-5. Conceptual model of ecosystem dynamics in bottomland hardwood forests of Southeast Coast Network Parks. Rectangles indicate predominant agents of change; circles represent major components of the ecosystem (detailed in supporting text). Large green arrows link agents of change to the entire ecosystem, including biotic, chemical, and physical components. The dark blue area includes those agents of change or resources that are currently / actively managed by NPS.

Rivers and Streams

Isphording and Fitzpatrick (1992) described the Southeast's rivers and streams as an evolutionary laboratory. Thirty major river systems drain to the Gulf of Mexico or the Atlantic Ocean. Long isolation of these waters has produced high species richness and local endemism. Continental high points in diversity occur in fishes, salamanders, aquatic insects, crayfishes, mollusks, and freshwater snails (Wallace et al. 1992, Isphording and Fitzpatrick, Jr. 1992, Bogan et al. 1995). Taxonomic revision is ongoing in these groups, and new species are still being discovered. Systematic and genetic relatedness among the species has been used to describe biogeographic provinces and evolutionary histories (for example, Sheldon 1988). Six broad geographical provinces were based on several animal groups (fishes, mollusks, and crayfishes): the Atlantic Coastal Plain, the eastern Gulf Coastal Plain, the southern Appalachians, peninsular Florida, the Great River (Ohio-Mississippi) systems, and the trans-Mississippi region (Isphording and Fitzpatrick, Jr. 1992). The faunas of the Atlantic Coastal Plain and the eastern Gulf Coastal Plain had their origins in different parts of the southern highlands. The southern Appalachians have a high degree of endemism in isolated headwater streams. SECN parks contain systems within four physiographic provinces.

Only 20% of the nation's freshwater communities are protected by federal laws, and of these, only 10% are east of the Mississippi (Benke 1990). Despite having the highest diversity of fish

species in the United States (McAllister et al. 1986), the rivers and streams of the Southeast are little understood and only minimally protected. Lotic species (those that live in moving water), especially those of higher elevations, are most seriously affected, as their specialization to clear, fast-moving streams renders them unable to adapt to conditions caused by dredging or impoundment (Hackney and Adams 1992).

River systems in the Southeast generally follow trends as described in Vannote et al.'s (1980) River Continuum Concept. This model describes linkages between streams, floodplains, and the watersheds that they drain along a longitudinal gradient from the headwaters to the sea (Figure 2-6). The River Continuum Concept maintains that biological, physical, and chemical properties and functions of river systems and their associated floodplains follow a general pattern from their headwaters to their mouths due to changes along gradients such as elevation, geomorphology, amount of water, and the amount of light.

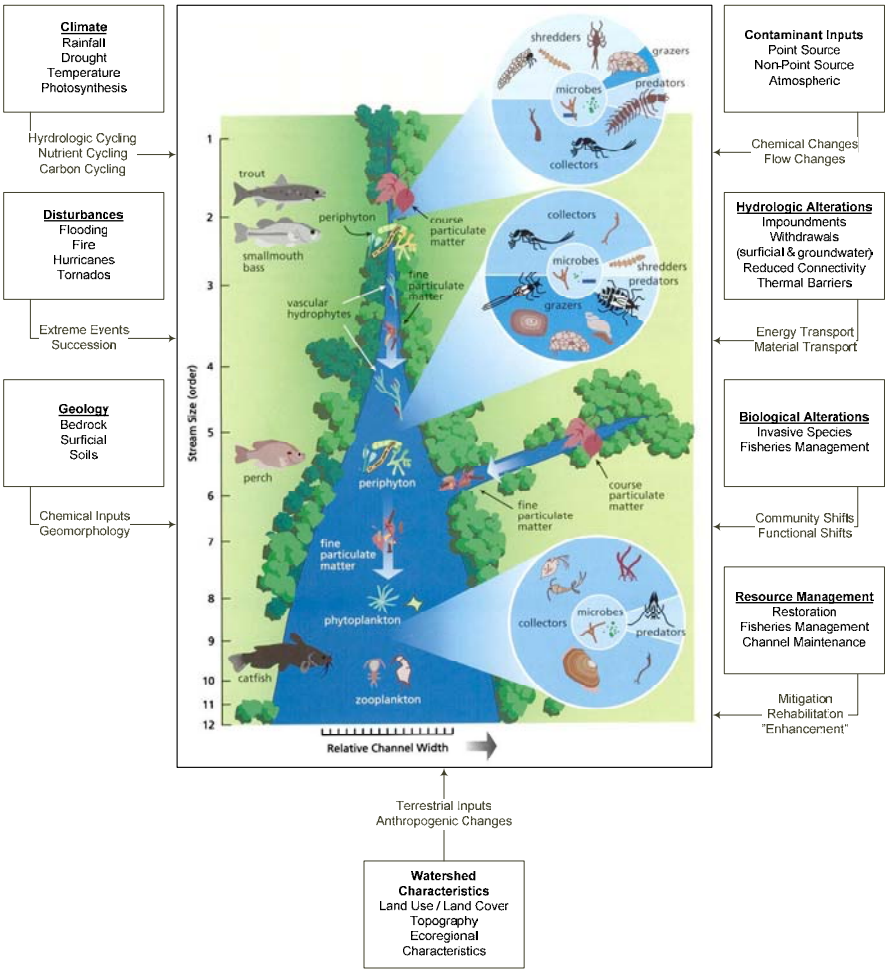


Figure 2-6. General ecosystem model for river and stream systems within the Southeast Coast Network. Modified from Vannote et al. (1980).

Rivers and Streams in the Southeast Coast Network. Southeast Coast Network parks contain significant riverine resources within three distinct zones along the river continuum—CHAT and KEMO are located in the Piedmont province, HOBE and OCMU are on the fall line, and MOCR and COSW are located within the coastal plain (Figure 2-7). Coastal parks within the network also contain smaller isolated systems.

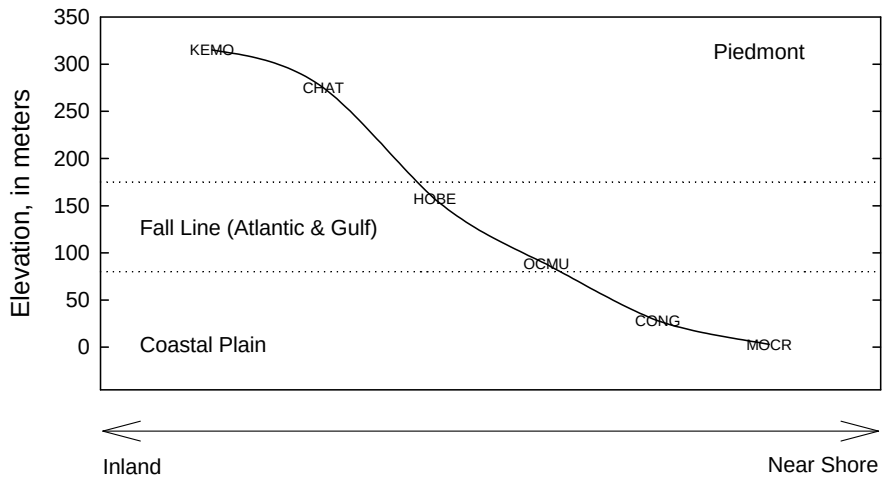


Figure 2-7. Location of the six river parks within the Southeast Coast Network along an elevation gradient. River systems within the network span two physiographic provinces (Piedmont and Coastal Plain) within the region as well as the transition zone between those provinces.

SECN stream systems have been altered by human activities, including impoundment, channelization, lowering of water tables, increased runoff, acid mine drainage, air and water pollution, sedimentation, recreation, and introduced species (including mussels, fishes, and aquatic plants) (Figure 2-8). Many examples of effects on stream biota can be cited (Hackney and Adams 1992)—nearly all major stream systems have been channelized or dammed (Adams and Hackney 1992). In the Southeast, 144 major reservoirs have been built (Soballe et al. 1992), and one-third of all Florida rivers have impoundments. The closing of the Norris Dam on the Clinch River in Tennessee in 1936 caused a loss of 45 mussel species below the dam within 4 months (Soballe et al. 1992). The creation of the Tennessee-Tombigbee Canal is allowing mixing of formerly isolated native biota; Sheldon (1988) predicted this mixing will result in species loss through competition and interspecific hybridization. Between 1930 and 1971, 2,017 square kilometers were surface-mined in the Appalachian Highlands, leading to acidification of nearby streams and reductions in aquatic species diversity and biomass (Mulholland and Lenat 1992). Water hyacinth, a nonindigenous plant first introduced to New Orleans in 1884, had become a problem locally by 1890 and covered 80,000 hectares in Florida by 1975 (Crisman 1992). Major hydropower facilities are located upstream of three of the six river parks in the network (CONG, HOBE, CHAT).

Southeast Coast Network streams and rivers are in a modified to highly modified state due to a combination of river regulation and rapid changes in land use that have resulted in extreme changes in water quality, habitat quality (through sedimentation) and aquatic community structure (Figure 2-8). Southeastern streams that were once dominated by coarse woody debris and gravel-bottom substrates have seen those substrates either cleared or buried, and many

sensitive species (such as mussels) have been extirpated as a result. Although natural disturbances cause local or system-wide modifications to one or more of these components, these variations are considered to be a part of the natural state. Key processes that drive the natural system to one or more of the modified states include flow restriction and redirection, water withdrawal, species introductions, erosion (Figure 2-8).

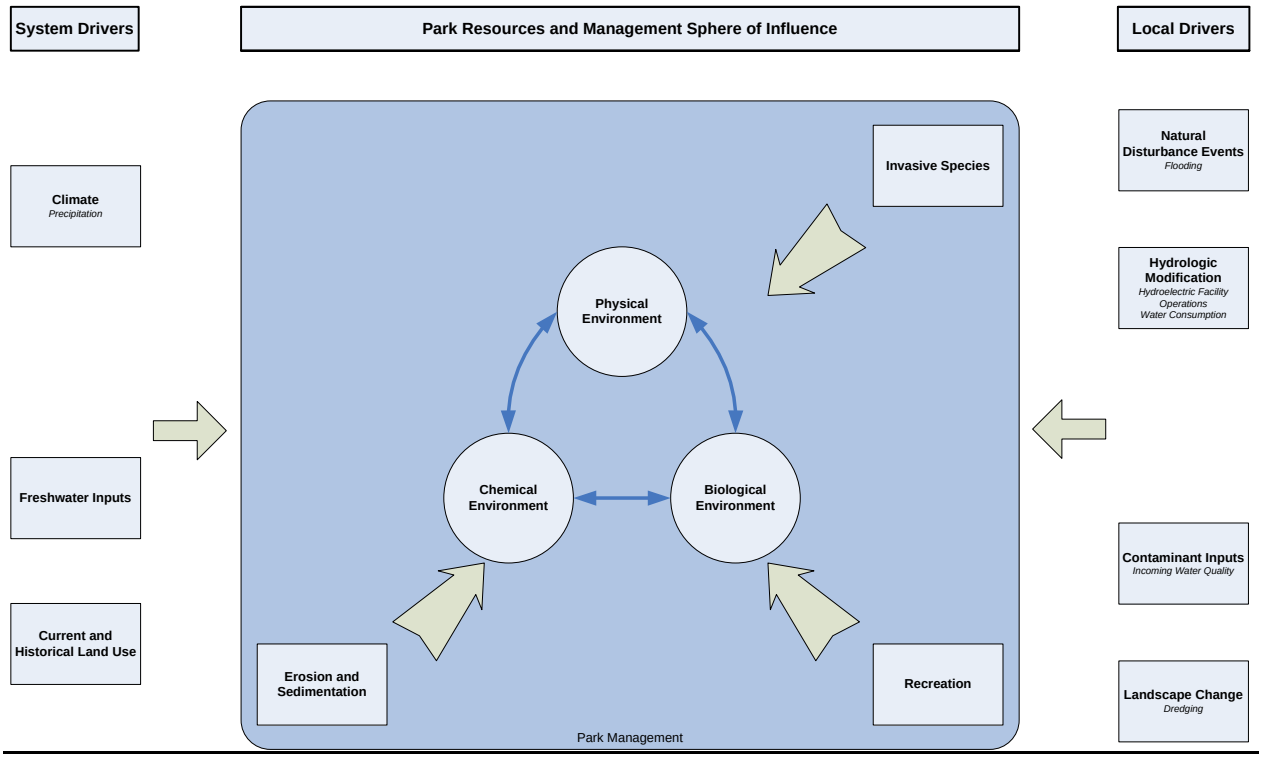


Figure 2-8. Conceptual model of ecosystem dynamics in rivers and streams of Southeast Coast Network Parks. Rectangles indicate predominant agents of change; circles represent major components of the ecosystem (detailed in supporting text). Large green arrows link agents of change to the entire ecosystem, including biotic, chemical, and physical components. The dark blue area includes those agents of change or resources that are currently / actively managed by NPS.

Salt Marshes and Coastal Wetlands

The Southeast region is characterized by vast expanses of coastal marshland, large beds of seagrasses, and some of the most highly productive fisheries in the country. On a global scale, a positive relationship has long been recognized between the extent of coastal wetlands and fishery landings (Turner 1977). On a smaller scale, investigations of animal distributions within estuaries have documented high densities of juvenile fishes, shrimps, and crabs in seagrass and marsh habitats compared with sites lacking bottom vegetation (Zimmerman and Minello 1984, Hoss and Thayer 1993, Peterson and Turner 1994). These patterns indicate that wetlands provide important nursery functions. Indeed, other research has shown that wetland habitats provide young fishery species with both an abundant source of food to support rapid growth and also protective cover to reduce mortality from predators (Boesch and Turner 1984, Kenworthy et al. 1988, Minello et al. 1989, Minello and Zimmerman 1991).

The linkages between wetlands and fishery productivity, however, can be complex. For example, the importance of marsh availability has only been fully recognized within the last decade. Availability of coastal marshes to fishery organisms is determined by tidal flooding patterns, the

amount of marsh-water edge, and the extent of connections between interior marsh and the sea. Within the Southeast, low-elevation marshes in the northern Gulf of Mexico are flooded almost continually during some seasons and are extensively fragmented, providing maximum access for young fishery organisms. In contrast, marshes along the South Atlantic coast have relatively little marsh-water edge and appear to be infrequently flooded. The density of fishery species using the marsh surface also varies between these areas; densities in the Gulf of Mexico marshes are generally an order of magnitude greater than those on the Atlantic coast (Rozas 1993). Researchers now believe that these differences in wetland availability and use are at least partially responsible for the higher landings of estuarine-dependent species in the Gulf of Mexico compared with the South Atlantic.

One major function of wetlands is to provide food for fishery species, and there is evidence that this function also varies regionally. Historically, salt marshes were thought to contribute mainly to detrital food webs by outwelling plant debris into downstream estuaries (Nixon 1980). Such an indirect use of marsh plant production is consistent with the high elevations and large tidal regimes characteristic of Atlantic coast marshes. In the northern Gulf of Mexico, however, direct use of the marsh surface appears more common and is fostered by low marsh elevations and extensive flooding with small tidal regimes. If organisms have access to the marsh surface, primary producers such as benthic and epiphytic algae, along with abundant small consumers, provide plenty of the high-quality food necessary for young fishery species. Thus, the relative importance of different trophic pathways is probably controlled by wetland availability (McIvor and Rozas 1996).

Overlying and perhaps overshadowing these concepts of relative wetland value are the extensive rates of coastal marsh loss occurring in the Southeast, mainly in the northern Gulf of Mexico. Because of the linkages between wetlands and fishery production, we might expect dramatic declines in estuarine-dependent fisheries as marsh habitats are lost. However, over the last 20 to 30 years, productivity and landings of three dominant fishery species (brown shrimp, white shrimp, and menhaden) in the northern Gulf of Mexico have increased (Klima et al. 1990, Smith 1991). In contrast, production of these species did not increase on the Atlantic coast where wetland loss was low compared with the Gulf of Mexico. We are left with a paradox—increased production of fishery species appears correlated with the degradation of their habitat. The explanation may lie in understanding the process of wetland degradation. Wetland loss in the northern Gulf of Mexico is mainly caused by coastal submergence, canal dredging, levee construction, and erosion (Rozas and Reed 1993, Turner 1997). Concurrently, marsh flooding increases, fragmentation and habitat edge increase, zones of saline and brackish wetland expand, and connections with the sea are shortened. These processes increase the availability and value of the remaining marsh and may be supporting short-term increases in fishery production (Zimmerman et al. 1991, Rozas 1995). If this hypothesis is true, enhanced levels of fishery productivity in the Gulf of Mexico are temporary. Continued wetland loss will overcome any benefits of habitat degradation and result in future declines in fishery production dependent on these coastal wetlands.

The salt marsh ecosystem is extremely diverse, including plant, animal, and microbe communities of the marsh and plankton, invertebrates and fish in the tidal creeks, and estuaries (discussed below). In general, plant communities follow a predictable zonation, which is largely driven by salinity and latitude. Ecosystem functions of salt marshes include the following:

- Primary productivity is generally high,
- Detrital production is both high and important for fish nurseries and linked estuarine systems,
- Detrital decomposition is the major pathway for energy flow within salt marshes
- Salt marshes can be either a source or a sink for nutrients.

Salt Marshes and Coastal Wetlands in the SECN. Wetlands within SECN parks vary widely from intermittent interdunal pools to riparian floodplains to vast salt marshes. These systems are particularly sensitive to changes in water quantity. TIMU is the "type" location for *Spartina* salt marshes in the Southeast. Within network parks, these areas are threatened by visitor uses, commercial and recreational fishing and ecosystem drivers from inland and upstream areas (Figure 2-9). The long-term stability of salt marsh ecosystems will likely be increasingly driven by those inland and upstream processes such as water use, landscape dynamics, and their cumulative effects on incoming water quality and quantity (Figure 2-9).

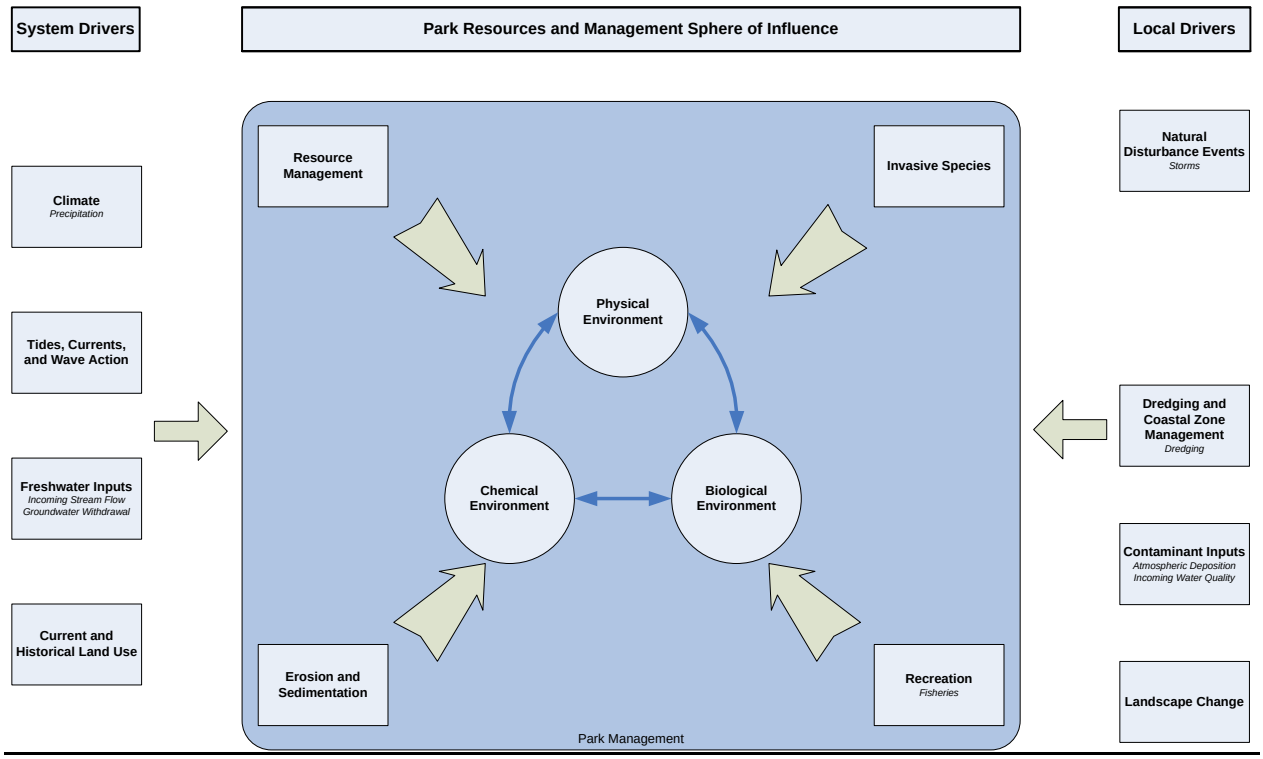


Figure 2-9. Conceptual model of ecosystem dynamics in salt marshes and coastal wetlands of Southeast Coast Network Parks. Rectangles indicate predominant agents of change; circles represent major components of the ecosystem (detailed in supporting text). Large green arrows link agents of change to the entire ecosystem, including biotic, chemical, and physical components. The dark blue area includes those agents of change or resources that are currently / actively managed by NPS.

Estuaries and Nearshore Marine Systems

Most fishery species within the Southeast shelf ecosystem spend part of their life cycle in estuaries, where there appears to be an important linkage between coastal wetlands and fishery productivity. Existing data show that the overall condition of the U.S. coastal waters as fair to poor, varying from region to region and that 44% of estuarine areas in the U.S. are impaired for

human use or aquatic life use (Environmental Protection Agency 2004a). To determine the overall condition of the Nation's estuaries, EPA measured seven coastal condition indicators, including water clarity, dissolved oxygen, sediments, benthos, fish contamination, coastal wetlands loss, and eutrophication. These indicators were rated in estuaries in each region of the country (northeastern, southeastern, Gulf of Mexico, west coast, and Great Lakes regions). The condition of each resource was rated as good, fair, or poor. The indicators were combined to describe the overall coastal condition for each of the regions (U.S. Environmental Protection Agency 2001).

The northeastern estuaries, Gulf of Mexico and the Great Lakes are in fair to poor ecological condition, while southeastern and west coast estuaries are in fair ecological condition. Water clarity is good in west coast and northeastern estuaries, but fair in the Gulf of Mexico, southeastern estuaries, and the Great Lakes. Dissolved oxygen conditions are generally good and sediment contaminant conditions are generally poor throughout the estuaries and Great Lakes of the United States. Eutrophication in coastal waters is increasing throughout much of the United States and results in poor eutrophic conditions in the Gulf of Mexico, west coast and northeastern estuaries and in fair to good conditions in the remaining estuaries of the continental United States.

Living resources are in fair condition in estuaries throughout the United States, although small changes in water quality could cause this condition to worsen and result in a poor rating. Living resources in the Great Lakes, northeastern estuaries, Gulf of Mexico and the west coast are currently in poor condition. Contaminant concentrations in fish tissues are low throughout the estuarine waters of the United States with exceptions in selected northeastern estuaries, Gulf of Mexico estuaries and the Great Lakes. Fish consumption advisories exist throughout the Gulf of Mexico and northeastern coastal areas, although these advisories largely pertain to offshore species (e.g., king mackerel).

State assessments of water quality presented in the EPA's *National Water Quality Inventory* Report largely agree with the water quality and ecological assessment of the Nation's estuaries in the *National Coastal Condition Report* (Environmental Protection Agency 2004b). States determine water quality conditions by comparing available water quality data to their state water quality standards. If a body of water does not fully support its designated use, such as recreation and swimming, drinking water source, or aquatic life habitat, then it is considered impaired. In 1998, states reported that 44% of estuaries and 12% of coastal shoreline in the United States (excluding Alaska) were impaired by some form of pollution or habitat degradation.

Estuarine and nearshore marine systems represent a biological continuum from riverine and salt marsh systems out to the sea (Livingston 1990). Most parks within the network (even within the coastal parks) do not have jurisdiction within estuarine or marine systems. However, many resources within park boundaries rely on estuarine or nearshore marine systems for part of their life cycle.

Estuarine and Nearshore Marine Systems in the SECN. The Southeast Coast Network contains seven parks with significant portions of estuarine and nearshore marine systems either within or adjacent to their boundaries (CAHA, CALO, FOSU, FOPU, CUIS, TIMU, and CANA). Estuarine systems are sensitive to changes in hydrology; particularly those that can

affect salinity levels. The major anthropogenic agents of ecosystem change in estuarine and nearshore marine systems include coastal zone management (dredging, beach renourishment, and shoreline stabilization projects), fisheries, changing landscape dynamics, and hydrological modifications resulting from both upstream river regulation and groundwater extraction (Figure 2-10). Potential changes to the ecosystem include modified hydrology (flushing), modified disturbance regimes (flooding frequency), modified habitats (a combination of changes in sand / sediment budgets and water quality), and resultant shifts in community structures or distributions.

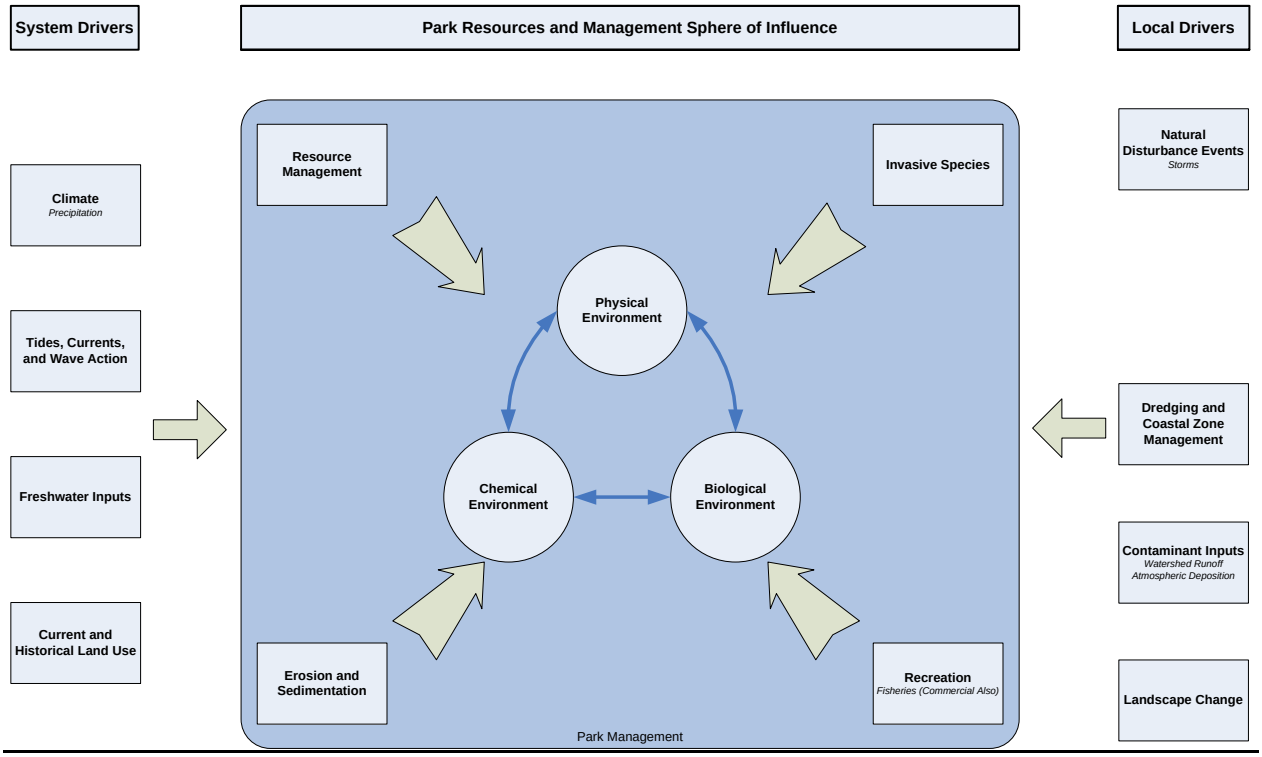


Figure 2-10. Conceptual model of ecosystem dynamics in estuaries and nearshore marine systems of Southeast Coast Network Parks. Rectangles indicate predominant agents of change; circles represent major components of the ecosystem (detailed in supporting text). Large green arrows link agents of change to the entire ecosystem, including biotic, chemical, and physical components. The dark blue area includes those agents of change or resources that are currently or actively managed by NPS.

Barrier Islands

The Southeast supports over 200 individual barrier islands with a total area of over 610,000 hectares (Bellis and Keough 1995). The ecosystems of these islands are diverse and dynamic, a product of regional climate, geomorphology, local sediment deposition, and the forces of ocean currents, tides, wind, salt spray, erosion, and violent ocean storms (Bellis 1992, Stalter and Odum 1993, Bellis and Keough 1995). The islands are grouped into five geographical categories: the mid-Atlantic region, extending from New Jersey to Cape Hatteras, North Carolina; the Sea Islands, bordering the coasts of South Carolina and Georgia; the Florida Atlantic; the eastern Gulf of Mexico coast; and the Louisiana-Texas Gulf of Mexico coast (Stalter and Odum 1993).

Human activities have only had a major effect on the barrier islands in the past 50 years. Eighteenth- and nineteenth-century settlements were small, scattered, and difficult to reach. Most

activities were confined to forestry, livestock grazing, and subsistence agriculture, except in the Georgia and South Carolina Sea Islands, where cotton and rice plantations were widespread. The construction of bridges and causeways and the improvement of transportation in the early part of the 20th century brought new opportunities for recreation, tourism, and second-home development. Development has meant the construction of jetties and sea walls, filling and draining of marshes, and extensive dune stabilization and beach nourishment programs, all of which obstruct the natural fluctuations of the barrier island communities. Despite limited fresh water and the constant threat of storm damage, development continues at an accelerating pace (Stalter and Odum 1993). Barrier island development in the Southeast has increased more than 300% in the past 50 years, and coastal Florida's development proceeds at a rate nearly twice that of the entire Atlantic and Gulf of Mexico coasts combined (Johnson and Barbour 1990). Although there are stretches of protected barrier island beaches and dunes and intact salt- and freshwater marshes, close to half of the area of these communities is estimated to have already been lost (Noss et al. 1995).

Experience with severe storm damage on coastal structures has modified development activities to some extent. Today, setback requirements in effect in many areas prohibit the destruction of the foredunes and reduce effects on beach areas. Existing structures, however, still require protection from beach migration, as well as regular, costly, beach nourishment projects (Johnson and Barbour 1990). About one-third of the barrier islands lining the Atlantic and Gulf of Mexico coasts have been protected by being set aside as parks, wildlife management areas, and national seashores (Stalter and Odum 1993). Areas that are open for development, however, are largely at risk for continued severe habitat degradation and other environmental losses. Most of the Atlantic coast of Florida is unprotected and very little natural coastline remains.

Maritime communities have decreased in aerial extent since settlement, but the magnitude is known only for local areas. For example, coastal wetlands around Tampa Bay have decreased by 44% (Johnston et al. 1995). From 1950 to the present, the area of coastal wetlands along the Gulf of Mexico decreased by 20%-35% (Johnston et al. 1995); the largest losses were in Louisiana, where coastal impoundments flooded wetlands. In general, freshwater wetlands have decreased to a much greater extent than estuarine wetlands. In 1982 the Coastal Barrier Resources Act restricted the use of federal funds for development of barrier islands. An extensive monitoring system has shown that the area of undeveloped barrier islands has been stable since that law was passed (Williams and Johnston 1995). Within SECN parks, changes in plant community types have been driven by a history of ditching and draining, conversion of lands for silviculture, and extensive grazing (Figures 2-11 through 2-13).

Development, of course, has many effects. Beach traffic disturbs nesting birds and sea turtles, compacts the soil, and disrupts dune-building activities. Jetties, sea walls, inlet stabilization, and artificial dunes disrupt normal overwash activities, altering normal dune development and increasing erosion in some areas and sand deposition in others. Development within the foredune zone and forest clearing destroy natural protective barriers to salt spray and wind damage. Pollution of marshes, estuaries, and creeks is a common result of inputs of treated and untreated sewage, fertilizer runoff from developments such as golf courses, and numerous contaminants from marinas, fish-processing plants, highways, and small industries (Stalter and Odum 1993). Finally, fragmentation of vegetation interferes with natural migration patterns.

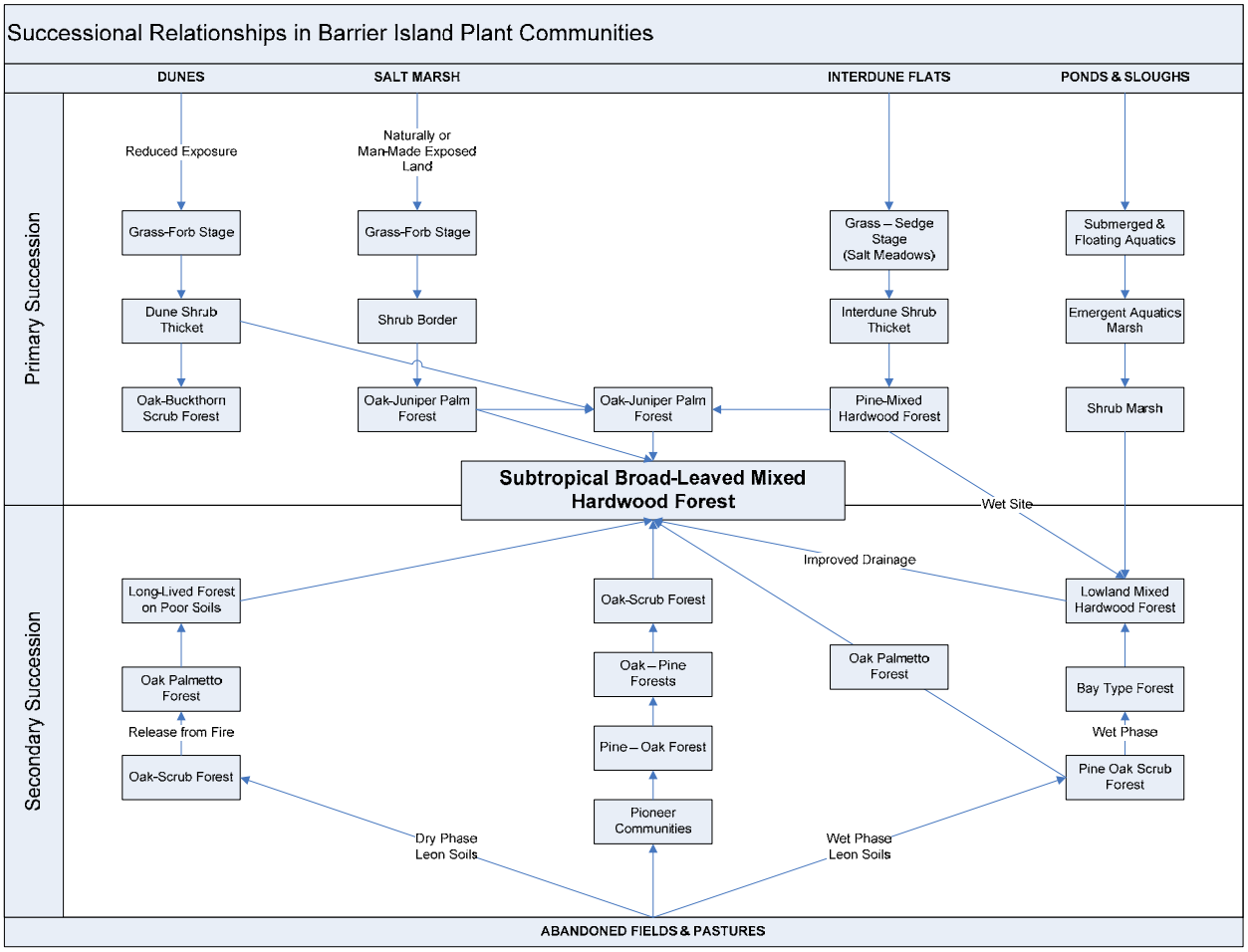


Figure 2-11. Successional relationships of plant communities on barrier islands. Modified from Hillestad et al. (1975).

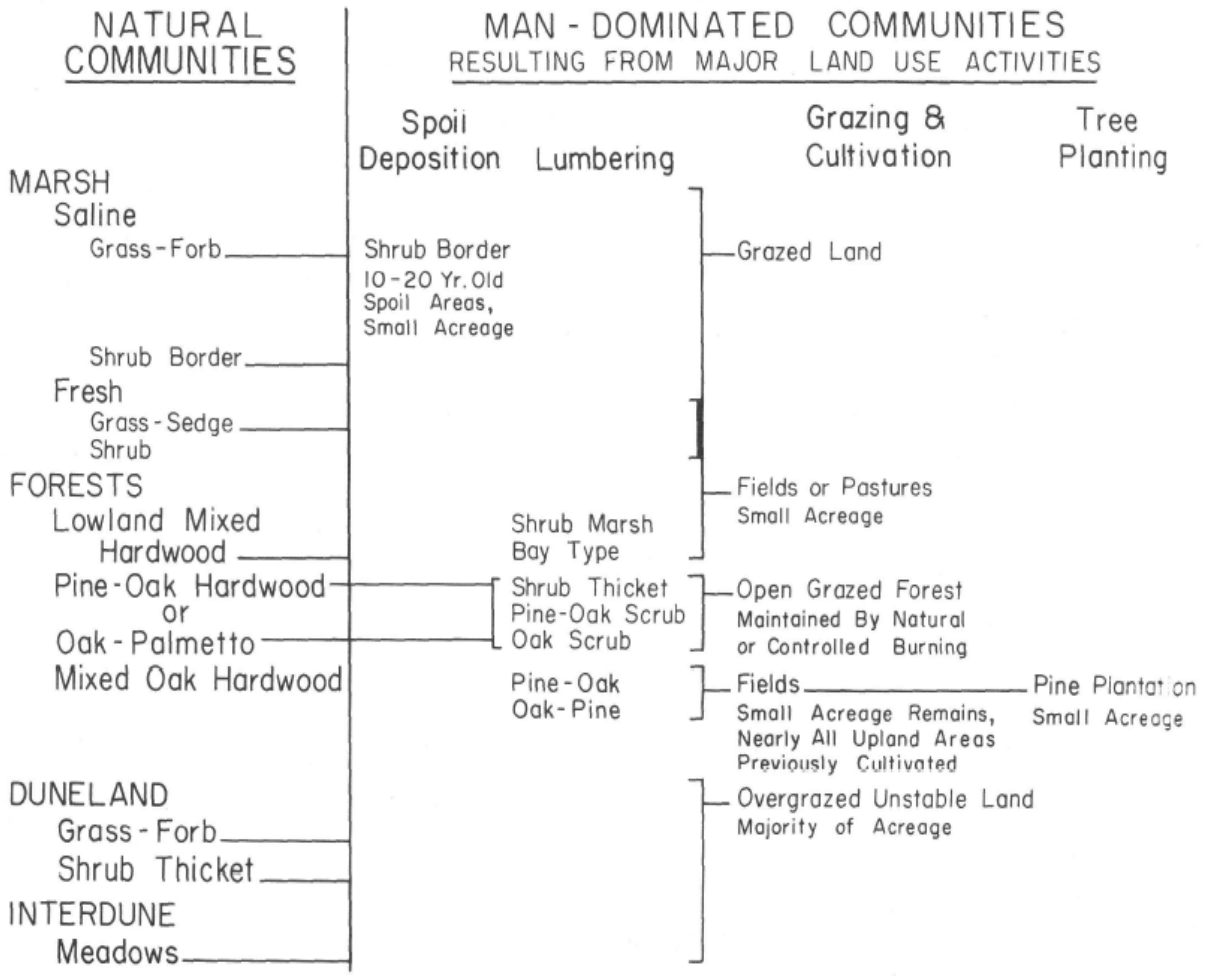


Figure 2-12. Relationship of the natural plant communities and historical land use practices on barrier islands. From Hillestad et al. (1975).

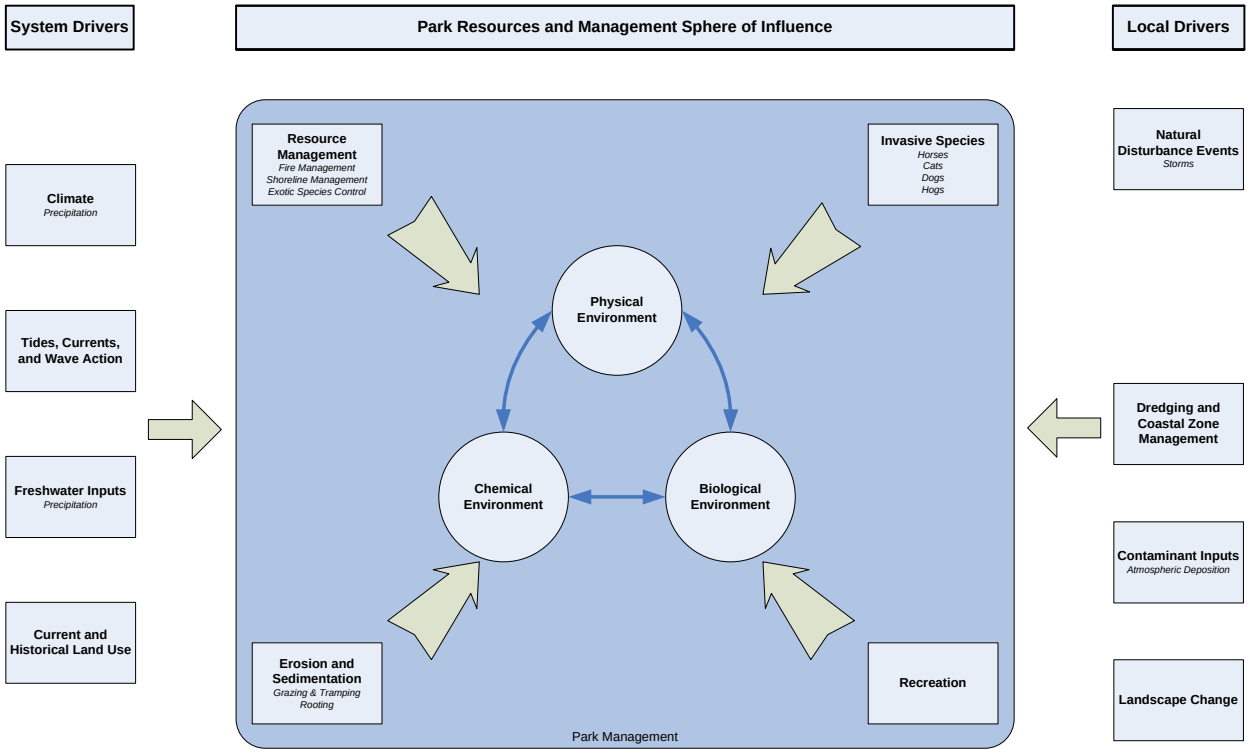


Figure 2-13. Conceptual model of ecosystem dynamics in barrier islands of Southeast Coast Network Parks. Rectangles indicate predominant agents of change; circles represent major components of the ecosystem (detailed in supporting text). Large green arrows link agents of change to the entire ecosystem, including biotic, chemical, and physical components. The dark blue area includes those agents of change or resources that are currently / actively managed by NPS.

Bellis and Keough (1995) estimated that 39,000 hectares of maritime forest occurred in North Carolina, Georgia, and Florida, the three states with the best inventories. This represents an unknown fraction of the original extent of these forests. About half of the remaining forests are unprotected and likely to be developed within the next decade (Bellis and Keough 1995). The degree of human disturbance and changes within the small forest fragments that remain (for example, edge effect and the fact that fragments may not be large enough to support a population big enough to convey long-term persistence) produce declines in the numbers and species of many animals (Gaddy and Kohlsaat 1987, Bellis and Keough 1995).

Several investigators noted the inadequacy of existing data for detection of trends. Bellis and Keough (1995) suggested the need for a complete survey and assessment of maritime forests. Besides effects of development and nonindigenous species, maritime communities will probably be influenced by sea-level rise and drawdown of freshwater supplies (Bellis and Keough 1995). Daniels et al. (1993) modeled the influence of sea-level rise on endangered species in South Carolina and showed that 52% of the regionally endangered species were found within 3 meters of current mean sea level and that several scenarios of sea-level rise would drastically reduce the habitat for these species.

Large numbers of migratory and nesting bird species are found on barrier islands (Stalter and Odum 1993); for example, 350 species have been recorded on barrier islands in North Carolina alone (Parnell et al. 1992). Coastal marshes are critical to overwintering populations of many

waterbirds. In addition, migration routes of many raptor species include southeastern barrier islands. Neotropical migrants use the islands as a point of departure and arrival in their travels to and from their winter habitats in the tropics (Stalter and Odum 1993).

Many birds have been negatively affected by development and human encroachment. Species that nest in bare sand can be disturbed by pedestrian and off-road vehicle traffic and by the construction of artificial dunes. Harrington (1995) reported that for 27 species of eastern shorebirds, 12 had stable populations, 1 was increasing, and 14 were decreasing. Surveys initiated off the North Carolina coast in the early 1970's tracked the fluctuations in nesting bird populations (Parnell et al. 1992). Eight species were increasing strongly (brown pelican, cattle egret, white ibis, glossy ibis, laughing gull, herring gull, royal tern, and Sandwich tern), three were increasing (yellow-crowned night-heron, great black-backed gull, and caspian tern), four were declining (gull-billed tern, common tern, least tern, and black skimmer), and seven were presumed stable. Some of the species have even shifted locations; Parnell et al. (1992) suggested that cutting of coastal swamps during the last 50 years resulted in movement to the estuaries. Further, creation of new habitat from dredged material may have caused populations to shift from one estuary to another.

Stalter and Odum (1993) listed nine endangered species of birds that are wholly or partially dependent on habitat on southeastern barrier islands: whooping crane, Eskimo curlew, bald eagle, Arctic peregrine falcon, eastern brown pelican, Cape Sable seaside sparrow, Bachman's warbler, Kirtland's warbler, and red-cockaded woodpecker. These species use the barrier islands in a variety of ways: nesting (five species), migration (four species), wintering (five species), feeding (seven species), and resting-roosting (seven species). Stalter and Odum (1993) attributed population losses in these species to development (direct loss of nesting, resting, and foraging habitat), dredging and filling of marshlands (loss of community structure and composition used by the birds), pollution, and direct disturbance on recreational beaches.

Five species of sea turtles are found in the open ocean and coastal waters of the Southeast, and all nest on open beaches: the green sea turtle (status: endangered/threatened; U.S. Department of Commerce 1994a), the hawksbill (endangered), Kemp's ridley (endangered), the leatherback (endangered), and the loggerhead (threatened). Sea turtles are difficult to census in open waters and, because of the concentration of female turtles nesting on the beach strand and the apparent faithfulness of their return to specific beaches, the number of nesting females is considered the single best indicator of population trends (Committee on Sea Turtle Conservation 1990a). The Kemp's ridley nests annually, but the other species nest less regularly. Long-term data sets (that is, over a decade of observations) are essential to detecting trends (Committee on Sea Turtle Conservation 1990b). The dependence of sea turtle species on the narrow beach strand also makes them vulnerable to a host of human-caused problems, including beach development and recreation, artificial lighting (which disorients hatchlings), and increases in nest predators such as raccoons. Recently, federal law has mandated that shrimp trawlers use turtle exclusion devices, which should decrease mortality in a critical life stage for reproduction (Committee on Sea Turtle Conservation 1990c).

Population estimates are available for only two of the five species of sea turtles (U.S. Department of Commerce 1994b): 20,000-28,000 loggerheads and 400-500 green sea turtles nest in the United States. Although the number of nesting loggerheads has declined by 3% annually at

a site in Georgia and by 26% during the 1980's at a site in South Carolina, it has increased at several sites in Florida (Committee on Sea Turtle Conservation 1990d, Dodd, Jr. 1995a). Summed across the Southeast, loggerheads increased from 1982 to 1990 and decreased from 1990 to 1993 (Dodd, Jr. 1995a), although the recent decline has been relatively mild, leaving the species at higher levels than in the early 1980's. A recent review concluded that the overall status of loggerhead population size was stable (U.S. Department of Commerce 1994c). This study also concluded that there was inadequate data to report an overall trend in green sea turtle populations, but numbers at one Florida site had increased from 1971 to 1989, and the species is presumed to be recovering. The green sea turtle was drastically reduced by fishing (it was served in turtle soup) during the early 1900's.

At one study site in Mexico, Kemp's ridley is presumed to have declined sharply from 1947 to 1990, to 1% of original levels (Committee on Sea Turtle Conservation 1990e). Data collected at that site from 1977 to 1990 suggested a continued but much less drastic downward trend. Very few hawksbills and leatherbacks nest in the United States, and data are inadequate for precise statements of trends of these species, although expert opinion holds that the hawksbill is declining (U.S. Department of Commerce 1994d).

SECN Barrier Islands. Coastal dunes and barrier island ecosystems are major features at CAHA, CALO, CUIS, and CANA. Future land acquisitions at TIMU might result in the addition of dune habitats there as well. Coastal dunes are particularly important due to the fact that (a) they support a wide variety of sensitive or protected species, (b) they are fragile, (c) they are particularly threatened by visitor uses, and (d) they play a significant role in the overall stability of the island.

Within Network parks, the primary drivers of ecosystem change include invasive species (plant and animal), visitor uses, shoreline erosion (Figure 2-13). Many of these drivers are influenced by one or more factors outside of park boundaries linked to on-shore or upland landscape dynamics, regional climatic drivers and current and historical fire / forest management practices.

Overgrazing by exotic animals is also a problem on barrier islands, not only because of a large white-tailed deer population but also because of the large numbers of feral animals introduced to the islands, including horses, cattle, goats, pigs, and sheep (Stalter and Odum 1993). Eradication of some of the larger feral species has been successful on some islands, but other introduced animals, especially feral dogs and cats, negatively affect small mammal populations. Other introduced species include European rats and nutria (Stalter and Odum 1993). Two parks within the network (CUIS and CALO) have managed feral horse populations that are significant drivers physical, biological, and chemical components of barrier island processes.

Common Elements

Reptiles and Amphibians

Several resources of interest are common to multiple ecosystems within the network. Although discussed in greater detail in Appendix 7, the following are of importance to the network because of their selection of Vital Signs (next chapter).

Reptiles and amphibians are present in virtually all natural habitats in the Southeast. All the turtle species nest on land, some aquatic turtles and snakes hibernate on land, and dozens of species of southeastern frogs and salamanders are terrestrial as adults but require wetlands for breeding and development of young. Also, terrestrial corridors among aquatic habitats are essential for reptile and amphibian dispersal during unfavorable periods such as drought.

The Southeast has the highest regional total (130 species) of amphibians in the United States (Echternacht and Harris 1993), including 38 species of frogs and toads (12 of these are endemic to the Southeast) and 92 species of salamanders (45 of which are endemic to the Southeast). The southern Appalachians are a world center of diversity for salamanders and have 68 species of a unique group of lungless salamanders that evolved in this region of well-oxygenated streams and high rainfall. The Southeast has six species of large, fully aquatic salamanders and the Coastal Plain has 32 species of frogs and toads, of which 11 are endemic.

There are 52 species of snakes in the Southeast, of which 11 are endemic (Conant and Collins 1991, Echternacht and Harris 1993). Of the 91 species of lizards native to the United States, 21 occur in the Southeast, and 6 of these are endemic. The Southeast has 36 species of turtles, 13 of which are endemic; the Coastal Plain possesses North America's highest diversity in this group. One of the two greatest concentrations of freshwater turtle species in the world (the other is in Asia) is in the Mobile River basin (Iverson 1992, Lydeard and Mayden 1995).

The greatest threat to reptiles and amphibians comes from habitat loss and changes in water quality. Numerous examples can be given of population declines in individual wetlands as a consequence of human activities. Drainage and destruction of temporary ponds have resulted in the reduction of striped newts in Georgia (Dodd, Jr. 1995a), the extirpation of the flatwoods salamander from a portion of its range, and apparent declines of gopher frogs in Alabama and Mississippi (Dodd, Jr. 1995a).

Species that are adapted to terrestrial habitats have also suffered. Of the 242 native reptiles and amphibians in the Southeast, 170 (74 amphibians, 96 reptiles) are native to longleaf pine-wire-grass ecosystems (Dodd, Jr. 1995a). The near loss of this natural community, through timbering, development, and fire suppression, has had a significant, though largely unquantified, effect on reptiles and amphibians.

Highway deaths also deplete the numbers of many species of reptiles and amphibians that travel overland. A two-meter long indigo snake, for example, does not move fast enough to safely get across today's highways.

Some ecologists have reported declines in amphibian populations and related these to specific threats, such as acid rain, destruction of the ozone layer, global warming, or other forms of nonpoint pollution (Blaustein 1994). It is unclear if any of these factors are responsible for amphibian declines in some regions (Pechmann et al. 1991, Pechmann and Wilbur 1994), but habitat destruction is the primary threat to most species of reptiles and amphibians in this country and probably in most countries in the world today. Timber harvest, for example, dramatically reduces amphibian populations in the southern Appalachians (Petranka et al. 1993). Habitat destruction may take more subtle forms, though, and what may appear to be protected and pristine habitat may actually be experiencing degradation because of changes in hydrology,

pollution, herbicide and pesticide runoff, the introduction of competitive nonindigenous species, the introduction of disease organisms, or the loss of important breeding sites such as temporary ponds (Blaustein 1994, Dodd, Jr. 1995b).

Insufficient knowledge of the distribution and ecology of native reptiles and amphibians is a major shortcoming in any national effort to detect change and avoid loss in this group. An example of the difficulty that ecologists face in confirming the presence of herpetofauna is apparent from studies by investigators at the Savannah River Ecology Laboratory and from studies by other investigators on the Savannah River Site in South Carolina. This site is the largest tract of land (750 square kilometers) in North America with high herpetofaunal species diversity and a long-term record of intensive ecological research and survey. Since the 1950's, herpetologists have collected data on more than a million individual reptile and amphibian specimens representing more than 100 species (Gibbons and Semlitsch 1991). Nonetheless, despite intensive surveys, the presence of new species has been verified on the Savannah River Site at a rate of more than five species per decade.

Birds

The Southeast originally had 237 native species of birds, none of which were strictly endemic to the region (Echternacht and Harris 1993). Three species are nearly restricted to the Southeast: Bachman's warbler (which may be the rarest vertebrate in the region), Swainson's warbler, and the brown-headed nuthatch. Twenty-six percent of the total (61 species) is associated with water. Of these, 19 are large wading bird species, a group for which the Southeast has the continent's highest total. The greatest species richness of birds occurs in the coastal wetlands. Thirty-one species (13.4%) are restricted to the high mountains. Echternacht and Harris (1993) estimated that there are 17 established nonindigenous bird species in the Southeast, but they warned that the number may be an underestimate, considering that other species have been released in the area.

Land clearing and hunting were responsible for the extinction of two bird species in the Southeast: the passenger pigeon (last reported in the wild in 1899) and the Carolina parakeet (last reported in the wild in 1913). Passenger pigeons were hunted for their market value whereas Carolina parakeets, birds of old wetland forests, were hunted to protect fruit crops.

Three species have been extirpated from the Southeast: ivory-billed woodpecker (last seen in the 1950's and thought to persist in Cuba), which was dependent on large-cavity trees in extensive and old riparian forests; and the Zenaida dove and the Key West quail-dove, which were rare Caribbean species restricted to Florida-- the reason for their extirpation is not known (Echternacht and Harris 1993). An additional subspecies, the dusky seaside sparrow, became extinct because of poor fire management of its marsh habitat in coastal northern Florida.

Fourteen species and subspecies of birds are federally listed, of which 12 are Coastal Plain species: crested caracara, Mississippi sandhill crane, Florida scrub-jay, brown pelican, piping plover, Cape Sable seaside sparrow, dusky seaside sparrow (now extinct), wood stork, least tern, Bachman's warbler, ivory-billed woodpecker, and red-cockaded woodpecker. The fate of these species is largely tied to habitat loss, including reductions in longleaf pine savannah, Florida scrub, wetlands, and beach communities. Two other federally listed species, the bald eagle and

the peregrine falcon, were formerly wide-ranging species sensitive to pesticides; these species are now recovering.

The Southeast is important not only for summer breeding populations but also for birds that winter in the Southeast and for birds that migrate farther distances (for example, to the Caribbean and Central and South America) after passing through the South in spring and fall. Coastal habitats, maritime forests, and longleaf pine savannah are all important to migrating species. Threats to bird species include land-use changes, forest fragmentation (which often results in increased nest predation and cowbird parasitism), tropical deforestation (for Neotropical migrants), elimination of wetlands, and coastal development.

Critical information for the conservation of bird species includes understanding the relationship between reproductive success and habitat size and quality. Hunter (draft report) stated that to create populations that will endure and that will generate excess individuals to colonize new sites, some bird species (for example, the ivory-billed woodpecker) require 2,000 to 40,000 hectares of unbroken habitat. Further, we have to understand the relation between reproductive success and such microhabitat variables as forest-age structure. Hunter also reported that species that require large areas can act as umbrella species for species with smaller area requirements. If we understand the habitat area each bird species needs, it will help us determine optimum block sizes and rotations for harvested forests. The need for large habitat areas is another argument for reforestation of marginal farmlands and the retention of wetlands. Because the southeastern landscape is so heavily in private ownership, land used for agriculture and forestry must play a large role in the survival of bird species diversity. Erwin (1995) suggested that recent increases in great blue heron populations resulted from this bird's practice of feeding in aquaculture ponds. Finally, regional monitoring of bird populations is essential because of geographic movements of species. For example, white ibis and wood stork populations have declined in south Florida but are stable in the Southeast as a whole because of population shifts northward to northern Florida, Georgia, and the Carolinas (Erwin 1995).

Fishes

The Southeast has about 485 known species of native freshwater fishes, representing 27 families. Most of the diversity of the southeastern fish fauna is in five families: the darters and perches (family Percidae; 31.3%); the minnows (family Cyprinidae; 29.7%); the madtoms and bullhead catfishes (family Ictaluridae; 6.8%); the suckers (family Catostomidae; 6.6%); and the sunfishes and basses (family Centrarchidae; 5.8%). The greatest diversity is in the Appalachian Mountains and Interior Plateau, but other regions of the Southeast also harbor many more species than do similar-sized geographic areas elsewhere in the United States.

In the Southeast, fish declines are the result of the same factors that cause global deterioration of aquatic resources, primarily habitat loss and degraded environmental conditions. The principal causes of freshwater fish imperilment in the Southeast and other areas of the United States are dams and channelization of large rivers, urbanization, agriculture, deforestation, erosion, pollution, introduced species, and the cumulative effects of all these factors (Moyle and Leidy 1992, Warren, Jr. and Burr 1994). The most insidious threat to southeastern fishes is sedimentation and siltation resulting from poor land-use patterns that eliminate suitable habitat required by many bottom-dwelling species. Cumulative effects of physical habitat modifications

have caused widespread fragmentation of many fish populations in the Southeast, presenting difficult challenges for those trying to reverse and restore diminished fish stocks.

Aquatic resources are often resilient and capable of recovery, given favorable conditions. Conservation of southeastern fishes will require significant changes in land management and socioeconomic factors (Moyle and Leidy 1992, Warren, Jr. and Burr 1994), but such changes are necessary to stem future losses of biodiversity. The first step required is to improve public education on the value and status of native aquatic organisms. For resource managers and policy makers, increased efforts must be made to assume proactive management of entire watersheds and ecosystems; establish networks of aquatic preserves; restore degraded habitats; establish long-term research, inventory, and monitoring programs on fishes; and adopt improved environmental ethics concerning aquatic ecosystems (Warren, Jr. and Burr 1994). The southeastern fish fauna is a national treasure of biodiversity that is imminently threatened. If this precious heritage is to be passed on, its stewardship must be improved through cooperative actions of all public and private sectors within the region.

Mammals – modified from White et al. (1998)

Terrestrial and freshwater habitats in the Southeast are home to 101 mammal species (Echternacht and Harris 1993). Of these, five are extirpated, all of them ecologically important large carnivores or grazers: jaguar, ocelot, gray wolf, elk, and bison (Echternacht and Harris 1993). Two other large carnivores are on the verge of extinction: the Florida panther, the only remaining subspecies of mountain lion in the eastern United States, and the red wolf.

Endemic species represent a relatively small percentage of the mammals. According to Echternacht and Harris (1993), eight small mammal species are endemic to the Coastal Plain province of the Southeast: southeastern pocket gopher, colonial pocket gopher, Sherman's pocket gopher, Cumberland Island pocket gopher, oldfield mouse, Florida mouse, Perdido Key beach mouse, and round-tailed muskrat. The region also has eight species of introduced mammals, four of which have many adverse effects on native communities: coyote, pig (feral domesticated pigs and wild boar) in the mountains and Coastal Plain, and nutria and horse in the Coastal Plain. Beavers were extirpated in the Southeast but have become reestablished in the last 20 years. Although beavers were historically important in the maintenance of habitat diversity, beavers of today inhabit landscapes with reduced predation and where the remnant habitats may themselves be vulnerable to loss from flooding.

There are 22 federally listed mammals in the Southeast: eastern mountain lion and the Florida panther, Key deer, gray wolf, red wolf, Louisiana black bear, four species of bats, nine small mammal species restricted to the Coastal Plain in Florida or Alabama, a shrew restricted to Virginia and North Carolina, and two species of flying squirrels restricted to the mountains (Lee et al. 1982, Humphrey 1992). The eastern mountain lion and the gray wolf are already extirpated in the Southeast. In the following sections we discuss these and other species representative of trends in southeastern mammals.

Small mammal species that are most at risk in the Southeast have narrow distributions. Most of the threats to these species come from development and subsequent loss of habitat. In isolated communities, such as beach habitats, feral cats represent a significant threat. Shrews and other insectivorous mammals suffer from the concentrated effects of residual pesticides. Fleming and

Holler (1989) described ongoing efforts to reintroduce the endangered Perdido Key beach mouse to a site in Gulf Islands National Seashore.

The future of the fox squirrel is linked to that of its habitat, the longleaf pine savannah. A long-lived species with low reproductive rates, the fox squirrel has not been well studied or understood, but timbering, fire suppression, and development are all limiting its range and reducing its population sizes.

Chapter 3. Vital Signs

The term *Vital Sign* is defined in this program as "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. Vital Signs might occur at any level of organization including landscape, community, population, or genetic level, and might be compositional (referring to the variety of elements in the system), structural (referring to the organization or pattern of the system), or functional (referring to ecological processes)." In this chapter, we describe the process used to select and prioritize the Vital Signs for the Southeast Coast Network, followed by a discussion of the Vital Signs selected for implementation.

The Southeast Coast Network has identified 25 Vital Signs that represent a systems approach to our monitoring program. Five Vital Signs relate to air and climate, three relate to geology and soils, four relate to water, two relate to human use, two relate to ecosystem pattern and processes, and nine relate to biological integrity. The network developed this list through a process of meetings and ranking exercises to determine the optimal suite of Vital Signs that could be monitored to best inform management decisions at SECN parks. Protocols for all Vital Signs will be developed or implemented in the next three to five years.

Scoping and Vital Signs Selection Process

During the last twenty years many indicator-based monitoring programs have been developed to assess many ecosystems around the world (Busch and Trexler eds. 2003). Many recent syntheses have focused on topics such as qualities of "good" vs. "bad" indicators, statistical sampling design, and methods to integrate monitoring programs with adaptive management programs—all in an effort to ensure that new programs meet desired objectives (Busch and Trexler eds. 2003).

To ensure that monitoring objectives were met for all SECN parks, the network built upon these syntheses and developed a resource-allocation model to govern the scoping and Vital Sign selection processes. In essence, the model sought to maximize the number of high-priority programmatic objectives that could be met for the greatest number of parks while keeping within set budgetary and staffing limitations (for a complete description of the model, please see Appendix 4). This model essentially helped the network select an ideal suite of "good" indicators that would meet our managers' programmatic needs.

To do this, the SECN used a muti-step process for scoping and selection of its Vital Signs (Figure 3-1). First, through a combination of scoping meetings and literature reviews, the network identified monitoring objectives related to park natural resources (including key resources, threats, and agents of change). This was done in conjunction with the literature reviews and scoping meetings that resulted in the network's conceptual models presented in Chapter 2. Second, each park prioritized the importance of meeting each of the monitoring

objectives. Third, existing monitoring protocols were identified that could be implemented (as published or with potential modifications) to meet those monitoring objectives. Fourth, each protocol was evaluated to determine which Vital Signs they contained based on the NPS Ecological Monitoring Framework. Last, the SECN selected the optimal suite of protocols and data-acquisition SOPs that could be implemented within known budgetary, staffing, and logistical constraints. The SECN Vital Signs presented in this chapter represent this optimal suite of "good indicators" that the SECN will monitor.

Monitoring objectives were identified by conducting a review of those objectives identified by the first 12 funded I&M networks where monitoring objectives were clearly identified (Welch 2003, Weber 2003, Milstead and Stevens 2003, Leibfreid 2003, Hubbard et al. 2003, Emmott et al. 2003). Where appropriate, monitoring objectives were also included from EPA's Draft Report on the Environment 2003 (United States Environmental Protection Agency 2003), and were augmented further with objectives identified during park scoping meetings. In total, roughly 400 monitoring objectives were identified that were of potential importance to SECN parks.

Monitoring objectives were reviewed by all fifteen management units in the network and categorized into standardized priority rankings (Table 3-1). In each case, the goal of the scoping meetings was to determine the degree of importance for meeting any given objective from ecological conservation, park management, and park mission standpoints. Initial rankings were established during scoping meetings between Network and Park staff between February and July 2004. Follow-up phone interviews were conducted with park staff during July 2004 to complete the data set. For each objective the overall average score was calculated, as well as an adjusted average score based only on scores at which a monitoring question would be considered relevant (i.e., scores for marine or coastal issues were only averaged among coastal parks). Individual park scores, justifications, average scores, and adjusted average scores are presented in Appendix 9.

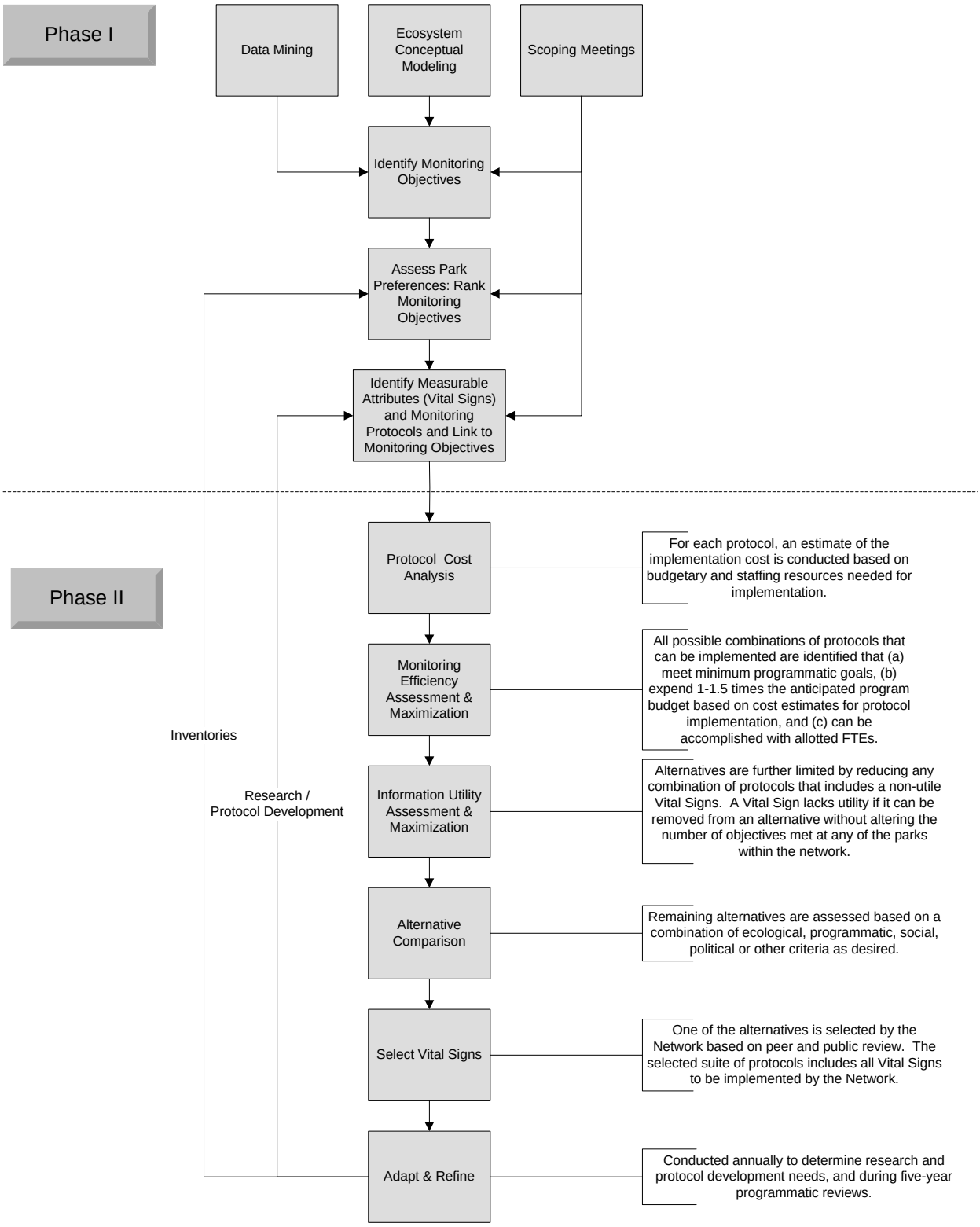


Figure 3-1. Implementation process used by the Southeast Coast Network for developing options for a Vital Signs Monitoring Program.

Table 3-1.
Criteria for prioritizing monitoring objectives based on the relative importance for meeting each monitoring objective.

Rank	Park Question	Examples	Examples (For T&E Species)
5	Mandated (for the Park). The park is required to meet specific monitoring objective as per legal or contractual obligations.	Anything directly or explicitly mentioned in Park legislation or current / future management plans. Examples might include the size and impacts of horse populations at CALO, water quality trends at CHAT, etc.	Monitoring red cockaded woodpeckers. If breeding pairs are present on the park, required under the recovery plan to conduct 100% census of population on an annual basis.
4	Mission Critical. The Park should meet this objective to effectively manage its resources. Meeting this objective will provide information relevant to multiple resource issues.	Success of NR Management, such as fire effects monitoring.	T&E Species that are known to breed on NPS-managed lands, populations are in decline or critical, and Park has responsibility for managing those populations.
3	Mission Support. Meeting the monitoring objective would provide information that would help the Park to better manage its resources, but is not necessary. Provides information that will influence one or more management decisions. Meeting this objective will provide information relevant to multiple resource issues.	Trends in external / adjacent land use Trends and impacts of Air Quality (for some parks) Habitat fragmentation Distributions of key species	T&E Species that are known to exist within park boundaries. Documentation of changes to populations (or lack thereof) would influence management or policy decisions.
2	Answering this question is of interest to the Park, but is not necessary for natural resource management. Effectively answering this question through a monitoring program might or might not shed light on multiple resource issues.	Research Biological inventories Protocol development	Park is in range of species, but occurrence in Park is unknown or undocumented. Species known to migrate over, but not necessarily in park lands.
1	Not the responsibility of the Park.	Marine Fisheries at CAHA (perhaps).	N/A
0	Not applicable to the Park.	Estuarine processes at HOBE	Species range and park boundaries do not overlap.

Concurrently, SECN staff conducted literature reviews on appropriate monitoring techniques that could be employed to meet the identified monitoring objectives (Figure 3-1). These monitoring techniques primarily included published protocols that could be implemented with little-to-no modification. Further, ongoing monitoring activities conducted by other agencies were evaluated for data utility in addressing the Network's needs with minimal effort to accommodate Network-specific needs.

A selection model was developed based on park scoring, identified methods, and relevance to each park within the network (see Appendix 4 for details on the model). The selection methods were designed to allow for the comparison of potential programs by explicitly identifying which monitoring objectives would be met at network parks given any combination of Vital Signs. The model generated prioritized lists of Vital Signs based on (a) the number of high-priority monitoring objectives they would help meet, and (b) their degree of similarity to other Vital Signs that might be implemented concurrently. Suites of Vital Signs were then identified that that as a group met the greatest number of monitoring objectives of the highest priority, for the greatest number of SECN parks. Only the final list of Vital Signs that was selected is presented in this chapter; for a complete discussion of program alternatives see Appendix 12.

Park-assigned priorities, appropriate methodologies, and overall monitoring objectives were evaluated during a series of subject-matter scoping sessions held in 2005. The Vital Signs discussed below (and the protocols discussed in Chapter 5) represent those identified as the optimal suite of Vital Signs for the SECN.

Vital Signs Selected for Implementation

Using the selection methods described in Appendix 4, the Southeast Coast Network has selected 25 Vital Signs for implementation (Table 3-2). The Vital Signs were selected to take maximum advantage of ongoing monitoring efforts being conducted by parks within the network and partnering agencies throughout the region, while meeting high-ranking monitoring objectives at all parks. Eleven of the selected Vital Signs will be monitored using data collected by park staff or other partnering agencies, and eleven will be monitored by SECN staff. Monitoring of three Vital Signs will be deferred until additional funding or partnership opportunities can be identified.

Relationship of Vital Signs to Conceptual Models and Justifications

Each Vital Sign is linked to our general ecosystem model, which encompasses the system drivers, local drivers, and key resources within each the six SECN ecosystems (Figure 3-2, Table 3-3). Monitoring data from the outermost Vital Signs (Local and System Drivers) will be important for interpreting the status and trends of monitoring collected from Vital Signs toward the center of the model.

Table 3-2.
Vital Signs to be monitored by the Southeast Coast Inventory & Monitoring Network. [✚ - Vital 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 monitored by a network park, another NPS program, or by another federal or state agency using other funding; ◈ - Monitoring deferred].

Ecological Monitoring Framework			Network Vital Sign	Measures	KEMO	CHAT	HOBE	OCMU	CONG	MOCR	CAHA	CALO	FOSU	FOPU	FOFR	CUIS	TIMU / FOCA	CASA / FOMA	CANA
Air and Climate	Air Quality	Ozone	Ozone	Atmospheric ozone concentration, damage to sensitive vegetation.	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
		Wet and Dry Deposition	Wet and Dry Deposition	Wet and dry sulfate and nitrate deposition.	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
		Visibility and Particulate Matter	Visibility and Particulate Matter	IMPROVE suite for visibility and fine particulates, particle size analyses: pm 10, pm 2.5, haze index.	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
		Air Contaminants	Air Contaminants	Concentration of mercury, semi-volatile organic compounds, acidic components of contaminants.	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	Weather and Climate	Weather and Climate	Weather and Climate	Air temperature, precipitation, relative humidity, tides, location and magnitude of extreme weather events.	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Geology and Soils	Geomorphology	Coastal / Oceanographic Features and Processes	Coastal Shoreline Change	Shoreline position.							✚	✚	✚	✚	✚	✚	✚	✚	✚
			Salt Marsh Elevation	Sediment elevation, salinity.							✚	✚		✚	✚	✚	✚	✚	✚
		Stream / River Channel Characteristics	Stream / River Channel Characteristics	Percent cover of coarse woody debris, detritus, distribution and extent of geomorphic features (runs, riffles, pools); grain size distribution; distribution, extent, and rate of change of erosion features.	✚	✚	✚	✚	✚	✚									
Water	Hydrology	Groundwater Dynamics	Groundwater Dynamics	Water table levels for freshwater and saltwater.	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
		Surface Water Dynamics	Surface Water Dynamics	Discharge, magnitude and duration of flooding events.	●	●	●	●	●	●							●		
	Water Quality	Water Chemistry	Marine Water Quality	pH, temperature, dissolved oxygen, turbidity, salinity, concentrations of chlorophyll a, TDN, TIN, TDP, TIP, metals, and volatile organic compounds.							✚	✚	◈	✚	◈	✚	✚	◈	✚
			Riverine Water Quality	pH, temperature, dissolved oxygen, specific conductance, turbidity, trace ions, nutrient concentrations.	✚	✚	✚	✚	✚	✚									
Biological Integrity	Invasive Species	Invasive/ Exotic Plants	Invasive / Exotic Plants	Occurrence of invasive plant species.	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚
	Focal Species or Communities	Marine Invertebrates	Marine Invertebrates	Occurrence of selected marine invertebrate species.							◈	◈	◈	◈	◈	◈	◈	◈	◈
		Fishes	Fish Communities	Fish community diversity, relative abundance, Index of Biotic Integrity, percentage of non-native species, number of crevice spawner species.	◈	◈	◈	◈	◈	◈	◈	◈	◈	◈	◈	◈	◈	◈	◈

Ecological Monitoring Framework			Network Vital Sign	Measures	KEMO	CHAT	HOBE	OCMU	CONG	MOCR	CAHA	CALO	FOSU	FOPU	FOFR	CUIS	TIMU / FOCA	CASA / FOMA	CANA
		Amphibians and Reptiles	Amphibians	Species occurrence, diversity, percent area occupied, disease incidence.	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚
		Birds	Breeding Forest Birds	Species occurrence, diversity, relative abundance.	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚
		Mammals	Small Mammals	Species occurrence, diversity, percent area occupied, relative abundance.	◈	◈	◈	◈	◈	◈	◈	◈	◈	◈	◈	◈	◈	◈	◈
		Vegetation Complex	Plant Communities	Plant species occurrence, diversity; percent cover by herbaceous, shrub and overstory; rooting by feral hogs and armadillos; occurrence of disease, occurrence of insect outbreaks, occurrence of non-native species; NVCS class.	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚
	At-risk Biota	T&E Species and communities	Shorebirds	Number and location of piping plover, red knot, Wilson's plover, American oystercatcher.							●	◈	◈	◈	◈	◈	◈	◈	◈
		T&E Species and communities	T&E Species	Abundance, distribution, and recruitment of rare species such as sea beach amaranth, beach mouse, sea turtles, red-cockaded woodpeckers.	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Human Use	Consumptive Use	Consumptive Use	Fisheries Take	Species occurrence, weight, size based on compilation of existing data from State and other sources.							●	●	●	●	●	●	●	●	●
Human Use	Visitor and Recreation Use	Visitor Usage	Visitor Use	Monthly and annual visitor attendance compiled from existing Park and other sources.	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Landscapes	Fire and Fuel Dynamics	Fire and Fuel Dynamics	Fire and Fuel Dynamics	Burn area and extent, down woody debris, duff depth.	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚
Landscapes	Landscape Dynamics	Landscape Dynamics	Land Cover and Use	Extent and distribution of land cover and use types, fragmentation, extent and distribution of management actions (compiled from park records).	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚

Table 3-3.
Vital Signs to be monitored by the Southeast Coast Inventory & Monitoring Network and the ecosystems in which they are relevant. [✚ - Vital 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 monitored by a network park, another NPS program, or by another federal or state agency using other funding; ◈ - Monitoring deferred].

Ecological Monitoring Framework			Network Vital Sign	Measures	Upland Forests	Bottomland Hardwoods	Rivers and Streams	Salt Marshes and Coastal Wetlands	Estuaries and Nearshore Marine	Barrier Islands
Air and Climate	Air Quality	Ozone	Air Quality	Atmospheric ozone concentration, damage to sensitive vegetation.	●	●	●	●	●	●
		Wet and Dry Deposition	Wet and Dry Deposition	Wet and dry sulfate and nitrate deposition.	●	●	●	●	●	●
		Visibility and Particulate Matter	Visibility and Particulate Matter	IMPROVE suite for visibility and fine particulates, particle size analyses: pm 10, pm 2.5, haze index.	●	●	●	●	●	●
		Air Contaminants	Air Contaminants	Concentration of mercury, semi-volatile organic compounds, acidic components of contaminants.	●	●	●	●	●	●
	Weather and Climate	Weather and Climate	Weather and Climate	Air temperature, precipitation, relative humidity, tides, location and magnitude of extreme weather events.	●	●	●	●	●	●
Geology and Soils	Geomorphology	Coastal / Oceanographic Features and Processes	Coastal Shoreline Change	Shoreline position.						✚
			Salt Marsh Elevation	Sediment elevation, salinity.				✚		
		Stream / River Channel Characteristics	Stream / River Channel Characteristics	Percent cover of coarse woody debris, detritus, distribution and extent of geomorphic features (runs, riffles, pools); grain size distribution; distribution, extent, and rate of change of erosion features.		✚	✚			
Water	Hydrology	Groundwater Dynamics	Groundwater Dynamics	Water table levels for freshwater and saltwater.	●	●	●	●		●
		Surface Water Dynamics	Surface Water Dynamics	Discharge, magnitude and duration of flooding events.		●	●	●		
	Water Quality	Water Chemistry	Marine Water Quality	pH, temperature, dissolved oxygen, turbidity, salinity, concentrations of chlorophyll a, TDN, TIN, TDP, TIP, metals, and volatile organic compounds.				✚	✚	
			Riverine Water Quality	pH, temperature, dissolved oxygen, specific conductance, turbidity, trace ions, nutrient concentrations.			✚			
Biological Integrity	Invasive Species	Invasive/ Exotic Plants	Invasive / Exotic Plants	Occurrence of invasive plant species.	✚	✚	✚	✚		✚
	Focal Species or Communities	Marine Invertebrates	Marine Invertebrates	Occurrence of selected marine invertebrate species.				◈	◈	
		Fishes	Fish Communities	Fish community diversity, relative abundance, Index of Biotic Integrity, percentage of non-native species, number of crevice spawner species.	◈	◈	◈	◈	◈	◈

Ecological Monitoring Framework			Network Vital Sign	Measures	Upland Forests	Bottomland Hardwoods	Rivers and Streams	Salt Marshes and Coastal Wetlands	Estuaries and Nearshore Marine	Barrier Islands
		Amphibians and Reptiles	Amphibians	Species occurrence, diversity, percent area occupied, disease incidence.	✚	✚	✚	✚		✚
		Birds	Breeding Forest Birds	Species occurrence, diversity, relative abundance.	✚	✚				✚
		Mammals	Small Mammals	Species occurrence, diversity, percent area occupied, relative abundance.	◈	◈				◈
		Vegetation Complex	Plant Communities	Plant species occurrence, diversity; percent cover by herbaceous, shrub and overstory; rooting by feral hogs and armadillos; occurrence of disease, occurrence of insect outbreaks, occurrence of non-native species; NVCS class.	✚	✚		✚		✚
	At-risk Biota	T&E Species and communities	Shorebirds	Number and location of piping plover, red knot, Wilson's plover, American oystercatcher.						●
		T&E Species and communities	T&E Species	Abundance, distribution, and recruitment of rare species such as sea beach amaranth, beach mouse, sea turtles, red-cockaded woodpeckers.	●	●	●	●	●	●
Human Use	Consumptive Use	Consumptive Use	Fisheries Take	Species occurrence, weight, size based on compilation of existing data from State and other sources.			●		●	
Human Use	Visitor and Recreation Use	Visitor Usage	Visitor Use	Monthly and annual visitor attendance compiled from existing Park and other sources	●	●	●	●	●	●
Landscapes	Fire and Fuel Dynamics	Fire and Fuel Dynamics	Fire and Fuel Dynamics	Burn area and extent, down woody debris, duff depth.	✚	✚				✚
Landscapes	Landscape Dynamics	Landscape Dynamics	Land Cover and Use	Extent and distribution of land cover and use types, fragmentation, extent and distribution of management actions (compiled from park records).	✚	✚	✚	✚	✚	✚

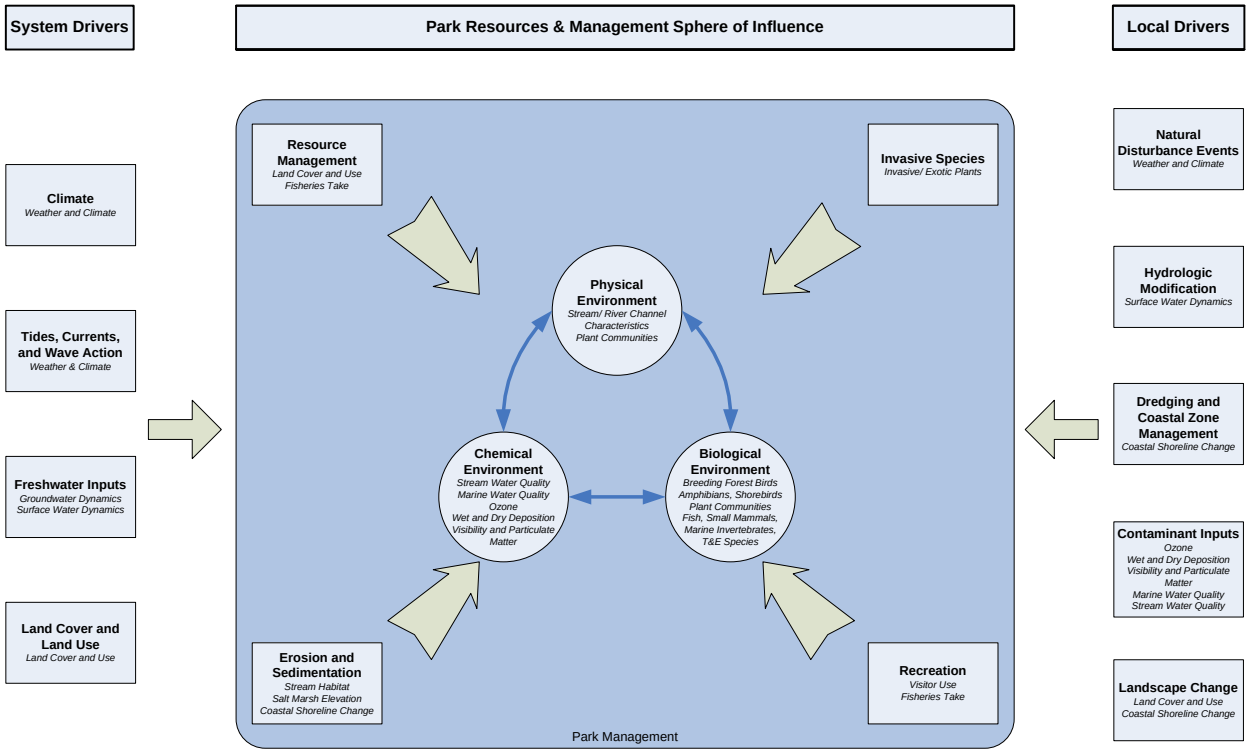


Figure 3-2. General Ecosystem Conceptual Model for the Southeast Coast Network with associated Vital Signs. Rectangles indicate predominant agents of change; circles represent major components of the ecosystem (detailed in supporting text). Large green arrows link agents of change to the entire ecosystem, including biotic, chemical, and physical components. The dark blue area includes those agents of change or resources that are currently/ actively managed by NPS.

Chapter 4. Sampling Design

Providing valid, unbiased, and relevant information on the status and trend of selected Vital Signs is one of the overarching goals of Southeast Coast Network long-term monitoring (see Chapter 1). Ensuring that monitoring data are representative of the resources of interest across space and time requires careful attention to sampling design; a proper design is one of the major means by which the SECN ensures utility of the data and scientific reliability and defensibility of the monitoring program.

Sampling designs, in general, outline the spatial and temporal strategy implemented to sample specifc attribute responses. Sampling designs must be explicitly connected to (a) monitoring goals and objectives (e.g., Knopman and Voss 1989; Gilbert 1987; see Chapter 1) and (b) analyses of monitoring data (see Chapter 7). This chapter identifies the major themes and concepts behind Southeast Coast Network sampling designs and discusses how sampling design facilitates integration among SECN protocols and with other monitoring efforts. Details of specific sampling designs will be documented in their associated monitoring protocols.

As part of the overall design of the SECN monitoring program, our goal is to develop a program where Vital Signs monitoring data collected under multiple protocols are integrated and analyzed holistically to improve science-based management of Park resources. The sampling framework to be employed by the SECN is consequently designed to allow Park and Network staff to assess environmental conditions across space and time, while developing an information base that will eventually allow us to explore relationships among multiple Vital Signs and forecast current or future ecosystem conditions.

It is not the intent of this chapter to discuss the sampling design for each of the SECN protocols. Each SECN Vital Sign or protocol has an evaluation and refinement period (see Appendix 13) that builds upon the sampling-design framework identified this chapter and is applied specifically to each protocol. In most cases, sampling designs are implemented following those in use by other agencies (e.g., those developed in partnership with cooperating agencies). In other cases, sampling designs are developed following a period of 1–3 protocol-evaluation years during which year, site, and other variance components are estimated in the context of a long-term monitoring effort. In all cases, a degree of flexibility is built into the designs so that adjustments can be made as network staff evaluates variability. This will ensure that all protocols utilize the most efficient sampling designs possible to meet SECN goals and objectives.

This chapter describes the overall sampling framework that will be used to guide the development and implementation of SECN protocols. Included in the discussion are the following:

1. Strategies for monitoring Vital Signs across space,
2. Strategies for monitoring Vital Signs across time,
3. Measurement approaches to be used by the SECN, and
4. Strategies for integrating sampling designs within and outside of the network's program.

Monitoring Across Space

To varying degrees, the SECN will employ census, probability, and non-probability designs. Probability-based designs are primarily Spatially Balanced Random Sampling (SBRS) while non-probabilistic designs include judgement, census, and opportunistic sampling. Table 4-1 briefly describes these design types, shows the major advantages and disadvantages of each type, and identifies the degree to which each type will be used.

Spatially Balanced Random Sampling (SBRS). Almost all protocols to be implemented by SECN staff will use a SBRS design (Tables 4-1 and 4-2). Spatially-balanced samples will be generated by the Generalized Random Tessellation Stratified (GRTS) algorithm (Stevens 1997, Stevens and Olsen 2003, Stevens and Olsen 2004) or the Reversed Randomized Quadrant-Recursive Raster (RRQRR) algorithm (Theobald et al. 2005). In general, the sampling design for most terrestrial -monitoring protocols is based on a systematic 0.5 ha grid in which all points, a systematic subset, or some random subset of the total, might be sampled.

Sentinel Site Monitoring. Sentinel sites will be used to (a) address site-specific management questions, (b) serve as a means to collect pilot data for future sampling design and protocol development/ implementation, and (c) estimate temporal variance in Vital Signs measurements. These sites may be randomly or non-randomly selected and might be used in conjunction with SBRS designs to balance the large spatial representation of samples with samples collected at permanent sites over time. Within the Southeast Coast Network, for example, monitoring at Sentinel Sites will be one of the primary methods for monitoring stream water quality and quantity where the parks do not have enough ecologically-relevant (or logistically feasible) sampling locations to warrant a probabilistic design. Generally, monitoring at Sentinel Sites is composed of core monitoring parameters that are included in all related modules such as the core water quality monitoring parameters.

Census. Census approaches will be used when it is desirable to monitor the entire population within the sampling frame. For the SECN this applies primarily to monitoring at-risk biota where the number of sampleable units is small and detectability is high, and to landscape-scale monitoring protocols where data collection and analyses are conducted through remote sensing or modeling techniques. When used, complete-census sampling designs will be used to maximize the number of samples collected for sampling design refinement; likely used only during pilot implementation, and to address site-specific management questions (e.g., monitoring of wintering Piping Plovers at Cape Hatteras National Seashore).

Opportunistic Sampling. Opportunistic sampling designs are those that have limited or no strict spatial or temporal guidelines. Opportunistic sampling will not be a primary design for any SECN protocols, but may be used in some cases to involve the public and volunteers in the monitoring program, provide early detection for potential stressors/ agents of change, or record and document infrequent occurrences of species.

Table 4-1.
Site-selection methods used by the Southeast Coast Network.

Design Type	Description	Advantages	Disadvantages	SECN Use
Spatially Balanced Random Sampling (SBRS).	As a probabilistic sample, each unit or element in the resource of interest has a known, non-zero probability of being included in the sample; some form of randomization is always included in the selection of sample locations (Stevens 1994, 1997). Uses a hierarchical randomization process to achieve spatial balance across regions and resources (Jean et al. 2005). Generalized Random Tesselation Stratified Design (GRTS; a form of probability design) Reversed Randomized Quadrant-Recursive Raster (RRQRR) algorithm (Theobald et al. 2005).	Produces a spatially balanced sample. Has a robust, unbiased variance estimator. Allows sites to be replaced in a logical way that maintains the validity of any sample (Stevens 1997; Stevens and Olsen 2003, 2004; Theobald et al. 2005. Samples are more representative than those produced by other probability designs. Can be used in virtually any monitoring design scenario. Applicable to aquatic or terrestrial resources. Can incorporate subsets of indicator suites by nesting sub-samples within a larger design. Can be fully specified to occur across time and to contain a complex array of site revisits. Can include primary and alternate (or oversample) sites. Can integrate resource classification or spatial structure in the resource of interest into the design. Can account for variability in response across boundaries. Subpopulations can be defined a priori or created after sampling based on observed patterns of variability on the responses.	The underlying sampling process is less intuitive to understand than alternative sampling schemes (Jean et al. 2005).	SECN default survey design.
Sentinel	Employs expert knowledge to varying degrees in the selection of sampling locations (Gilbert 1987).	Convenient. Efficient.	Unknown selection bias is common (Stehman and Overton 1994; Stoddard et al. 1998; Olsen et al. 1999). Often mismatched to monitoring goals. Population-scale inference is only possible with a (usually complex) model (Burke and Lauenroth 1993; Gilliom et al. 1995). No statistical inferential ability.	Limited to fixed-station water quality monitoring protocols. Data will be used as sentinels of conditions within the systems in which they are deployed with recognition that elements will be incorporated into more robust design types as appropriate.
Census	Examines every unit in the population of interest.	Random-sampling variation is eliminated. Error is limited to observer bias and monitoring technique (measurement error).	Expensive. Rarely possible.	Will be used only where relatively inexpensive techniques allow efficient collection of monitoring data across entire parks and it is clear that the census is valid (applies to most monitoring that is remotely sensed).
Opportunistic	Opportunistic sampling designs are those that have limited o no strict spatial or temporal guidelines. Includes incidental observations of species occurrences.	Allows for rapid collection of large quantities of data by interested parties. Provides opportunities for citizen science outreach and involvement.	Lack of standardized sampling design renders data of limited use for comparison with other data sets. Data reliability difficult to control. Data quality likely only high for species that are easily-identifiable, high profile, and well established in the area.	Opportunistic sampling will not be a primary design for any SECN protocols, but may be used in some cases to involve the public and volunteers in the monitoring program, provide early detection for potential stressors/ agents of change, or record and document infrequent occurrences of species. Will only be implemented *in addition* to other sampling designs.

Monitoring Across Time

Re-visitation schedules for SECN Vital Signs vary from continuous monitoring to once every five years. The frequency of monitoring Vital Signs is based on a combination of known or

expected rates of change, expert opinion, and the logistical constraints of implementing protocols at 17 parks.

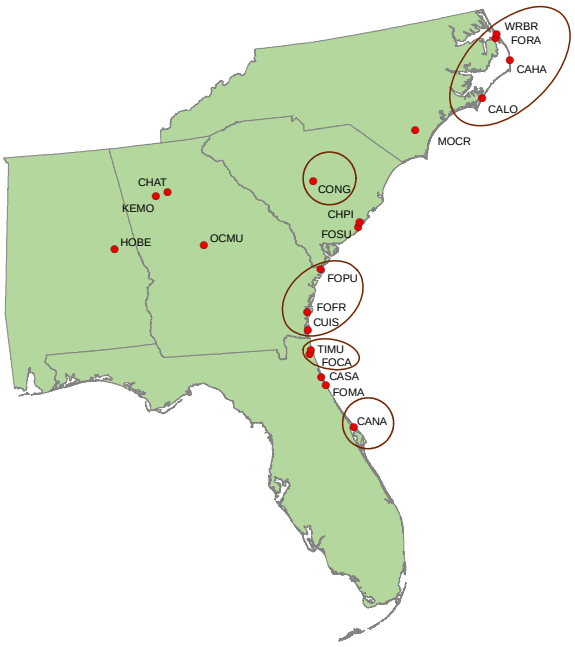


Figure 4-1. Sampling tours for probabilistic estuarine- and freshwater-quality monitoring protocols. Water bodies contained within each tour are sampled in the same sampling seasons and are revisited once every five years. See Chapter 9 for details for protocol implementation schedule.

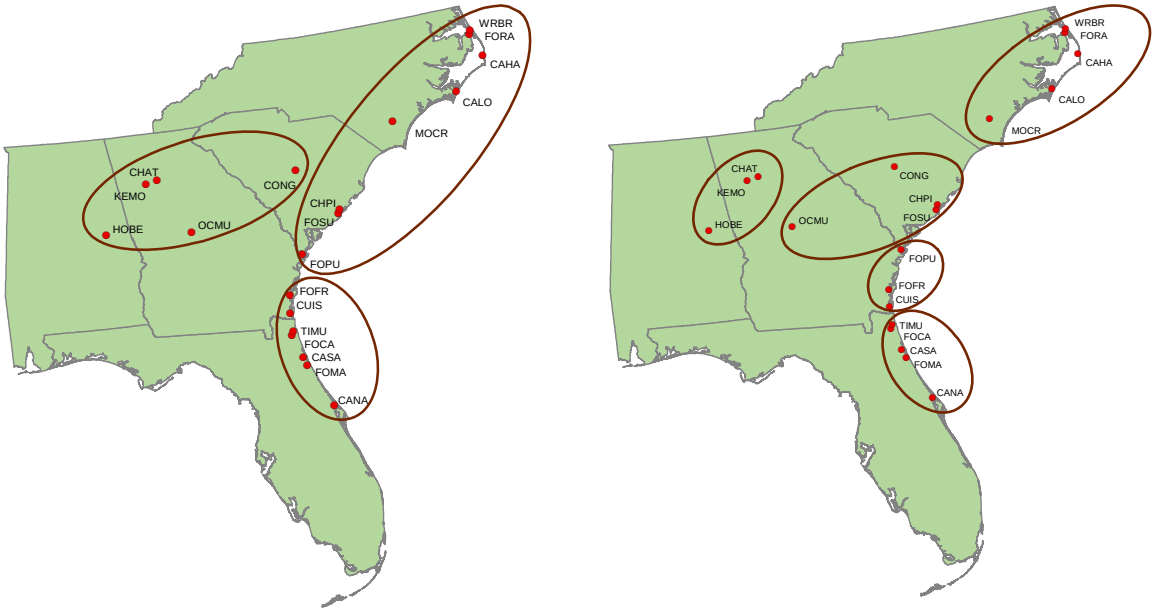


Figure 4-2. Sampling tours for wildlife and plant community monitoring protocols based on a 3-year (left) and 5-year (right) revisit schedule. See Chapter 9 for details on protocol implementation schedule.

The Network has been subdivided into multiple "tours," in which all parks within a tour are sampled the same year (Figures 4-1 and 4-2). The Network's estuarine systems are divided into four tours in which water quality is sampled once every five years (Figure 4-1). During the off year, freshwater quality will be monitored at CONG, which due to its increase size (and number of tributaries to be monitored) will require a larger sampling effort than the other parks with riverine resources. Tours have been similarly designed for parks to govern terrestrial sampling based on a three-year and five-year return interval (Figure 4-2). Initially all terrestrial monitoring is planned to be implemented once every three years, but the frequency might decrease depending on initial data.

Measurement Approaches

Three measurement approaches will be used when developing SECN protocols: *direct measures*, the use of *metric-based assessments*, and *modeled responses*.

- *Direct Measures.* Measures are those specific feature(s) used to quantify an attribute or indicator, as specified in a sampling protocol. For example, pH, temperature, dissolved oxygen, and specific conductivity are all measures of water chemistry. Measures can provide information about ecological attributes (measuring water chemistry provides information about water quality) or about ecological indicators (measures of water quality provide information about the overall "health" of the watershed).

- *Metric-Based Assessments.* Metrics are those *measures* that respond predictably to environmental stressors or gradients within an ecosystem and to which scoring criteria are applied. Scores for individual metrics are generally based on either (a) difference from reference conditions, (b) trends, threshold responses, or patterns along one or more environmental gradients, or (c) expert opinion/ judgment. *Metric-Based Assessments* are then the methods by which scores from two or more *metrics* are systematically combined provide a semi-qualitative summary about the condition of monitored resources, such as "Good," "Fair," or "Poor" (modified from Karr and Chu, 1997).

- *Modeled Responses.* Data from one or more sampling locations are used to infer the status of conditions in an area of interest. A modeling approach to Vital Signs Monitoring will only be used in limited situations where existing methods and data sets allow for inference of park conditions based on data collected in or around parks by NPS and partnering agencies (such as air quality and climate data).

Although the SECN will use all three measurement approaches, the network will initially rely most heavily on direct measures (Table 4-2). As protocols are implemented, the network will evaluate data from all measures for their suitability as metrics to be included in multimetric indexes. Monitoring protocols will describe the methods and rationale for selecting metrics, determining individual metric scores, and their systematic use in metric-based assessments.

Integration

In a successful comprehensive monitoring program, individual components must be integrated so that the interpretation of the whole program yields information more useful than that of its

individual parts. Integration among Vital Signs is needed for the SECN to (a) understand the dynamic responses to changes in drivers or stressors within parks, (b) understand the interaction effects among Vital Signs, and (c) reduce the confounding effects of other Vital Signs in the interpretation of a given Vital Sign. Much of this depends upon compatible sampling designs and analytical strategies. The remainder of this chapter deals with how SECN monitoring is integrated both within and outside of the NPS I&M program, and how sample designs factor into this.

Table 4-2.
Site selection strategy, measurement approaches, and re-visitation schedules for Vital Signs monitoring in Southeast Coast Network. See Chapter 5 for a description of the protocols. Multiple revisit schedules indicated for Vital Signs monitored using multiple protocols.

	Site Selection				Measurement Approach			Revisit Schedule
Network Vital Sign	Spatially Balanced	Sentinel	Census	Opportunistic	Direct	Metric-Based Assessments[1]	Modeling	
Ozone		●			●		●	Continuous
Wet and Dry Deposition		●			●		●	Continuous
Visibility and Particulate Matter		●			●		●	Continuous
Air Contaminants		●			●		●	Continuous
Weather and Climate		●			●		●	Continuous
Coastal Shoreline Change			●		●			6 month
Salt Marsh Elevation	●	●			●			1 year
Stream/ River Channel Characteristics	●				●	●		5 years
Groundwater Dynamics		●			●		●	Continuous
Surface Water Dynamics		●			●			Continuous
Marine Water Quality	●	●			●	●		Continuous Monthly 5 years
Riverine Water Quality	●	●			●			Continuous 5 years
Invasive/ Exotic Plants	●			●	●	●		3 years
Amphibians	●			●	●	●		3 years
Breeding Forest Birds	●			●	●	●		3 years
Plant Communities	●			●	●	●		3 years
Shorebirds			●	●	●			3 Per Month
T&E Species		●	●	●	●			TBD
Fisheries Take			●		●			1 year
Visitor Use		●			●			1 year
Fire and Fuel Dynamics	●				●			1 year
Land Cover and Use			●		●			3 years

[1]Metric-Based Assessments will largely not be implemented until data from initial sampling are analyzed, appropriate metrics are identified, and scoring criteria are determined.

Integration Among I&M Networks

One goal of the NPS I&M program is to provide the information needed by park managers for understanding and managing network parks; however, it also is intended that some subset of the selected Vital Signs will provide information at scales broader than network parks. Thus, an additional sampling design consideration is whether or not there is a need, value, or expectation for implementing designs that can be scaled up to levels beyond the SECN. Several SECN protocols are based on or adopted from other networks (especially the SFCN, NCBN, and PACN). Because many of these Vital Signs are using SBRS-based designs, integration at the design level with SECN protocols will be more efficient. Measurements and field methods also are standardized as much as possible with other NPS networks to facilitate comparative analyses.

Integration Among Agencies

Although the I&M program is an NPS endeavor, many Vital Signs cross jurisdictional boundaries, and interest and concerns about these Vital Signs are often shared by other agencies. Cooperative efforts among agencies also can increase efficiency and broaden application. Thus, the SECN coordinates and collaborates with other agencies and organizations that share a common interest in certain Vital Signs. Several SECN protocols, and subsequent sampling designs, are adopted directly from monitoring occurring at the state or regional scale (e.g., the EPA EMAP, NOAA NERR, and USGS NAWQA programs) and because some of these programs are using SBRS-based designs and analyses similar to those of the SECN, integration at the design level with SECN protocols will be facilitated. Measurements and field methods are also standardized as much as possible for comparability of data with state and federal programs.

Integration Within and Among SECN Protocols

Vital Signs are not environmentally and ecologically independent entities. Rather, they are often the products of complex interactions among other Vital Signs and/or other ecosystem components or attributes. Without some consideration of how Vital Signs interact, the SECN monitoring program would have no added value apart from the sum of its parts. As such, many SECN sample designs use SBRS designs and similar sample frames. This will allow for analytical as well as operational integration of the Vital Signs within these protocols.

Co-location and Co-visitation

The SECN's sample designs emphasize both co-location (monitoring multiple Vital Signs at the same physical locations) and co-visitation (recording observations on multiple Vital Signs during a sampling occasion), both of which are greatly facilitated by common or similar sample designs. One obvious benefit to co-location and co-visitation is operational efficiency; time and costs for plot establishment and sampling are reduced when multiple Vital Signs are measured at the same place and time. Co-location of samples also can facilitate assessment of the response of the system to drivers or stressors (e.g., vegetation responses to climate) as well as interactions among Vital Signs (e.g., effects of upland erosion on water turbidity). Under some circumstances, co-location can aid in the identification and interpretation of confounding effects and increase sampling efficiency.

Co-location of samples within and across protocols, however, is not a panacea for ecological insights, and the costs and benefits should be considered. To decide whether samples warrant co-

location, the SECN considers (a) the specific objectives of the Vital Sign(s) being sampled, (b) the feasibility of co-locating samples, (c) the probability of expected increased insights, and (d) the compatibility and overlap in the target populations and the Vital Signs spatiotemporal scale.

Ecological, Spatial, and Temporal Integration

Ecological, spatial, and temporal integration will largely not be possible for many years, until a sufficient body of data exist to explore relationships, and trends among the various measures. To facilitate this, SECN protocols and their sampling designs are intended to monitor scale-dependent processes and to accommodate future integration within and among scales. For example, estimates of climatic parameters derived from regional monitoring networks provide a backdrop for evaluating large-scale changes in abiotic drivers of change. Remotely sensed information on landscape structure, condition, and land use in and adjacent to park lands, and at multiple scales, provides key measures of spatial pattern and human disturbance, while the status and trends of fine-scale attributes are monitored with ground-based field plots. The spatial hierarchy of monitored attributes permits understanding of cross-scale interactions, for instance, the effects of regional climatic conditions on patterns and trends in landscape condition, or the effects of large-scale climatic conditions and proximate landscape structure on plot-based trends. Additionally, fine-scale data will be used to inform analyses of data collected at coarser scales (e.g., imagery classification and interpretation of land condition), and potentially as the basis for interpolating fine-scale measures to the landscape (Ohmann and Gregory 2002).

Ecological integration involves considering the ecological linkages among system drivers and the components, structures, and functions of ecosystems when selecting Vital Signs. An effective ecosystem monitoring strategy will employ a suite of individual measurements that collectively monitor the integrity of the entire ecosystem. By defining the analysis at a scale that encompasses multiple Vital Signs, data from different protocols can be analyzed as covariates, drivers, or responses to changes in each other. Defining the relevant scale of analysis and integrating data across Vital Signs is a critical component of analysis and interpretation. One approach for effective ecological integration is to develop measures at various hierarchical levels of ecological organization (e.g., landscape, community, population, genus).

Spatial integration involves establishing linkages of measurements made at different spatial scales within a park or network of parks, or between individual park programs and broader regional programs. It requires an understanding of scalar ecological processes, the co-location of measurements of comparably scaled monitoring indicators, and the design of statistical sampling frameworks that permit the extrapolation and interpolation of scalar data.

Temporal integration involves establishing linkages between measurements made at various temporal scales. It requires determining a meaningful timeline for sampling different attributes while considering characteristics of temporal variation in those attributes. For example, sampling changes in the structure of a stream channel (e.g., channel sinuosity) may require much less frequent sampling than is required to detect changes in the composition or density of aquatic invertebrates. Temporal integration requires nesting the more frequent and, often, more intensive sampling within the context of less frequent sampling.

Chapter 5. Sampling Protocols

Overview

To implement the SECN Vital Signs Monitoring Program, the Network will implement ten protocols to monitor eleven of the Network's Vital Signs (Table 5-1). An additional eleven Vital Signs will be monitored using data collected by partnering agencies, parks, or other organization (Table 5-2).

The SECN 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 taken by different people or in slightly different ways (Oakley et al. 2003). Protocols are essential for monitoring Vital Signs consistently through time.

Monitoring protocols include a narrative providing the rationale for Vital Sign selection, an overview of the monitoring protocol components, and a history of the development of the protocol. The narrative details protocol sampling objectives, sampling design, field methods, data analysis and reporting, staffing requirements, training procedures, and operational requirements (Oakley et al. 2003). Narratives also summarize the design phase of a protocol development and any decision-making that is relevant to the protocol. Documenting the history of a protocol during its development phase will also ensure future refinement of the protocol continues to improve the protocol and is not a mere repetition of previous trials or comparisons (Oakley et al. 2003). Narratives also provide a listing and brief summary of all standard operating procedures (SOPs), which are developed in detail as independent sections in the protocol.

The SOPs included with all protocols thoroughly explain in a step-by-step manner how each procedure identified in the protocol narrative will be accomplished. At a minimum, SOPs address pre-sampling training requirements, data to be collected, equipment operations, data collection techniques, data management, data analysis, reporting, and any activities required at the end of a field season (i.e., equipment storage). An additional SOP identifies when and how revisions to the protocol are undertaken. As stand alone documents, SOPs are easily updated compared to revising an entire monitoring protocol. A revision log for each SOP identifies any changes that are implemented.

Finally, monitoring protocols identify supporting materials critical to the development and implementation of the protocol (Oakley et al. 2003). Examples of this material may include databases, reports, maps, geospatial information, species list, species guilds, analysis tools tested, and any decisions resulting from these exploratory analyses. Material not easily formatted for inclusion in the monitoring protocol also can be included in this section.

Table 5-1.
Monitoring protocols and associated Vital Signs to be implemented by the Southeast Coast Network, with the parties responsible for data collection indicated. Development schedule and status of each protocol are provided in Appendix 13.

Protocol Name (***Vital Sign, Where Different***)	**Monitoring Objectives**	**Parks**	**Park**	**Partner**	**SECN**
Coastal Shoreline Change	Measure the position of ocean-side shorelines annually to semi-annually. Measure the position of sound-side shorelines every three years. Identify coastal erosion hotspots in ocean- and sound-side shorelines within network parks.	CAHA, CALO, FOPU, FOFR, CUIS, TIMU, FOMA, CANA, FOSU			X
Stream Habitat Assessment	Determine trends in the quantity and distribution of macrohabitat features such as channel dimensions (longitudinal profile and cross-sections), percent cover of habitat units (runs, riffles, and pools), and channel hydraulic relationships. Determine trends in the quantity and distribution of microhabitat features such as detritus, coarse woody debris, and bed sediments.	HOBE, KEMO, CHAT, OCMU, CONG, MOCR			X
Salt Marsh Elevation	Determine the rate of salt marsh accretion or subsidence. Determine trends in soil salinity.	CAHA, CALO, FOPU, FOFR, CUIS, TIMU, FOMA, CANA			X
Marine Water Quality	Determine the status, trends, and spatial variability of salinity, dissolved oxygen, pH, nutrients, chlorophyll, temperature, and sediment chemistry in park estuaries.	CAHA, CALO, CUIS, CANA, TIMU, FOPU		X	X
Fixed-Station Water Quality (*Stream and Marine Water Quality*)	Determine the trends as well as diel, monthly, and annual variability of salinity, dissolved oxygen, pH, and temperature at select sites in park estuaries. Determine the trends as well as monthly and annual variability of total dissolved nitrogen, total dissolved phosphorus, secchi depth, and chlorophyll a at select sites in park estuaries.	CAHA, CALO, CUIS, TIMU, FOPU, CONG	X	X	X
Amphibians (*Amphibians and Fire & Fuel Dynamics)*	Determine trends in amphibian species distribution, diversity, and detection/non-detection within SECN parks. Determine trends in soil moisture, down woody debris (DWD) and duff depth within SECN parks. Determine trends in frequency of occurrence of Batrachochytrium *dendrobatidis* in amphibians in SECN Parks.	All			X
Breeding Forest Birds	Determine trends in breeding forest-bird species distribution, diversity, and detection/non-detection in SECN Parks.	All			X
Plant Communities (*Plant Communities, and Invasive / Exotic Plants*)	Determine trends in percent cover and diversity of plant species (both native and non-native) in the herbaceous, shrub, and overstory strata. Determine trends in warm season species richness and diversity within SECN parks.	All			X
Wintering & Migratory Shorebirds	Identify areas of consistent use by migratory and/or wintering focal shorebirds at CAHA and if these areas remain consistent over time. Determine habitats in which wintering/focal shorebirds are most frequently observed at CAHA. Determine spatial and temporal variability in beached birds at CAHA.	CAHA	X		
Landscape Change Detection	Determine the physiognomic class and change class of 0.5-ha grid cells for all areas of SECN parks. Determine trends in the type, location, and variability of land cover and land use within and around SECN parks as determined by analysis of existing and emergent GIS data layers.	All			X

Table 5-2.
Vital Signs to be implemented through the use of data collected by partnering parks, agencies, or other organizations. Development schedule and status of each SOP that outlines for the acquisition, management and interpretation of data for these Vital Signs are provided in Appendix 13.

Vital Sign(s)	Monitoring Objectives	Parks	Data Source(s)
Ozone	Determine the weekly, seasonal, and annual status and trends in ozone concentration.	All	NPS-ARD
Wet and Dry Deposition Air Contaminants	Determine the weekly, seasonal, and annual status and trends in dry deposition chemistry. Determine the weekly, seasonal, and annual status and trends in concentrations of sulfate, nitrate, nitrate, nitric acid, sulfur dioxide, ammonium, and other selected cations from wet deposition.	All	NADP/NTN CASTNET
Visibility and Particulate Matter	Determine the weekly, seasonal, and annual status and trends in concentrations of visibility-reducing pollutants.	All	IMPROVE
Weather & Climate	Determine status, trends, and variability of precipitation and temperature over time inside and around SECN park units. Determine the status, trends, and variability of derived weather data (i.e., drought indices) inside and around SECN park units. Track the location, magnitude, and frequency of extreme weather events that affect SECN park resources. Determine the time, and magnitude of lunar and storm-driven tidal events for marine and estuarine water bodies within SECN parks.	All	NOAA NWS States NPS
Groundwater Dynamics	Determine status and trends of freshwater and saltwater Table levels in existing groundwater wells.	All	USGS States
Stream Flow Discharge	Determine the status and trends of stream flow discharge in streams that flow into park boundaries. Determine the frequency, duration, and magnitude of stream discharge during peak flow events in streams that flow into park boundaries.	HOBE, KEMO, CHAT, OCMU, CONG, MOCR, FOPU, TIMU, FOMA	USGS
Stream Water Quality	Determine status and trends of water temperature, pH, conductivity, dissolved oxygen, nutrients, major ions (sulfate, chloride, nitrate, magnesium, calcium, potassium, sodium), and trace metals (including aluminum, copper, iron, manganese, lead, zinc), and/or fecal coliform bacteria in streams that flow into park boundaries.	HOBE, KEMO, CHAT, OCMU, CONG, MOCR	USGS States
Fisheries Take	Compile data from existing data sources related to commercial and recreational fisheries take (finfish and shellfish) in waters inside and adjacent to park boundaries. Determine the status and trends of commercial and recreational fisheries take in waters inside and adjacent to park boundaries.	CAHA, CALO, CUIS, CANA, TIMU, FOMA, FOFR, FOSU, FOPU	States
Visitor Use	Compile and summarize existing NPS visitor use data to determine monthly, seasonal, and annual visitor use rates for all SECN parks (as data permit).	All	NPS
Land Management & Disturbance	Determine the frequency, and spatial extent of natural and anthropogenic and natural changes to the landscape caused by park management or natural disturbance events.	All	NPS

A summary of each of the monitoring protocols to be implemented during the program's first five years is provided below. The descriptions include the Vital Signs to be monitored, monitoring objectives to be addressed, and a description of monitoring approach to be implemented. Justifications for the selection of Vital Signs are included in Chapter 3. Brief descriptions are presented below for all protocols to be developed by the SECN. More detailed descriptions of the protocols including justification, monitoring objectives, and development and implementation schedules can be found in Appendix 13. Methods for acquiring, analyzing, and managing data collected by partners will be included as appendices in the SECN Information Management Plan (Wright et al., 2007) as they are developed.

Coastal Shoreline Change

Parks

Cape Hatteras National Seashore
Cape Lookout National Seashore
Fort Pulaski National Monument
Fort Frederica National Monument
Cumberland Island National Seashore
Timucuan Ecological and Historic Preserve
Fort Matanzas National Monument
Canaveral National Seashore
Fort Sumter National Monument

Objectives

- Measure the position of ocean-side shorelines annually to semi-annually.
- Measure the position of sound-side shorelines every three years.
- Identify coastal erosion hotspots in ocean- and sound-side shorelines within network parks.

Monitoring Approach

Coastal Shoreline Change will be measured in one of two ways: through GPS positional and attitude measurements of shorelines on the foreshore, and through change detection of remotely sensed data on the sound-side shore. Mapping will occur annually to semi-annually and following storm events.

GPS Measurements. To determine park-wide trends in shoreline movement, a sampling design that includes all ocean shorelines and selected sandy beach bay/estuary areas will be used following protocols developed by the United States Geological Survey (USGS) (List et al. Unpublished). SECN will monitor the horizontal position of mean high water (MHW) contour using the measurement system SWASH (Surveying Wide Area Shorelines). SWASH consists of GPS positioning and a GPS-based attitude sensor mounted on an amphibious all-terrain vehicle (ATV), which is driven along the beach foreshore at low tide. Vehicle attitude and position in three dimensions are used to calculate the horizontal location of the MHW contour through linear extrapolation from the position of the vehicle track. Contour positioning errors are estimated by two approaches: a standard method whereby bulk statistics are used to estimate a 95% confidence interval, and a local method for estimating error that depends on the local beach slope and the deviation between the ATV track height and the target MHW elevation. The standard method gives an estimate of shoreline positioning error on the order of +/-1.6 meters. The local method provides error increases as the vehicle track deviates significantly from MHW. The SWASH system can survey up to 70 km of coast within the 3-4 hours bracketing low tide, and is ideal for rapid-response measurements of storm impacts as well as for repetitive shoreline survey programs over longer periods. Data collected by SWASH is compatible with LIDAR (Light Detection and Ranging) based shoreline studies.

Remote Sensing. Change detection methods and GPS ground surveys will be used to estimate sound-side shoreline change over time using remotely sensed data from a variety of sources. The SECN is currently working with the University of Georgia Natural Resource Spatial Analysis Lab on change detection methods based on existing methodologies and technologies (Phillipson 1997, Richards and Jia 2005). The frequency at which remotely-sensed data will be collected will vary from park to park, but will occur at a minimum of once every three years.

Stream Habitat Assessment

Applicable Parks

Horseshoe Bend National Military Park
Kennesaw Mountain National Battlefield Park
Chattahoochee River National Recreation Area
Ocmulgee National Monument
Congaree National Park
Moores Creek National Battlefield

Objectives

- Determine trends in the quantity and distribution of macrohabitat features such as channel dimensions (longitudinal profile and cross-sections), percent cover of habitat units (runs, riffles, and pools), and channel hydraulic relationships.

- Determine trends in the quantity and distribution of microhabitat features such as detritus, coarse woody debris, and bed sediments.

Monitoring Approach

Stream Habitat Assessments will be conducted using a combination of protocols available from federal and State agencies. A combination of transect- and reach-based approaches will be used to monitor stream habitat once every five years (such as Gorman and Karr 1978, Platts et al. 1983, Simonson et al. 1993, Simonson et al. 1994, Illinois Environmental Protection Agency 1994, Fitzpatrick et al. 1998). A hybrid of several protocols will be implemented to ensure data comparability among SECN parks, and the various State and federal agencies with whom the SECN will partner.

In general, the spatial unit to be evaluated will be a reach composed of three sequential riffle-pool units with an overall length of approximately four riffles from crest to crest. Selection of reaches within parks will follow a generalized random tessellation stratified (GRTS) design which randomly selects sites with guaranteed spatial balance, ensuring park-wide inferences can be made (McDonald and St.Clair 2004).

SOPs will be developed for SECN streams as well as for three reach scales: (a) small wadeable streams that are <10 meters wide), (b) large wadeable streams that are10-50 meters wide), and (c) nonwadeable streams (width measures are approximate). For example, methods for monitoring sediment grain size distribution may vary depending on the depth of the river.

Salt Marsh Elevation

Parks

Cape Hatteras National Seashore
Cape Lookout National Seashore
Fort Pulaski National Monument
Fort Frederica National Monument
Cumberland Island National Seashore
Timucuan Ecological and Historic Preserve
Fort Matanzas National Monument
Canaveral National Seashore

Objectives

- Determine the rate of salt marsh accretion or subsidence.
- Determine trends in soil salinity.

Monitoring Approach

Monitoring *Salt Marsh Elevation* following methods described in Cahoon et al. (2006) will provide data to assess the potential threats to salt marsh resources at SECN parks as well as contribute to a worldwide effort to monitor sea level rise.

Cahoon and others have demonstrated that subsurface processes can exert significant influence over sediment elevation in many wetland systems (Cahoon et al. 1995, Cahoon et al. 1999, Cahoon et al. 2000). The question arises as to whether sediment elevation in a given wetland is controlled by a biological, hydrological, or geological process. One approach to determining which process is driving sediment elevation is to quantify elevation change over different portions of the sediment profile (e.g., the root zone versus the entire profile between the sediment surface and base of the bench mark). The Southeast Coast Network will be deploying Rod Surface Elevation Table (RSET) monitoring stations at parks with significant saltmarsh wetland resources to measure the relative effects of surface and subsurface processes on salt marsh elevation change using or modifying protocols in development by the CACO prototype monitoring program (*in development*). The RSET works on the same principle as the Surface Elevation Table (Cahoon et al. 2002) but permits the determination of elevation change occurring over different portions of the sediment profile because it can be attached to bench marks that are driven to both deeper and shallower depths than the SET. A minimum of three RSET index stations will be deployed in each park following the methods of Cahoon et al. (2006). Elevation measurements will be conducted annually at each station.

In addition, soil salinity will be measured at all points where *Vegetation Community* monitoring occurs within network salt marshes.

Marine Water Quality

Parks

Cape Hatteras National Seashore
Cape Lookout National Seashore

Cumberland Island National Seashore
Canaveral National Seashore
Timucuan Ecological & Historic Preserve / Fort Caroline National Monument
Fort Pulaski National Monument

Objectives

- Determine the status, trends, and spatial variability of salinity, dissolved oxygen, pH, nutrients, chlorophyll, temperature, and sediment chemistry in park estuaries.

Monitoring Approach

When developing designs to meet specific objectives for the *Marine Water Quality* protocol, the SECN will use designs used by EPA's Environmental Monitoring and Assessment Program (EMAP) (i.e., probabilistic site selection using simple random, stratified, or nested designs). An integrated design for assessing water quality incorporates multiple tools in a tiered approach to address management decisions at multiple scales. These tools include probabilistic designs, landscape and water quality modeling, and targeted site-specific monitoring. This tiered approach will allow NPS to make statistically valid inferences of the extent that waters meet water quality standards, to predict which waters are most likely degraded or at risk for degradation, and to target site-specific monitoring needed to address local water quality concerns and short-term variability.

To accomplish this, the SECN will augment existing annual sampling efforts (i.e., those conducted by state and federal agencies) to ensure adequate sampling coverage in or adjacent to park resources. Parks will be sampled once every five years for water quality and once every ten years for sediment toxics. This monitoring will follow the probability-based sampling conducted by the National Estuarine Program (NEP). Field work will be conducted following methods in Strobel and Heitmuller (2001).

Fixed-Station Water Quality

Parks

Cape Hatteras National Seashore
Cape Lookout National Seashore
Cumberland Island National Seashore
Fort Pulaski National Monument
Timucuan Ecological and Historic Preserve
Canaveral National Seashore
Congaree National Park

Objectives

- Determine the trends as well as diel, monthly, and annual variability of salinity, dissolved oxygen, pH, and temperature at select sites in park estuaries.

- Determine the trends as well as monthly and annual variability of total dissolved nitrogen, total dissolved phosphorus, secchi depth, and chlorophyll a at select sites in park estuaries.

Monitoring Approach

This protocol is modeled after the water quality monitoring program established by the National Estuarine Research Reserve Program (NERR) (Wenner and Geist 2001). It is based on fixed monitoring sites that use automatic dataloggers to collect semi-continuous data on pH, dissolved oxygen, temperature, salinity/conductivity, depth, and turbidity. Guidance from local, regional and national experts at our water quality monitoring scoping meeting (DiDonato 2005) for estuarine and nearshore marine waters suggests additional samples be taken monthly (standardized at low tide) at each fixed site. Parameters to include in this sampling are Total Dissolved Nitrogen (TDN), Total Dissolved Phosphorus (TDP), Chlorophyll a (Chl a) and Secchi depth. Quarterly, dissolved nutrients should be broken down by species. Sampling these additional parameters will help us to address management concerns regarding development, discharges, land use practices and recreational use. Placement of sites are made in conjunction with park staff based on accessibility, their suitability as reference stations, or to measure current or potential problems within the park.

At each site, a datalogger (e.g., YSI 6600) will be deployed and installed using methods developed by the NERR program (Wenner and Geist 2001). Instruments will be attached to a fixed piling and, where possible, be deployed at a standard 1m from bottom. Dataloggers will be programmed to take a reading every 30 minutes. Parameters to be measured include: Depth, Temperature, pH, DO, Salinity, and Turbidity. Although a Chlorophyll probe is available for these instruments, experience of subject matter experts has shown that these data are neither accurate nor reliable. Every 2-4 weeks (depending on time of year) each datalogger will be retrieved and replaced with another calibrated datalogger. At that time it will be useful to also record site data such as the presence/absence of fish kills, algal blooms, marine mammal strandings, and marine debris will also be collected. Data from each retrieved datalogger will be downloaded, and the instrument cleaned. In addition to datalogger data, monthly at these sites samples will be collected using protocols developed by the NERR program.

Amphibians

Parks

All SECN Parks

Objectives

- Determine trends in amphibian species distribution, diversity, and detection/ non-detection in SECN parks.

- Determine trends in soil moisture, down woody debris and duff depth within SECN Parks.

- Determine trends in frequency of occurrence of *Batrachochytrium dendrobatidis* in amphibians in SECN Parks.

Monitoring Approach

Three methods will be used to monitor amphibians: (a) automated recording devices (ARD), (b) intermediate intensity visual encounter surveys (VES), and (c) sampling of select amphibians for presence of *B. dendrobatidis*. The ARDs will be deployed prior to implementing the VES

technique to minimize any possible confounding effects the VES might have on vocal-anuran presence. Amphibian monitoring will be conducted at each park once every three years.

Automated Recording Devices. Auditory surveys are appropriate for monitoring breeding populations of many frog and toad species that advertise their breeding activities with distinctive calls. The ARD consists of a timer, digital recording device, and a microphone housed in a waterproof case. The device does not record environmental variables. Each ARD is positioned at the center point of the macroplot. The ARDs will be initially programmed to record one minute intervals every 10 minutes for fourteen hours (84 intervals / night) for nine days. ARDs will be deployed at a maximum of 30 sites per park depending on samplable area. Data are downloaded at the end of the deployment period and recordings are analyzed using call recognition software (Song Scope Bioacoustics Monitoring Software, Wildlife Acoustics, Inc.). Species accumulation curves will be generated during pilot implementation to determine the minimum amount of recording time necessary in order to maximize species diversity.

Visual Encounter Surveys. The VES technique is an effective method for determining species richness of amphibians in a given area (Crump and Scott 1994). All habitats and potential cover objects (e.g., leaf litter, under logs/rocks, other potential cover items) are searched and all species detected are identified and recorded. Animals are captured, if necessary, to facilitate accurate identification. If streams or wetlands are encountered within the macroplot, dip-nets and hand-capture is used, as necessary, to detect aquatic amphibians. All cover objects are returned to their original position to reduce habitat impacts. This method is time-constrained; however the duration of the survey within each macroplot will be determined through pilot implementation (ca 60 min.). Each 0.5-ha macroplot is systematically sampled with ten transects spaced 15m apart; five oriented north / south and five oriented east / west.

***Batrachochytrium dendrobatidis* Surveys.** Sampling for presence of *B. dendrobatidis* entails collecting skin swabs from captured individuals and conducting a polymerase chain reaction amplification of each sample using an established assay to determine the presence of the fungus. The level to which we will implement this component has yet to be determined.

This protocol is implemented at randomly-selected locations determined by the spatially-balanced random sampling design utilized by this protocol and several other terrestrial Vital Signs (e.g., plant communities, breeding forest birds) (see Chapter 4). Habitat data are collected in conjunction with *Plant Community Monitoring* and will be conducted within one month of amphibian data collection. Measures collected by this protocol include: (a) species detection/non-detection, (b) detection location, (c) detection counts, and (d) frequency of occurrence of *B. dendrobatidis*.

Breeding Forest Birds

Parks

All SECN Parks

Objectives

- Determine trends in breeding forest-bird species distribution, diversity, and detection/ non-detection in SECN parks.

Monitoring Approach

Breeding Forest Bird surveys are limited to the breeding season (April through mid-June) in an attempt to sample species that have the highest likelihood of reproducing within a park. Point counts of birds will be conducted with the variable circular plot (VCP) methodology (Reynolds et al. 1980, Scott et al. 1986, Buckland et al. 1993, Ralph et al. 1993, Fancy 1997, Nelson and Fancy 1999, 2001). Surveys will occur from 0530 – 1100. Station locations are determined by the spatially-balanced random sampling design utilized by this protocol and several other terrestrial Vital Signs (e.g., plant communities, amphibians) (see Chapter 4). At each station, counts are separated into three time segments, 0-3 minutes (to allow comparisons with Breeding Bird Survey data), 3-5 minutes, and 5-10 minutes. Each station is sampled three times over the course of a two-week period to capture different environmental conditions and facilitate generation of the percent area occupied (PAO) metric (MacKenzie and Nichols 2004, MacKenzie and Royle 2005, MacKenzie et al. 2006) for all detected species. All birds, regardless of distance detected from the observer are counted and recorded. An important benefit of using the variable circular plot method is the ability to accommodate a wide range of bird species, each of which possesses a different singing style and each of which may occur in a variety of acoustically-different habitats. VCP counts operate by essentially allowing the habitat to determine the size of the area being surveyed.

Habitat data are collected under the co-located SECN Plant Community Monitoring Protocol within one month of VCP-data collection. Measures collected by this protocol include: (a) species detection/non-detection, (b) detection location, and (c) detection counts. *Breeding Forest Bird* monitoring will be conducted at each park once every three years.

Plant Communities

Parks

All Parks

Objectives

- Determine trends in percent cover and diversity of plant species (both native and non-native) in the herbaceous, shrub, and overstory strata.

- Determine trends in warm season species richness and diversity within SECN parks.

Monitoring Approach

Plant communities will be sampled following an adaptation of methods developed by Canfield (1941), Shimda (1984), Stohlgren et al. (1995), Stohlgren et al. (1997a), Stohlgren et al. (1997b), Yorks and Dabydeen (1998), and Barnett and Stohlgren (2003). The sampling technique will utilize nested subplots of various dimensions within the 0.5-ha macroplot, where different subplot dimensions will be used to measure different strata, including the overstory, shrub, and herbaceous components, and fuel loads (e.g., downed woody debris, duff depth). All plants will be identified to species, or the finest resolution available given available characteristics necessary for identification. Data will be summarized in a multimetric context using methods developed by the SECN (e.g., Floristic Quality Indices, other bioassessment techniques) and adaptations of those developed by others (Taft et al. 2006, Diffendorfer et al. 2007, U.S. Environmental Protection Agency 2008).

Plant Community sampling will be conducted from March to September, with various components implemented by the SECN Botanist, technicians, and interns. Sampling locations are determined by the spatially-balanced random sampling design utilized by this protocol and several other terrestrial Vital Signs (e.g., forest breed birds, amphibians) (see Chapter 4). Plant communities will be monitored at each park once every three years at sites co-located with wildlife community monitoring. Additionally, a subset of locations will be treated as index sites (permanent plots) where data will be used to train automated imagery analyses developed for the *Landscape Change Detection* protocol.

Migratory & Wintering Shorebirds

Parks

Cape Hatteras National Seashore (though applicable at other SECN coastal parks)

Measurable Objectives

- Identify areas of consistent use by migratory or wintering focal shorebirds at CAHA and if these areas remain consistent over time.

- Determine habitats in which wintering/focal shorebirds are most frequently observed at CAHA.

- Determine spatial and temporal variability in beached birds at CAHA.

Monitoring Approach

Migratory & Wintering Shorebird monitoring will be conducted using an adaptation of protocols developed to monitor shorebird populations at Cape Cod National Seashore (Erwin et al. 2003). This protocol consists of two components: 1) the migratory & wintering component and 2) the beached / dead bird component; both of which are modified specifically for implementation at Cape Hatteras National Seashore (CAHA). The migratory & wintering shorebird protocol is designed with specific emphasis on Piping Plover, Wilson Plover, Red Knot, and American Oystercatcher.

The survey technique is an adaptation of a line-transect survey (Anderson 1979, Buckland et. al 1993). The observer walks a straight line, as indicated from a compass bearing, along the beach along a trajectory that parallels the surf zone and maximizes observability across the entire beach. Random transect placement within the sampling unit is not possible as there is typically only one possible position for transect placement due to the narrow characteristics of the CAHA beach; however randomization is maintained in the order in which sampling units are sampled. The number of shorebirds, habitat-type where the observation occurs, and possible sources of disturbance (e.g., cars, people, and unleashed dogs) are recorded during each sampling event. Distance sampling will be conducted for the wintering population (i.e., a closed population) to generate density estimates if an adequate number of distance measurements necessary to calculate a detection function (ca. 80-100) are collected (Buckland et al. 1993). During each sampling event, the number of beached birds is also recorded and any associated information possibly related to morbidity (e.g., oil, ORV-induced, predated). Measures collected by this protocol include: (a) shorebird observation numbers, (b) distance estimates to observations, (c) habitat type where observation occurs, and (d) frequency of beached birds.

Although developed for CAHA, this protocol can be easily adapted for implementation at other coastal parks or to monitor additional species.

Landscape Change Detection

Parks

All SECN Parks

Measurable Objectives

- Determine the physiognomic class and change class of 0.5-ha grid cells for all areas of SECN parks

- Determine trends in the type, location, and variability of land cover and land use within and around SECN parks as determined by analysis of existing and emergent GIS data layers.

Monitoring Approach

Landscape change will be measured in two ways: through analysis of imagery to assess changes in physiognomic class, and through analysis of existing GIS data to assess changes in land use and land cover.

Physiognomic Class: Park-wide analyses of SPOT imagery will be conducted to classify 0.5 ha grid cells into one of nine physiognomic classes and one of 15 change classes. SPOT imagery has been selected because of cost, a wide range of resolutions (20m to 2.5 m), the expected longevity of the technology, and the ability to acquire imagery on request. Mapping of physiognomic classes and change detection analysis will be conducted on a three- to five-year rotating schedule, with analysis to be completed on imagery acquired no more than one year prior to sampling plant and wildlife communities.

Land Use and Cover: Once every three years, geospatial data will be collected from SECN parks and surrounding local governments. Analyses will be conducted to determine the status and trends of type, location, and variability of land cover, land use, and other anthropogenic features that might affect within-park resources or explain trends seen in other Vital Signs. Data to be analyzed will include:

- Changes in the types and distribution of various land cover classes over time as well as derivative analyses such as fragmentation,

- Changes in census data, dock permits, and other measures of human population growth.

- Changes in the status and reported condition of state-listed waterbodies upstream of park units

- Changes in the location and extent of protected lands

- Changes in NPDES discharge points, river regulation facilities, fish advisories, superfund sites, and other hazardous releases.

Analyses will be conducted at the watershed level as defined in each park's watershed condition assessment (where completed) or subsequent natural resource condition assessments to provide trend data useful for multiple programs.

Chapter 6. Data Management and Archiving

As part of the National Park Service's effort to "improve park management through greater reliance on scientific knowledge," a primary role of the Inventory and Monitoring (I&M) Program is to collect, organize, and make available natural resource data and to contribute to the Service's institutional knowledge by facilitating the transformation of data into information through analysis, synthesis, and modeling. To meet these objectives, each I&M Network needs a decision support system that effectively stores, maintains, analyzes, and distributes the data, information and products of scientific work conducted at each of the network parks. Thus, a foundation of the I&M program is the strong emphasis placed on data and information management for which networks are expected to devote at least 30 percent of available resources.

This chapter summarizes the SECN information management strategy, which is presented in greater detail in the SECN Information Management Plan (Wright et al. 2006). The information management plan documents the SECN strategy for ensuring that programmatic (and relevant, non-programmatic) data are documented, meet quality assurance objectives, and remain secure, accessible and useful throughout the lifecycle of the data. Additional details related to information management and products may be found in individual Vital Signs monitoring protocols and associated standard operating procedures (SOPs).

Numerous individuals and organizations are actively collecting natural resource data, either within the park boundary or on adjacent lands. In addition, similar data collection efforts have occurred throughout the past. Three primary sources of natural resources data are of interest to the SECN Vital Signs monitoring program:

- *Vital Signs Monitoring Data.* Data collected during implementation of the long-term monitoring program following peer-reviewed protocols and standard operating procedures. Data collection is conducted on either an ongoing (continuous), cyclic (once every few years), or synoptic (one point in time) schedule.

- *Project Data.* Data that are collected following standardized methods during a distinct time period with no expectation of recurrence following those same methods. Examples include baseline inventories, data collected during protocol development, and data collected during research by network, park, or cooperator personnel. Legacy datasets are also considered project data.

- *Incidental Observation Data.* Data collected following no standardized protocol (e.g. opportunistic species observations).

Together, these studies contribute to the body of knowledge or baseline information that the I&M Program utilizes to build its long-term monitoring program.

Due to the many potential sources of relevant natural resource data and information, it is important to prioritize data management efforts to receive the greatest benefit from effort expended. Of highest priority are data collected and managed from within the I&M program. As time and resources permit, SECN data management staff will assist with data management for

current projects, legacy data and data originating outside the I&M program. Finally, SECN data management staff will help ensure good data management practices for park-based natural resource projects that are being developed and implemented.

By providing guidance and facilitating good data management practices at all levels, SECN information management goals will be met in a more efficient and timely manner. The information management strategy described below is focused only on data collected during the implementation of Vital Signs monitoring protocols. Management of data, specimens, or archives outside of this scope is addressed in existing NPS or Park-specific SOPs. Where such SOPs do not exist the Network will develop procedures (or protocols) to appropriately and consistently manage those data.

Information Management Goals

The overarching goal of the SECN information management strategy is to ensure the quality, efficiency, interpretability, security, longevity, and availability of ecological data and information resulting from previous and ongoing natural resource relevant scientific investigations.

- *Quality.* Due to the complexity of most ecological studies, the term "quality" affects several different aspects of protocol implementation. Within an information management context, our primary objective is to ensure that appropriate quality assurance measures are taken during all phases of implementation: data acquisition, data handling, summary and analysis, reporting and archiving. Avoiding inconsistent or poor-quality data is critical for data analysis and interpretation, as well as the long-term success of the I&M Program. To ensure that the SECN produces and maintains data of the highest possible quality, procedures are established to identify and minimize errors at each stage of the data lifecycle.

- *Efficiency.* The concept: "don't collect data if you don't know what you're going to do with it" is essential for maximizing resources (including time, money, and personnel) within a long-term monitoring program. To avoid this pitfall, the SECN held meetings with subject matter experts that combined the planning needs for both information management and long-term monitoring protocol development. By examining protocol needs from data collection through reporting, we sought to ensure that data will be understood and interpreted within the context of their original scope and intent.

- *Interpretability.* SECN conducted an information needs assessment focusing on the end-use of data and information originating from the I&M program at the Park, Network and Regional level. Details of this process are presented in Chapter 2. Overall, an important outcome of the information needs assessment was the SECN conceptual object model which is a roadmap for information management system design and development that supports end-user needs and expectations. Combined with rigorous data documentation, all users should have an informed appreciation of the applicability and limitations of all SECN data sets.

- *Security*. Digital and hard-copy data must be maintained in environments that protect against loss from a wide variety of factors including: improper storage conditions, hardware failure, software obsolescence, storage media deterioration, and natural disasters (e.g., hurricanes). Digital data of the SECN are stored in multiple formats on a secure server and are part of an integrated backup routine that includes rotation to off-site storage locations. In addition, the SECN and Park curatorial staff are responsible for ensuring that programmatic materials such as field notes, data forms, specimens, photographs, and reports are properly cataloged, stored and managed in archival conditions.

- *Longevity*. Countless data sets have been lost over time simply because they were not sufficiently documented, organized, and maintained following their creation. Closely tied to security, data longevity can be enhanced through proper documentation (e.g. metadata) and by maintaining the data in current, accessible and interpretable formats. The SECN information management plan addresses proper storage conditions, backups, data migration, and data set documentation requirements to ensure data utility into the future.

- *Availability*. One of the most important responsibilities of the I&M Program is to ensure that data collected, developed or assembled by SECN staff or cooperators are made available in a timely manner for decision-making, research, and education – to a wide-range of end-users. To support these objectives, the SECN must ensure that: data are easily located and obtained, data have gone through rigorous quality assurance screening prior to release, data are accompanied by complete metadata (documentation), and that sensitive data are identified and protected from unauthorized access or distribution.

One mechanism for distributing SECN data will be the internet, which allows data and information to reach a broad range of end-users. To standardize and facilitate accessibility, the national I&M Program has developed several web-based applications or repositories to store and distribute park natural resource information (Table 6-1) that the SECN will use to the greatest extent possible.

Table 6-1.
Data that are provided on national Inventory & Monitoring Program web sites.

Web Application / Repository	Data Available at Site
NPSpecies	Database of species documented on NPS park units – focusing on vertebrates and vascular plants but includes all taxonomic groups. (http://science.nature.nps.gov/im/apps/npspp/index.htm)
NatureBib	Bibliographic database of park-related natural resource information. (http://www.nature.nps.gov/nrbib/index.htm)
NPSFocus	Portal to a variety of NPS information sources. (http://npsfocus.nps.gov/)
Biodiversity Data Store	A digital repository of documents, GIS maps, and data sets that contribute to the knowledge of biodiversity in National Park units. (http://science.nature.nps.gov/im/inventory/biology/)
NR-GIS Metadata and Data Store	Database that manages and shares natural resource and GIS metadata and data generated by the Natural Resource and Servicewide GIS Programs of the National Park Service. (http://science.nature.nps.gov/nrdata/index.cfm)

Information Management Strategy

The Vital Signs prioritization process used by the SECN is described in detail in Appendix 4 of the SECN Vital Signs Monitoring Plan. Vital signs were selected to take maximum advantage of ongoing monitoring efforts being conducted by parks within the network and partnering agencies throughout the region – while meeting high ranking monitoring objectives at all parks. This approach of developing an integrated monitoring program has been stressed in NPS policies, particularly NPS-75 (US Department of the Interior, National Park Service 1992) and was identified as a core requirement of the Network's information management strategy based on the SECN information needs assessment (DataLOGIC, Inc., 2005). The SECN has identified four levels of integration through its planning process:

- *Integration among Vital Signs*. NPS-75 provides examples and suggestions for ways I&M program managers can view data from multiple Vital Signs to assess, model, predict, or interpret patterns in data across space and time.

- *Integration among Parks*. Integration of data from multiple parks into unified data sets allow for Network-wide roll-ups and within network comparisons.

- *Integration with Partnering Agencies*. NPS-75 encourages integration with other agencies in two manners: through leveraging efforts with other agencies that monitor similar resources and by sharing data in standardized multi-agency formats (e.g. STORET).

- *Programmatic Integration*. Monitoring data can be analyzed and reported in many ways depending on the target audience and intended use of the data. Only by linking findings and predicted outcomes to proscribed actions can the Network's activities become fully integrated with other aspects of park management (e.g. planning, law enforcement, interpretation, and performance management).

The SECN conducted an exhaustive information needs assessment (INA) that facilitated the integration of SECN Vital Signs monitoring planning and its information management planning efforts (DataLOGIC, Inc. 2005a). The SECN INA scoping meetings brought together subject matter experts and NPS end-users to begin protocol development in order to define monitoring objectives of interest and make recommendations on data collection needs and techniques, analysis methodology, and reporting requirements for a wide range of user groups. As a collection, these protocol documents begin to define the data and information requirements of the SECN I&M program – which are depicted graphically in the SECN conceptual object model. The conceptual object model is a theoretical representation of the programmatic requirements that potential users of the decision support system need and interact with on an ongoing basis. Thus, the information gained during the INA and conceptual object model development will serve as the foundation for future SECN information management planning and decision support system development activities (Figure 6-1).

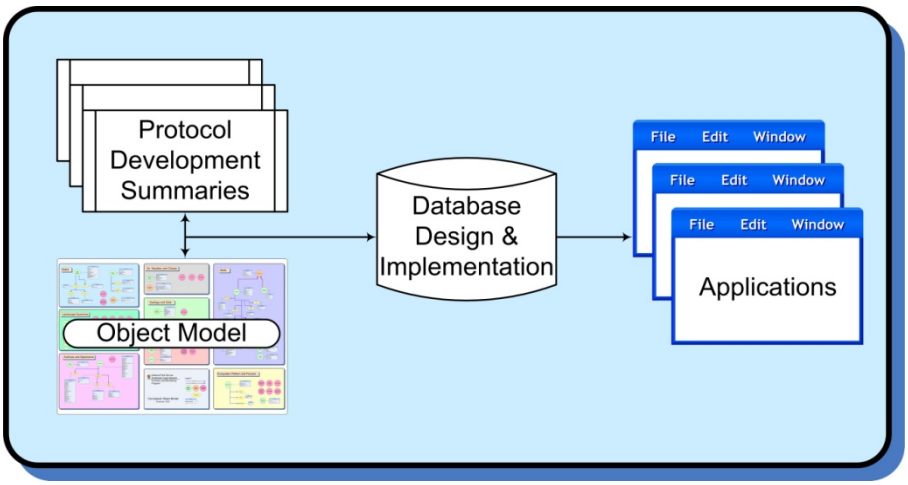


Figure 6-1. The object model is the strategic foundation for future information management efforts.

Collecting natural resource data is the first step towards understanding the ecosystems within national park units. These ecosystems are evolving, as is our knowledge of them and how they function. Raw data are used to analyze, synthesize, and model aspects of ecosystems. In turn we use results and interpretations to make decisions about network park's critical natural resources. Thus, data collected and maintained by the SECN will become information through analysis, synthesis and adaptive modeling.

Because one of the goals of the I&M program is to base management decisions on scientific knowledge in a rapidly changing environment, it is incumbent on the SECN to develop tools that allow managers to make decisions on the most recent data available from as many related sources as possible. It is therefore the interpretation of the Southeast Coast Network that this necessitates the development of a single decision support system that efficiently and cost-effectively allows for concurrent analysis of data from multiple Vital Signs and predictive modeling (See Chapter 4). This integration will allow the network to institutionalize quality information management practices across network parks and to build partnerships with external agencies.

However, initial database development work began in Microsoft Access to support the collection of protocol pilot testing data and to reduce the effects of network bandwidth issues among the SECN network offices. Even though the original database development began in MS Access as individual, stand-alone databases, this development process has proceeded within the framework of the network's conceptual object model – making the transition to a long-term, client-server solution much smoother. In other words, this incremental development process will allow databases to be implemented and added to the decision support system over a period of years without encountering many common problems that result from a lack of data management planning.

Data Stewardship Roles and Responsibilities

The collection of natural resource information is often a costly and complex process, involving many people. As more people become involved in a project, the likelihood of miscommunication

or misunderstanding between project members increases. Thus, the need for well-defined roles and responsibilities becomes crucial to the success of long-term monitoring protocol implementation and the quality of data and information produced (Table 6-2).

Table 6-2.
SECN roles and responsibilities for data stewardship.

Role	Data Stewardship Responsibility
Network Roles	
Field Crew Member	Collect, record, and verify monitoring data.
Field Crew Leader	Supervise crew and organize data.
GIS Specialist or Data Technician	Acquire data sets from external sources. Process and manage data.
Remote Sensing Specialist	Acquire data sets from external sources. Process and manage data. Integrate spatial data and develop network sampling framework with program ecologists.
Program Ecologists	Oversee and direct data collection operations following standard operating procedures and protocols, including data management. Identify, justify and document "outlier" data. Apply standard statistical methods to develop sampling designs and analyze data. Oversee all aspects of specimen acquisition, documentation and preservation. Interpret and report findings.
Science Information Specialist (Data Manager)	Ensure inventory and monitoring data are organized, useful, compliant, secure, and available. Oversee archival of related field documents and resultant reports as appropriate.
Database Programmer	Develop network databases within the NRDT and SECN conceptual object model framework. Develop "front-end" applications to facilitate the rapid entry and quality control of monitoring data. Work with network Ecologists and Science Information Specialist to facilitate data querying and reporting for different end-user groups.
Park Roles	
Field Crew Member	Collect, record, and verify monitoring data.
Learning Center GIS coordinator	Support park management objectives with GIS needs .
End Users (e.g. managers, scientists, interpreters, public)	Interpret information and use Information products to inform management decisions. Identify new information product needs and inform the scope and direction of science information product development .
Park Curator or Museum Specialist	Coordinate curation and archival processes with network Ecologists and Science Information Specialist. Maintain specimens and archives as appropriate.
Information Technology Specialist	Provide IT support for hardware, software and networking.
Regional Office Roles	
Regional GIS Coordinator	Update regional GIS catalog with published SECN data sets. Provide central repository data for relevant park, regional, and national GIS data sets and accompanying metadata documentation.
Information Technology Specialist	Provide IT support for hardware, software and networking.
National Roles	
I&M Data Manager (National)	Provide service-wide database availability and support.

Successful data stewardship requires that all people involved in SECN programs learn and understand the expectations for ongoing data management activities *and* be accountable to perform the duties required to meet these expectations. This requirement is equally important for network and park staff, as well as contractors or cooperators. All personnel involved in protocol

implementation receive training, briefings, materials and regular communication about data stewardship from supervisors, program ecologists and data management personnel. However, the chief personnel involved with data management include the SECN Ecologists responsible for designing and implementing monitoring protocols, and the Science Information Specialist and Database Programmer for developing the databases and facilitating the long term access to quality data. The Network Coordinator interacts with network staff to ensure that timelines for data entry, validation, verification, summarization/analysis and reporting are met. Figure 6-2 illustrates the core data management duties of the project leader (typically a network Ecologist) and where they overlap.

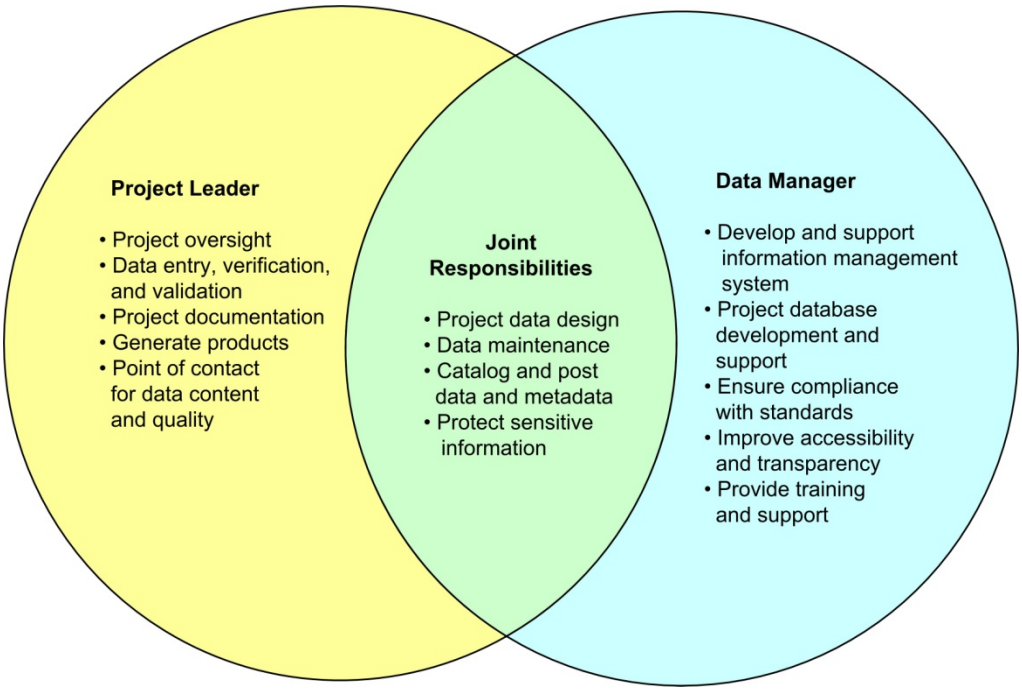


Figure 6-2. Core project data stewardship responsibilities of project leaders and data managers.

Information Technology Infrastructure and System Architecture

Information technology (IT) infrastructure refers to the network of computers and servers that SECN information systems are built upon. SECN relies heavily upon national, regional, and park IT personnel and resources to maintain its computer infrastructure (Figure 6-3). This includes, but is not limited to: computers, servers, other related hardware, software installation and support, email administration, security updates, virus-protection, telecommunications, computer networking, and server backup services.

SECN staff offices are located at the Southeast Regional Office (Atlanta, GA), Cumberland Island National Seashore (St. Marys, GA) and Fort Sumter National Monument (Charleston, SC). The Southeast Regional Office (SERO) location is considered the primary location (from an IT perspective) because it is co-located with the network Science Information Specialist, Network Coordinator and regional IT staff. Therefore, the SECN master database will be located

and administered out of SERO. Additionally, the placement of the master database server at SERO allows for protection from likely catastrophic events (e.g. hurricanes).

The SECN Information Management and Archiving Plan specifies the standards by which data and information will be handled (Wright et al. 2006). In addition, network data and information resources are compiled, organized, processed, and archived using a structured file system on the primary network server that is backed up onto tape as part of the Southeast Region IT backup schedule. Network staff will incorporate and follow NPS IT policies, standards, procedures and guidelines available from the Office of the Chief Information Officer or Regional IT division.

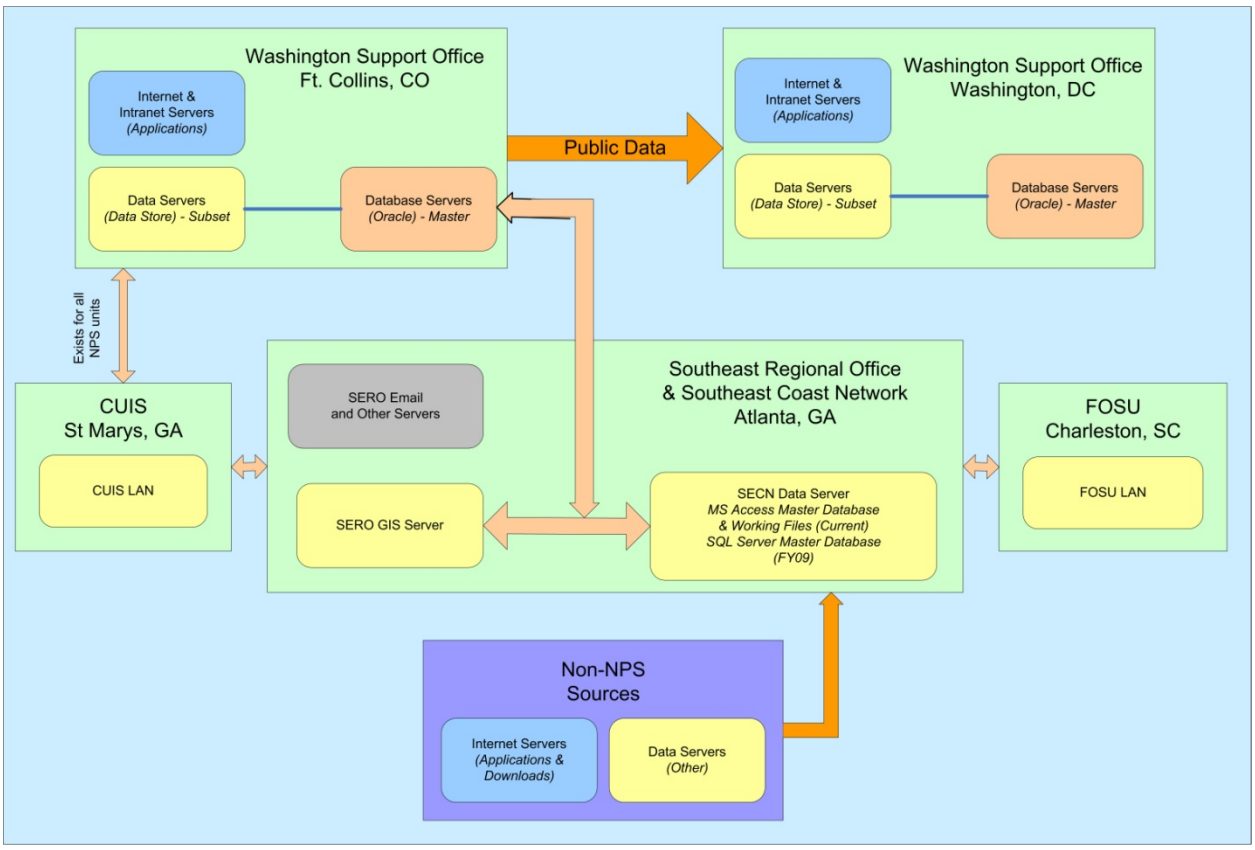


Figure 6-3. Information technology connectivity diagram.

Data Acquisition and Lifecycle

The key to a successful data management program is the involvement of all project staff in data management from the outset, combined with the establishment of data management standards, guidance and operating procedures that precede the implementation stage of all natural resource projects. In other words, data management will not succeed when implemented as an afterthought. Although a specific project may have individual data management requirements, the SECN Information Management and Archiving Plan provides guidance and standard operating procedures for all common project elements (Wright et al. 2006).

In general, data used by the SECN fall into three main categories: (a) Vital Signs monitoring data, (b) project data collection, including historical or legacy data, and (c) incidental observation

data. In all cases data might originate by NPS staff or external sources depending on the protocol. Most data acquired by the network will be collected as field data (inventory or monitoring protocols). Methods of field data collection such as paper field data forms, field computers, automated data loggers, and GPS units will be addressed in individual monitoring protocols and study plans. Field crew members will closely follow the established standard operating procedures in the project protocol. Data handling procedures for all data acquired by non-program sources, such as data downloaded from other agencies (e.g. air quality and weather data) will also be specified in individual monitoring protocols.

Project data, particularly legacy data exist in a variety of formats and may or may not be accompanied by documentation. Legacy data will therefore be dealt with on a case by case basis through the process of data mining activities at each park within the network. Project data that are adequately documented may be highly relevant to current/ongoing monitoring, serving as a baseline of information for future studies. As data are collected for each of the network's Vital Signs, data may take different forms and be maintained in different places as they are acquired, processed, documented and archived. Specific details of each protocol's data lifecycle may vary, depending on protocol implementation and project personnel. However, several standard practices will be implemented for all SECN protocols:

- Data are classified in one of three categories – Raw, Provisional, and Certified. All data migrate from Raw to Certified data following procedures set forth in network SOPs and Protocols. Category descriptions are as follows:
    - *Raw*. Data that have not been subjected to either quality control or documentation procedures.
    - *Provisional.* Data that have been initially screened for quality to meet minimum standards for generation of provisional information products.
    - *Certified.* Data that have undergone thorough quality assurance and screening as well as complete documentation.
- All raw data are archived, intact in their original format.
- Working databases are the focal point for all modification, processing, and documentation of data.
- Upon data certification all data will be archived and posted (as appropriate) or otherwise integrated with national information management applications.
- Certified data will also be uploaded into the SECN master database that will be write-protected to ensure data integrity over time.
- Information products (e.g. maps, charts, graphs, etc.) developed by the SECN will be based only on certified data. These products are also archived and made available to users through appropriate data servers or national repositories.

- Provisional information products may be developed using uncertified data in special cases, but will not be released to the public through national systems until such time as the underlying data have become certified.

- Any subsequent changes to certified data sets must be documented in an edit log which is distributed along with the data.

Quality Assurance and Quality Control

Director's Order 11b "Ensuring Quality of Information Disseminated by the National Park Service" states that "all information disseminated by the NPS must comply with basic standards of quality to ensure and maximize the objectivity, utility, and integrity of information disseminated to the public" (National Park Service 2002c). Although not every data element collected will ultimately be made public, this policy establishes the standard for quality data that are reliable, accurate, timely, and compliant with existing laws or policies. To achieve these objectives, the SECN has incorporated data and information quality assurance procedures into all applicable phases of project development including (but not limited to): data acquisition, data handling, summary and analysis, reporting and archiving.

Specific procedures to ensure data quality are included in long-term monitoring protocols or SOPs for each Vital Sign. Although many quality assurance or quality control procedures depend upon the individual protocol being implemented, some general concepts apply to all work being conducted by the network.

- Project team member and field crew training.

- Equipment maintenance and calibration.

- Standardized field data sheets with descriptive data dictionaries.

- Use of handheld computers and data loggers when appropriate.

- Standard operating procedures for collecting data in the field.

- Database features to minimize transcription or other errors including pick lists and range limits.

- Automated and user-assisted data verification and validation routines.

- Metadata or project documentation requirements.

- Access controls to project data.

Quality assurance methods will be established and in place at the inception of any protocol and continue through all implementation stages until the final archiving of data has occurred. It is critical that each member of the monitoring team work to ensure data quality. Finally, all SECN data will be accompanied by documentation and/or metadata as appropriate upon distribution.

Data Documentation

The definition of metadata is data documentation or data about data – making it a key aspect of data collection and analysis. Metadata documents the who, what, why, where, when, and how of a project and when linked to the project data enables users to properly evaluate and utilize data sets throughout the lifecycle of the data. In other words, the creation of metadata serves to facilitate data longevity, helps publicize data and facilitates access to and the use of data by others into the future.

At a minimum, all data managed by the network require the following:

- Feature-level metadata about each record in a database (e.g. data dictionaries and entity-relationship diagrams). Data records collected using network protocols will include the name, date and version of the appropriate protocol.

- Data set metadata must meet NPS or Federal Geographic Data Committee (FGDC) standards, as appropriate.

- Archives of field notes, laboratory reports and/or analysis procedures.

Project protocols and SOPs will provide complete background information, objectives, and methodology that directly relates to the metadata and vice versa. To achieve the required content and detail for metadata, the SECN uses a number of techniques, including:

- Specific metadata requirements included in all contracts and cooperative agreements for work being conducted through cooperators.

- Training in NPS and FGDC metadata content standards for geospatial, biological, and tabular data.

- Training and access to online resources and software tools for metadata generation.

- Incorporating feature level metadata requirements into data collection procedures.

For all monitoring protocols, extensive standard operating procedures provide detailed guidance on data quality objectives. These SOPs are specific to each protocol, yet fall within the guidelines established by the NPS and FGDC. Upon completion, metadata documentation will accompany all SECN data sets that are certified and available for distribution. The SECN Science Information Specialist is responsible for ensuring that metadata are complete for all network data sets.

Data Summary and Analysis

Providing meaningful results from data summary and analysis is a cornerstone of the I&M program and characterizes the network's information management mission to provide useful information for managers, scientists and other end-users. Each monitoring protocol establishes requirements for on-demand and scheduled data analyses and report or product generation. Based on these requirements, the associated information management system will include

functions to summarize and report directly from the data as well as output formats for import into other analysis software programs. In addition to tabular and charted summaries, the network provides maps of natural resource data and GIS analysis products to communicate spatial locations, relationships and geospatial modeling results. Please refer to Chapter 7 of the SECN Vital Signs monitoring plan for a more detail description of the SECN analysis and reporting schedule and procedures.

Data Dissemination

The SECN data dissemination strategy aims to ensure that:

- Data are easily discoverable and obtainable.
- Only certified data (data subject to complete quality assurance procedures) are released unless necessary to respond to a Freedom of Information Act (FOIA) request.
- Distributed data are accompanied by appropriate documentation.
- Sensitive data are identified and protected from unauthorized access and inappropriate use.

The Network's website and server (through a combination of SQL Server, Reporting Services, and Microsoft Office SharePoint Services) provide an information portal that assembles and links existing and planned services that provide for most of the Network's data and information distribution requirements. In the following list, access to virtually all network data and information is permitted according to the access permissions (security level) of the user. All data are available to network staff and network parks; most data are available service-wide and non-protected data are available to all external users.

- Inventory and monitoring planning and project reports are online at the SECN website and SharePoint.
- Park and network monitoring protocols and database designs are online at the NPS Protocol Clearinghouse.
- Searchable metadata are online at the NPS NR-GIS Metadata and Data Store.
- Original and processed data sets from the parks and network are online at the NPS Biodiversity Data Store and/or the NPS NR-GIS Metadata and Data Store.
- Annually updated water quality data are online at the Environmental Protection Agency's STORET website.
- Biodiversity data and information are available online at the NPSpecies website.
- Scientific citations are online at the NatureBib website.

The network also serves data requests using file transfer protocol (FTP), attaching reports and other products with small file sizes to email and shipping digital media such as DVD, CD-ROM, diskette and magnetic tape cartridge.

SECN data and information products are considered property of the NPS; however, the Freedom of Information Act (FOIA) establishes access by any person to federal agency records that are not protected from disclosure by any exemption or by special law enforcement record exclusions. The SECN will comply with all FOIA provisions regarding sensitive data. If the NPS determines that disclosure of information would be harmful, information may be withheld concerning the nature and specific location of:

- Endangered, threatened, rare or commercially valuable National Park System Resources (species and habitats).
- Mineral or paleontological objects.
- Objects of cultural patrimony.
- Significant caves.

Each Vital Signs Monitoring Protocol leader, as the primary data steward, will determine data sensitivity in light of federal law, and will stipulate the conditions for release of the data in the project protocol and metadata. Network staff will classify sensitive data on a case by case basis – working closely with network parks, cooperators, and contractors to ensure that potentially sensitive park resources are identified, and that information about these resources is tracked throughout the duration of any SECN-funded activities. The investigators, whether network staff, park staff or partners, will develop procedures to flag all potentially sensitive resources in any products that come from the project, including documents, maps, databases, and metadata. When submitting any products or results, investigators should specifically identify all records and other references to potentially sensitive resources. Partners should not release any information in a public forum before consulting with NPS staff to ensure that the information is not classified as sensitive or protected.

Director's Order #66 (the final guidance will be contained in the Reference Manual 66) provides guidance for determining whether information should be protected (National Park Service 2003a). Natural Resource information that is deemed sensitive or protected requires the following security steps:

- Identification of potentially sensitive resources.
- Compilation of all records relating to those resources.
- Determination of what data must not be released to the public.
- Management and archival of those records to avoid their unintentional release.

Data Maintenance, Storage and Archiving

SECN data maintenance, storage and archiving procedures ensure that data and related documents (digital and analog) are:

- Kept up to date with regards to content and format such that data are easily accessed and their lineage and quality easily learned.

- Physically secure against environmental hazards, catastrophe and security threats.

Technological obsolescence is a significant cause of information loss, and data can quickly become inaccessible to users if they are stored in out-of-date software programs or on outmoded media. Effective maintenance of digital files depends on the proper management of a continuously changing infrastructure of hardware, software, file formats, and storage media. Major changes in hardware can be expected every 1-2 years and in software every 1-5 years. As software and hardware evolve, data sets must be consistently migrated to new platforms, or they must be saved in formats that are independent of specific platforms or software (e.g., ASCII delimited files).

Data will be migrated so that data are maintained in software versions no older than one version behind the current version. Thus it is likely that data will be migrated once every three to five years – more frequently if there are major software changes that occur that render older versions obsolete and incompatible.

- Primary data maintenance will be performed on the SECN data servers. The data and information content of files stored on this server will be kept current. Accompanying metadata files will reflect any data updates as well.

- A catalogue of the data and information on these servers will be maintained on the SECN website and reflect changes and updates to data holdings. Additionally, program archives will also be updated to mirror content on the data servers.

- Latest versions of primary data will be available in conventional formats reflecting common data usages in the resource management community.

Natural History Archiving, Curation and Records Management

In most instances, administrative documents, natural history specimens, photographs, audio tapes and other materials are essential companions to digital data and information. Direction for managing many of these materials (as well as digital materials) is provided in NPS Director's Order 19 (National Park Service 2001b) and its appendix NPS Records Disposition Schedule(National Park Service 2003b). NPS-19 states that all records of natural and cultural resources and their management are considered mission-critical records – necessary for the fulfillment of the NPS mission and must be permanently archived.

The SECN Information Management and Archiving Plan includes a project close-out checklist (SOP X) to guide project leaders in complying with archival directives (Dahl-Kearney and Wright 2006). Natural resource archives may contain any or all of the following: field notes,

daily journals, maps, drawings, photos and negatives, digital photos, slides, videotapes, raw data sheets, remote sensing data, copies of contracts, correspondence, repository agreements, specialists' reports and analyses, reports and manuscripts, collection inventories, field catalogs, analytical study data, sound recordings, computer documentation and data, tabulations and lists, specimen preparation records, conservation treatment records, and reports on all scientific samples lost through destructive analysis. Standards for materials used in project involving natural resource specimens and archives are also presented in SOP X of the SECN Information Management and Archiving Plan (Russell Wright and Dahl-Kearney 2006).

A separate standard operating procedure entitled “Natural History Collections Laws and Policies” provides users with an overview of NPS rules and regulations pertaining to the collection of voucher specimens and other natural history collections (Harrison 2001).

Implementation

The purpose of this Information Management and Archiving Plan is to develop guidance for current and future staff of the SECN and network parks. In addition, the Plan strives to ensure that sounds data management practices are followed in all new projects while legacy data are brought up to standard and made useable. To that end, the SECN will keep the Information Management and Archiving Plan simple, flexible, and evolving. Continued involvement of end-users in the decision-making process is crucial to the successful adoption of the guidance and recommendations provided in this Plan.

The SECN 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 SECN Science Information Specialist by any interested party or user of network data and/or information products. These recommendations will be discussed by network and park staff as needed to decide what actions to implement. Simple changes can be made immediately while substantive changes will be made during scheduled updates to the plan (minimally every 5 years). Plan updates will be distributed to members of the network Technical Steering Committee prior to implementation and be housed on the SECN website (http://www1.nature.nps.gov/im/units/secn/).

Database Development and Implementation Schedule

As described previously, the results of the INA (Chapter 6.2) strongly supported the development of a single, integrated decision support system design rather than individual, stand-alone databases that address particular monitoring objectives. The conceptual object model combined with SECN long-term monitoring protocols and supporting SOP’s serve as the foundation for database and application development that will ultimately form the SECN decision support system. However, database development began in MS Access in order to address the following issues:

- SECN monitoring protocols are in the development or pilot testing phase. In these early stages, changes to data collection procedures and parameters are possible (if not guaranteed) and the deployment of supporting stand-alone databases will be much faster.

- Current bandwidth issues between network offices, make the use of a client-server (enterprise) database solution less feasible in the short-term. Thus local, working copies of protocol databases in MS Access will better meet network needs.

Even though the original database development took place in MS Access as individual, stand-alone databases, this development process proceeded within the framework of the network's conceptual object model – making the transition to a long-term, client-server solution much smoother. Initial development of the SECN decision support system has already begun with the implementation of SQL Server 2005, Microsoft Office SharePoint Server and Reporting services and will meet the following requirements:

- Database and application development will be compatible with NPS standards/requirements, and build upon the SECN conceptual object model.
- Database and applications will support both spatial (e.g. vector and raster GIS data) and non-spatial (tabular) data. The Environmental Systems Research Institute (ESRI) geodatabase model versus the geographic data type in SQL Server 2008 will be evaluated for use in this decision support system.
- SQL server will serve as the primary database repository

The current SECN production environment includes the following:

- Windows Server 2003
- SQL Server 2005, enterprise version (potentially migrating to SQL Server 2008 – enterprise version upon release)
- SQL Server Reporting Services
- Microsoft Office SharePoint Server (MOSS) 2007 – enterprise version
- Internet Information Services (IIS) 6.0
- .NET framework 2.0 and 3.0
- Dundas Data Visualization for Reporting Services

The current SECN development tools are Microsoft Office InfoPath 2007, Microsoft Visual Studio 2005, and Microsoft SQL Server 2005.

The tentative database development schedule is presented below (Table 6-3), indicating development in MS Access (if applicable) and migration to SQL server or direct implementation in SQL server. Migration to the SECN decision support system began in fiscal year 2008. As we progress through FY 2009 and beyond the network will reevaluate the implementation schedule based on a protocol by protocol basis, staffing and work plan requirements.

Table 6-3.
Database development schedule for all field protocols and data acquisition SOPs to be implemented by the SECN. Development schedule and status of each SOP that outlines for the acquisition, management and interpretation of data for these Vital Signs are provided in Appendix 13.

	Vital Sign(s)	MS Access Database	SQL Server Database	Automated Reporting
Field Protocols	Coastal Shoreline Change	Not Planned	FY09	FY10
	Stream Habitat Assessment	Not Planned	FY10	FY11
	Salt Marsh Elevation	Not Planned	FY09	FY10
	Marine Water Quality	Completed	FY08	FY09
	Fixed-Station Water Quality	Completed	FY08	FY09
	Amphibians	Not Planned	FY09	FY09
	Breeding Forest Birds	Not Planned	FY09	FY09
	Plant Communities	Not Planned	FY10	FY11
	Wintering & Migratory Shorebirds	Completed	FY08	FY09
	Landscape Change Detection	Not Planned	FY10	FY11
Data Acquisition & Analysis SOPs	Ozone	Not Planned	FY10	FY10
	Wet and Dry Deposition Air Contaminants	Not Planned	FY10	FY10
	Visibility and Particulate Matter	Not Planned	FY10	FY10
	Weather & Climate	Not Planned	FY09	FY10
	Groundwater Dynamics	Not Planned	FY09	FY09
	Stream Flow Discharge	Not Planned	FY10	FY10
	Stream Water Quality	Not Planned	FY10	FY11
	Fisheries Take	Not Planned	FY11	FY12
	Visitor Use	Not Planned	FY11	FY12
	Land Management & Disturbance	Not Planned	FY11	FY11

Chapter 7. Data Analysis and Reporting

The information obtained through the SECN monitoring program has a wealth of applications including management decision-making, research, education, and promotion of public understanding of SECN park resources. Park managers are the primary audience for the results of Vital Signs monitoring. Our goal is to provide superintendents and resource managers with the data they need to make and defend management decisions and to work with others for the benefit of park resources. Other key audiences for monitoring results include park planners, interpreters, researchers and other scientific collaborators, and the general public. To be effective, monitoring data must be analyzed, interpreted, and provided at regular intervals to each of these audiences in a format they can use. It is important to analyze SECN monitoring data at several different scales, and the same information needs to be distributed in different formats to resonate with different audiences.

This chapter presents an overview of how the SECN proposes to analyze, synthesize, and disseminate monitoring results to a wide variety of audiences in a timely manner.

Data Analysis

To conduct an appropriate analysis of monitoring data, one must consider the monitoring objectives, the spatial and temporal aspects of the sampling design used, the intended audiences, and management uses of the data. Selection of specific analytical methods should occur following determination of monitoring objectives and sampling design and before conducting field sampling. Each monitoring protocol will contain detailed information on analytical tools to be used, approaches for data analysis and interpretation, rationale for a particular approach including the advantages and disadvantages of each procedure, and standard operating procedures (SOPs) for each prescribed analysis. Four levels of analysis will be conducted by the SECN: data summarization and characterization, status determination, trends evaluation, and integrated analysis (Table 7-1).

In general, the lead ecologist for a particular protocol will determine the suite of analytic approaches for status and trends analyses and will also conduct and report the analyses. Integrated analyses that examine patterns across Vital Signs will require a team approach, necessitating collaboration among multiple lead ecologists.

To provide a context for data analysis, a brief conceptual overview of some of the analyitical tools that will be used by the SECN is presented below. More specific details of the proposed analyses for the SECN Vital Signs are presented in Table 7-2.

Parameter Estimation

The most common type of analysis for SECN Vital Signs will be parameter estimation. This can involve either the estimation of the state or condition of a given resource (status) or the change in that resource state over time (trend). This analysis focuses on measuring and describing the attributes of a population in terms of its distribution and structural features. Using this method requires an understanding of the distribution from which the samples are drawn such as the bias in the estimate of central tendency and the precision or variability in the data. If the expected value of the estimate (e.g., the mean from repeated samples) is equal to the true value of the

parameter, then the estimator is considered unbiased. If the parameter estimate differs systematically from the true value (e.g., repeated samples are always greater than the true value), then the estimator is biased. Precision reflects variation in the data; the greater the precision (or tendency of the samples to be close to the true value), the less variation in the data.

Table 7-1.
Categories of analyses for SECN Vital Signs.

Level of Analysis	Description
Data Summarization and Characterization	Calculation of basic statistics of interest including measures of location and dispersion. Summarization encompasses measured and derived variables specified in the monitoring protocol. Data Summarization and characterization forms the bases of more comprehensive analyses and for communicating results in both graphical and tabular formats.
Status Determination	Analysis and interpretation of ecological status (point in time) of a Vital Sign to address the following types of questions: • How do observed values for a Vital Sign compare with historic levels? • Do observed values exceed a regulatory standard, a known or hypothesized ecological threshold, or a management-driven target? What is the level of confidence that the observed values exceeded the standard, target, or threshold? • What is the spatial distribution (within the park, network, watershed, ecoregion) of observed values for a given point in time? Do these patterns suggest directional relationships with other ecological factors? Status determination involves comparison to established assessment criteria, expert interpretation of the basic statistics, and statistical analysis to address these monitoring questions. Assumptions about the target population and the level of confidence in the estimates will be ascertained during the analysis.
Trends Evaluation	Evaluations of trends in Vital Signs will address: • Is there a directional change in a Vital Sign over the period of measurement? • What is the rate of change (sudden vs. gradual), and how does this pattern compare with trends over broader spatial scales and known ecological relationships? • What is the level of confidence that an actual change (or lack thereof) has occurred? Analysis of trends will employ parametric, nonparametric, or mixed models based on assumptions made about the target population. Where appropriate, exogenous variables (natural, random phenomena that may influence the response variable) will be accounted for in the analysis.
Integrated Analysis	Examination of patterns across Vital Signs in a geospatial context to gain broad insights on ecosystem processes and integrity. Analyses may include: • Qualitative and quantitative comparisons of Vital Signs with known or hypothesized relationships. • Data exploration and confirmation (e.g., correlation, ordination, classification, multiple regression, structural equation modeling). • Development of predictive models. Synthetic analysis has great potential to explain ecological relationships in the non-experimental context of Vital Signs monitoring and will require close interaction with academic and agency researchers.

Evaluation of trend estimates (and determining if change has occurred over time) is a primary focus of our long-term monitoring program. SECN will employ several common statistical and graphical techniques to evaluate trends. One easily interpreted method of representing trends of the estimated parameters is to use graphs. This simple technique plots values of the parameter through time, and can easily show if the parameter is increasing, decreasing, fluctuating, or not changing significantly. A common statistical tool for evaluating the relationship of one or more independent variables to a single, continuous dependent variable is regression analysis. We will use regression analysis to calculate the trend slope of parameter estimates over time. In this case, determining if change has occurred is a form of hypothesis testing where the null hypothesis is

that the slope is 0. Analysis of variance-based (ANOVA) trend analysis will be employed when populations are categorized into domains of interest (e.g., vegetation types).

Hypothesis Testing

Related to detecting change in parameter estimates over time, we will also use hypothesis testing for other selected purposes. In scientific settings, hypothesis testing is a keystone approach in experimental research to determine effects of treatments. For our purposes, this method will be used when the status of a given resource is tested against reference values, such as legal thresholds (e.g., water quality standards) or desired conditions. We will use this method to test whether or not conclusions can be drawn about the relationship between the parameter estimate and the reference to which it is being compared.

Model Selection

A third analytical approach we will use is model selection to help better understand the dynamic relationships among park resources, ecosystem drivers, and stressors. One goal of developing models is to provide decision makers with an early warning of abnormal conditions or resource impairments. This approach considers multiple lines of evidence within the monitoring data to support development of a suite of models that represent multiple hypotheses concerning the desired relationships. The model selection approach will be used in developing the SECN integrated analysis reports (see below).

Model selection will be based on the principle of parsimony, where the appropriate model should contain only enough (significant) parameters to account for the variation in the data. One objective is to compare models with varying numbers of parameters and then select an "optimal" model that is neither too simple nor too complex and is biologically meaningful. A companion objective is to use information-theoretic approaches (Burnham and Anderson 2002) to compare the relative strength of competing models. Models can be evaluated and ranked using criteria such as how well data fit the model and the number of parameters.

Bayesian Approaches

We will consider use of a fourth analytical approach, Bayesian statistical methods, as an alternative to traditional, frequentist statistics. In general, Bayesian approaches allow for the incorporation of previous evidence (data) along with new information to estimate the probability of a particular outcome. This technique may be useful during model selection. These statistical methods are based on Bayes's theorem (Bayes 1763). More specifically, Bayesian methods use the observed data to calculate the probability of the value of a parameter. With additional data, Bayesian techniques draw on this prior (a priori) distribution to derive a new (posterior) distribution that incorporates the likelihood of the data given the prior distribution. This approach is appealing because it takes into account all of the information accumulated and enables an assessment about the probability of a given hypothesis being true, rather than rejection or acceptance based on a specified threshold (i.e., the α-level or p-value of traditional statistics). A Bayesian approach may be well suited in selecting models to relate the dynamic nature of park resources over the long-term because of its ability to continually incorporate updates to parameter estimates as data accumulate (e.g., Johnson 2005).

Data Reporting

We will use a variety of approaches to disseminate the results of the SECN monitoring program to park managers, scientists, and the general public. The network will regularly prepare two types of data reports for each monitoring project: data summary reports and long-term (3- to 10-year) trend reports. These reports will form the basis for a variety of secondary information products. Over a longer time interval, synthetic reports that integrate trend data from linked monitoring projects will be prepared to describe the overall condition or integrity of a park resource or ecosystem. In addition to these regular reporting formats, network staff will work individually with SECN parks to meet special park information requests. Parks engaged in the preparation of planning documents (e.g., General Management Plans, or Resource Stewardship Strategies) or management assessments might require specific data summaries to meet a particular need. Three types of reports are described below, as well as our other approaches to data dissemination.

Data Summary Reports for Individual Protocols

The primary purposes of data summary reports are to:

- Summarize data and document monitoring activities for the year
- Describe conditions of the resources sampled, and
- Provide data back to park managers in a timely way to increase data utility and improve communication within and among SECN parks.

Several of our monitoring protocols involve data collection each year (e.g., climate, water quality) and the protocols for these Vital Signs include producing annual reports. For monitoring projects involving less frequent data collection (e.g., breeding forest birds, plant communities, and landscape change detections), summary reports will be prepared in those years when sampling occurs. Where possible, annual reports will be based on automated data summarization routines built into the 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 more complex analyses, data will be analyzed using statistical software packages. Reporting for some Vital Signs (e.g., water quality) will include an evaluation of current status against historical levels, reference conditions, or regulatory standards. Data summary reports will be reviewed by network staff with responsibility for implementing relevant protocols to assure data quality.

Trend Reports for Individual Protocols

The primary purpose of trend reports is to report on the following:

- Patterns and trends in condition of resources being monitored,
- New characteristics of resources and correlations among related Vital Signs,
- Degree of change that can be detected by the current level of sampling, and

- Interpretation of monitoring data in a park, multi-park, and regional context.

Examples of trend reports for SECN include:

- Water quality trends at fixed water quality monitoring stations,
- Changes in the position of coastal shorelines over time,
- Changes in the elevation of salt marshes in SECN coastal parks, and
- Trends in the number of observed piping plovers at CAHA

Trend reports will be prepared every 3 to 5 years for Vital Signs that are sampled annually and at a 10-year interval for Vital Signs that are monitored less frequently. Trend reports will be peer-reviewed by an external three-member panel.

Integrated Analysis Reports

The primary purpose of integrated analysis reports is to examine patterns among Vital Signs and other data sets to gain broad insights into ecosystem processes and trends in ecosystem integrity. This may be accomplished through:

- Comparisons of monitoring trends with known or hypothesized relationships,
- Data exploration and confirmation of hypothesized relationships (e.g., ordination, classification, multiple regression, structural equation modeling), or
- Development of predictive models.

Examples of integrated analysis reports for SECN include:

- Trends in water quality, surface water dynamics, and stream habitat as a function of changes in watershed land use and land cover,
- Trends in the number of bird observations at CAHA as a function of visitor use and park management (closures), and
- Trends in marine water quality at SECN parks compared to that of the entire south Atlantic.

These analyses will contribute to our understanding of ecological relationships and provide a weight-of evidence approach to describing changes in ecosystem condition. Integrated analysis reports will be prepared at 10-year (or longer) intervals and will be peer reviewed by an external three-member panel.

Data Dissemination

The SECN will provide monitoring data through a variety of means including workshops, presentations, publications, newsletters, and websites.

Network Workshops

Network staff, park scientists, and collaborators involved in monitoring SECN Vital Signs will routinely meet with park managers to provide a briefing on the condition of park natural resources and discuss possible implications for management. These workshops may be organized by ecosystems or by broad monitoring topics. The workshops will serve to increase the availability and utility of monitoring results for park managers and promote communication among the contributing scientists and park managers.

Scientific Publications, Presentations, and Outreach

Publishing in scientific journal articles and book chapters is a key method for communicating advances in knowledge and improving the scientific rigor of the monitoring program. Network staff, park scientists, and collaborators will also periodically present their findings at professional symposia, conferences, and workshops to communicate the latest findings and identify emerging issues relevant to natural resource monitoring and management. Along with providing scientific reports, each scientist involved with network monitoring will be asked to contribute materials (e.g., story ideas, photographs) for use in newsletters, interpretive talks and exhibits, and other media in order to inform and entertain the general public.

Internet and Intranet Websites

Internet and NPS intranet websites are contemporary tools useful for promoting communication, coordination, and collaboration among the many people, programs, and agencies involved in the SECN monitoring program. 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 SECN internet website: http://www1.nature.nps.gov/im/units/secn/index.htm.

Documents available on this network website will include this monitoring plan; all protocols; annual, trend, and integrated analysis reports; and other materials of interest to NPS staff and our collaborators.

Additionally, to promote communication and coordination within the network, we will maintain a password-protected intranet website where draft products, works in progress, and other materials that require restricted access can be shared within the program.

Table 7-2.
Summary of proposed analyses for SECN Vital Signs. Deferred Vital Signs are not included.

Vital Signs (grouped by protocol / SOP)	Proposed Analyses
Air Quality Vital Signs (ozone, wet and dry deposition, visibility and particulate matter, and air contaminants)	Status: Monthly and annual means of air quality parameters for each sentinel station identified inside or near SECN parks. Trend: Analyses of major ions, particulates, and number of days with exceedences for ozone; qualitative comparison of regional trends.
Weather and Climate	Status: Monthly and annual means of climate measures for each sentinel station identified inside or near a park; number of days above 95th percentile and below 5th percentile for both air temperature and precipitation. Trend: Descriptive comparisons of current year climate measures to historical trends on a yearly and monthly basis; qualitative and quantitative comparisons of annual climate conditions and trends, and climatic extremes among SECN park units and with regional trends.
Coastal Shoreline Change	Status: Annual to semi-annual position of shorelines; Trends: Spatial pattern analyses to determine areas of high variance in shoreline position.
Salt Marsh Elevation	Status: Mean and variance of elevation of sentinel stations by park. Trend: Regression-based analyses of elevation data; correlative analyses among measured attributes and *Weather and Climate* and *Groundwater Dynamics* measures.
Stream/ River Channel Characteristics	Status: Mean and variance of measured attributes; reach-level inferences of monitored attributes. Trend: Regression-based analyses; correlative analyses with data from other related Vital Signs (*Land Use and Cover*, and *Stream Water Quality*); qualitative and quantitative comparisons of status and trends of measured attributes among SECN park units.
Groundwater Dynamics	Status: Mean and variance of freshwater and saltwater Table levels. Trend: Regression-based analyses of measured data; correlative analyses with data from other related Vital Signs (*Land Use and Cover*, and *Surface Water Dynamics*).
Surface Water Dynamics	Status: Mean and variance of freshwater and saltwater Table levels. Trend: Regression-based analyses of measured data; correlative analyses with data from other related Vital Signs (*Land Use and Cover*, and *Groundwater Dynamics*).
Marine Water Quality	Status: Mean and variance of measured attributes; park-level inferences of monitored attributes. Site and park-wide assessment of water quality based on EPA's National Coastal Assessment standards. Monthly quality assurance and control for data collected at fixed stations. Summarize site data by season and tabulate values exceeding and approaching exceedence of standards (70% or less below the applicable standard); summary Table, histograms, and central tendency plots to show frequency distribution, median and interquartile ranges (for non-normally distributed data), mean and standard deviation (for normally distributed data) and 95% confidence intervals for means and medians of parameters at each site. Trend: Site-level trend analysis adjusted for season and flow for individual constituents. Statistical tests include Seasonal Kendall tests for monotonic trends and Seasonal Rank Sum tests for step trends.
Riverine Water Quality	Status: Mean and variance of measured attributes; park-level inferences of monitored attributes. Monthly quality assurance and control for data collected at fixed stations. Summarize site data by season and tabulate values exceeding and approaching exceedence of standards (70% or less below the applicable standard); summary Tables, histograms, and box and whisker plots to show frequency distribution, median and interquartile ranges (for non-normally distributed data), mean and standard deviation (for normally distributed data) and 95% confidence intervals for means and medians of parameters at each site. Trend: Site-level trend analysis adjusted for season and flow for individual constituents. Statistical tests include Seasonal Kendall tests for monotonic trends and Seasonal Rank Sum tests for step trends.
Plant Communities, Invasive/ Exotic Plant Species	Status: Mean and variance of measured attributes; park-level inferences of monitored attributes. Trend: Regression-based analyses of breeding bird density and comparison of trends among park units, *Land Use and Cover*, *Amphibian*, *Breeding Forest Bird*, and *Weather and Climate* measures.

Vital Signs (grouped by protocol / SOP)	Proposed Analyses
Amphibians, Fire and Fuel Dynamics	Status: Mean and variance of species presence, absence and abundance, soil moisture, downed woody debris, duff depth, and incidence/prevalence rates of chytrid fungus by species and park. Trend: Regression-based analyses of breeding bird density and comparison of trends among park units, *Plant Community* measures, *Land Use and Cover* measures, and *Weather and Climate* measures.
Breeding Forest Birds	Status: Number of observations and density by species, and by park. Trend: Regression-based analyses of breeding bird density and comparison of trends among park units, *Plant Community* measures, *Land Use and Cover* measures, and *Weather and Climate* measures.
Shorebirds	Status: Monthly, seasonal and annual mean and variance of observations of shorebirds and beached birds by species, park mile, habitat, spit, island, or park. Location of observations of shorebirds and beached birds within the last day, week, or month. Trend: Analyses (regression-based, ANOVA) of observation records and measures of visitor use, habitat, season, tide, and location. Correlative analyses between *Land Cover and Use* (particularly areas of closures) and observations.
Fisheries Take	Status: Monthly mean and variance of quantity and size of catch by species for counties or states around SECN coastal parks (scale determined by availability of data). Trend: Regression-based analyses of monthly data.
Visitor Use	Status: Monthly mean and variance of numbers of visitors as determined by park visitor use surveys or other park-based visitor use measures. Trend: Regression-based analyses of monthly data.
Land Cover and Use	Status: Description and measures (including abundance, spatial distribution, and connectivity) of land use and cover and vegetation types within and adjacent to SECN parks from classified remotely-sensed imagery and from use of landscape metrics software programs. Trend: Change detection of land cover and vegetation types and patterns using spectral comparison methods; regression-based analyses of changes along and within park boundaries; correlative analyses of broad-scale climate changes with changes in landscape vegetation pattern; qualitative and quantitative comparisons of status and trends of land cover and vegetation patterns among SECN park units.

Chapter 8. Administration / Implementation of the Monitoring Program

Coordination among Network Parks

Network member parks are committed to cooperate and foster an atmosphere of fairness, trust, and respect throughout the Network. The parks within the Network are pursuing an inclusive approach in defining Network management issues and resources of concern, and in identifying the best locations to monitor these resources, as well as implementing the I&M program using scientifically credible standards. Operations of the partnership among the SECN parks are governed by the Network Charter, signed by all park Superintendents (Appendix 1), which explicitly spells out the roles and membership of three core groups of individuals: the Board of Directors, the Technical Steering Committee, and Network Staff (Figure 8-1).

Board of Directors

The SECN Board of Directors is comprised of five Network park Superintendents and the Southeast Region I&M Coordinator, with one superintendent elected to serve as the chairperson (Figure 8-1). Board member Superintendents serve for three years, while the Chair serves for two years. The Chair leaves the Board after serving as Chair. Terms are renewable other than the Chair, which rotates off at least one year after serving as chair. At a minimum, one new board member is added from the remaining parks every two years at the time a new chairperson is selected. Vacancies will be filled by the Chairperson with the concurrence of the remaining Board. The SER I&M Coordinator is a permanent member of the Board. The SECN Coordinator and Chairperson will facilitate meetings and communications of members and with all network parks. The SECN Coordinator will serve as advisor to the Board of Directors.

The Board promotes accountability and effectiveness by reviewing progress toward goals, quality controls, and Network expenditures. The Board collaborates with the Network Coordinator, Technical Steering Committee, and Network parks' natural resource staffs in the overall design and implementation of Vital Signs monitoring and in other management activities related to the Natural Resource Challenge.

Technical Steering Committee

The Technical Steering Committee is comprised of resource managers (elected by the Network Park Resource representatives with the concurrence of their Park Superintendent), and non-voting, volunteer scientists as needed. The Committee includes the Network Coordinator, Data Manager, CESU coordinator, park natural resource managers, and other scientists with knowledge of sampling procedures, monitoring techniques, and statistical methods that serve as reviewers to evaluate conceptual designs, monitoring strategies, and ecological relevance of monitoring proposals.

The Technical Steering Committee advises the Board and Network parks on the development and findings of the Network Monitoring Plan by:

- Compiling and summarizing existing information about park resources and the findings and recommendations of scoping workshops.

- Assisting in the development of a network monitoring strategy.
- Assisting in the selection of Vital Signs.
- Evaluating initial sampling designs, methods, and protocols to ensure that they are scientifically credible.
- Participating in the development of the Annual Work Plan and Annual Reports.
- Reviewing annual data reports, I&M deliverables, and otherwise acting as a peer science review group.
- Developing materials for and facilitating the Five Year Program Review.

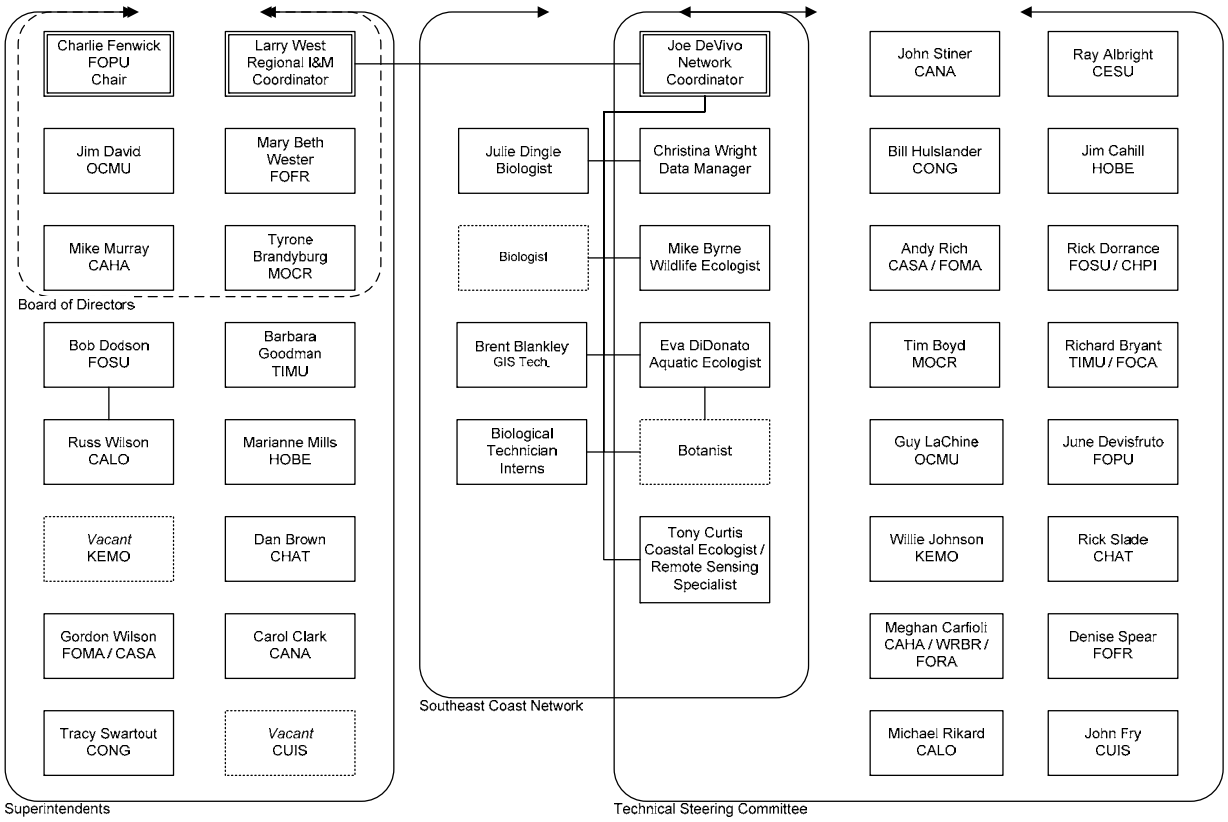


Figure 8-1. Organization and staffing plan for the Southeast Coast Network as of 09 September 2008. Staffing plan for the Network will change as the program moves from a planning to an operational phase.

Products and recommendations of the Technical Steering Committee are presented to the Board of Directors for discussion, modification, and approval. When necessary, the Network Coordinator may recommend to the Board of Directors the formation of groups of scientists or

specialists from within or outside the Technical Steering Committee to accomplish specific studies/tasks.

Network Staff

Staffing for the Southeast Coast Network is expected to change as the program moves from a planning to an operational phase. The staffing plan for implementation includes three "tiers" of position: (a) core professional-level staff with primary responsibility for stewardship of one or more of the SECN monitoring protocols, (b) support staff, to assist with program administration and field work related to long-term monitoring efforts, and (c) field staff to assist with (or lead) synoptic monitoring projects that augment baseline long-term monitoring efforts.

At full implementation, the network will require twelve full-time staff members and one part-time (shared) administrative support staff member (Figure 8-2). Because the network has a limited number of FTEs (eight), four of the technician-level positions will be filled through contractors or through partnerships with agencies, universities, or NGOs within the region. It is anticipated that the core staff will be divided among two offices – one located at Fort Sumter National Monument in Charleston, SC, and one located at Cumberland Island National Seashore, in Saint Mary's, GA. Both office locations were selected to minimize operational costs (rent, travel) while maximizing the Network's ability to partner with other agencies with expertise and interests in monitoring SECN Vital Signs.

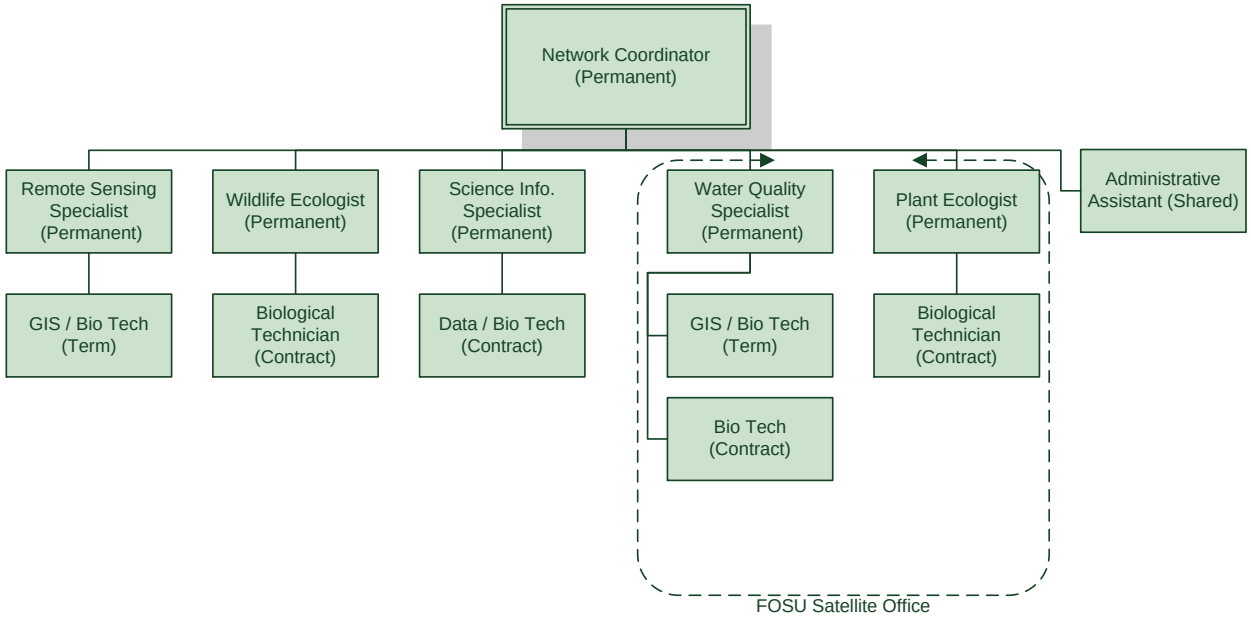


Figure 8-2. Operational organizational Chart for the Southeast Coast Network. Only core staffing positions and long-term support staff (administrative and field) are included. Additional field support staff might be added based on needs identified in annual work plans. Main office will be located at Cumberland Island National Seashore.

Core Job Functions for Network Staff

The following includes generalized descriptions of core job duties for those positions identified in the SECN organizational chart. Positions linked to Vital Signs that might be implemented in future years (i.e., *Fish Communities*, *Marine Invertebrates*, and *Aquatic Vegetation*) are not included at this time but will be developed when or if those Vital Signs are implemented.

Network Coordinator (GS 13 Permanent). Chief scientist for the network responsible for oversight and implementation of the Vital Signs Monitoring plan, developing annual budgets and workplans in consultation with the Technical Steering Committee, and reporting on program findings to the Steering Committee, the Board of Directors, and park Superintendents. Responsible for development and maintenance of partnerships to carry out or enhance Vital Signs monitoring within network parks. Responsible for the supervision of core and seasonal staff. Works with Park, Regional, National, and Network staff to develop and implement a communications strategy to guide reporting of Network findings to key audiences and to integrate those findings with existing and developing NPS programs (such as interpretation, maintenance, and law enforcement).

Science Information Specialist / Data Manager (GS 12 Permanent). Responsible for design, implementation, and maintenance of the data management system that supports the storage, analysis, and reporting of data for all SECN Vital Signs. Responsible for QA/QC, metadata generation, and coordination of information management among the Network, its parks, partners, and the national program. Holds primary responsibility for implementation of SOPs for Vital Signs that rely on external sources for data acquisition (see Table 5-2). At full performance, the incumbent will have supervisory responsibilities over other personnel involved with data management, including technicians and the remote sensing specialist.

Remote Sensing Specialist (GS 11 Permanent). Primary responsibilities are with the implementation of the *Coastal Shoreline Change* and *Landscape Change Detection* protocols, and the support of other Vital Signs where landscape-scale data are required for data analysis or interpretation. At full performance the incumbent would develop spatial models to identify relations among Vital Signs and where appropriate develop models to predict the distribution of communities, habitats, or species of concern based on those models.

Wildlife Ecologist (GS 12 Permanent). Primary responsibilities are with the implementation of wildlife-related Vital Signs, including *Amphibians*, *Fire and Fuel Dynamics*, *Breeding Forest Birds*, and *Wintering & Migratory Shorebirds*. Works with all network staff to analyze long-term monitoring data and to report findings to a variety of audiences. At full performance, the incumbent will be responsible for developing sampling designs for synoptic studies and authoring scientific publications on Network findings.

Aquatic Ecologist (GS 12 Permanent). Primary responsibilities are with the implementation of Vital Signs related to water quality and water quantity. Will be responsible for contract management and development of annual study designs in coordination with partners to implement water quality and quantity monitoring in tidal/ estuarine and freshwater ecosystems. At full performance, the incumbent will have supervisory responsibilities over the coastal field

office and will be responsible for analyzing data, reporting findings to a variety of audiences, and authoring scientific publications on Network findings.

Plant Ecologist (GS 12 Permanent). Primary responsibilities are with the implementation of wildlife-related Vital Signs, including *Plant Communities*, *Salt Marsh Elevation* and *Invasive/ Exotic Plants*. Because the majority of the incumbent's field work will be spent in coastal parks, the position will be duty-stationed in the coastal office. Works with all network staff to analyze long-term monitoring data and to report findings to a variety of audiences. At full performance, the incumbent will be responsible for developing sampling designs for synoptic studies and authoring scientific publications on Network findings.

Technicians (5/6/7 Term or Contract Positions). Four to six technician-level staff members are expected to be needed to implement the protocols or to assist with data management and analysis. It is anticipated that two of these positions will be government positions to enhance continuity in the implementation of monitoring protocols. Additional technician-level positions will be filled using a combination of options including contractors and agreements with NGOs, universities, and neighboring agencies.

Administrative Assistant. The SECN will share an administrative assistant with other I&M networks and the Exotic Plant Management program in the Southeast Region. The incumbent will primarily be responsible for budget tracking and procurement. The FTE for the position will be provided from outside the eight allotted to the SECN.

Integration with Park Operations

It is a goal of the SECN to serve as a catalyst in linking together individual park natural resource programs in a successful integrated inventory and monitoring program. Presently, most parks manage their natural resource programs independently and prepare proposals to develop their programs on an annual basis. The same or similar resource inventory, monitoring and management work is regularly proposed across network parks, in competing proposals.

Evaluation of existing and future needs at a network level presents a significant opportunity for parks to begin working together while spreading limited resources for greater effect. Already SECN has demonstrated the benefit of leveraging network and park funding to obtain additional financial support for large projects (e.g., vegetation mapping, watershed condition assessments, and exotic plant management).

The SECN is interested in fostering internal NPS cross-program coordination. Significant opportunity exists to link efforts with interpretation programs in the parks. The SECN is committed to making all park staff knowledgeable about the natural resource inventory and monitoring program.

Some examples of how SECN will integrate with other programs in network parks include:

- Providing park staff with information on natural resource status, trends (and significance thereof) for inclusion in new interpretive materials,

- Coordinating GIS and data management capacity with the Old-Growth Bottomland Foreest Research and Education Center at Congaree National Park,

- Developing data management and delivery systems that provide real-time monitoring information to park managers to institutionalize the use of I&M data for routine operations,

- Coordinating collections management and archiving needs of the Network with park procedures, and

- Providing information to park managers for the purposes of tracking progress and reporting on natural resource management performance measures.

Partnerships

Much of the monitoring work planned by the SECN cannot be accomplished without close coordination with partners from academic, State, NGO and other Federal agencies / organizations. The following are existing (formal and informal) partnerships that are critical to the implementation of the Network's monitoring plan:

- *University of Georgia Marine Extension Service.* Conducts probabilistic water quality monitoring protocols in marine / estuarine systems using protocols developed by EPA.

- *Florida Department of Environmental Protection / Office of Coastal and Aquatic Managed Areas.* Maintains three fixed water quality monitoring stations at TIMU, conducts QA on data and assists with data interpretation.

- *City of Jacksonville, Environmental Resource Department.* Collects monthly nutrient, bacteria, and Chlorophyll samples at 12 sites within TIMU.

- *North Carolina National Estuarine Research Reserve.* Maintains 1-2 fixed water quality monitoring stations at CALO; SECN provides all equipment and supplies.

- *NOAA – Hollings Marine Laboratory.* Assists with analysis and interpretation of coastal and estuarine water quality data.

- *Indian River Lagoon National Estuarine Program.* Collaborates on sampling designs to leverage water quality monitoring efforts.

Other partnerships will be developed to assist as needed or as opportunities arise to assist with field sampling, data management, and reporting.

Programmatic Reviews

The SECN I&M Coordinator, in consultation with the Technical Steering Committee and other designated subgroups, prepares and presents a draft Annual Report to the Board of Directors for consideration and approval on or before October 30th each year. Annual Reports detail specific accomplishments, products, lessons learned, coordination with others, and a budget summary. A

detailed accounting of all SECN I&M program funds allocated to each park and office will be appended to and made part of the Annual Report.

The SECN will undergo a “Start-up Review” 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, and will address whether the network is set up to succeed. The review will allow network and park staff to step back and evaluate initial progress against the objectives and schedule set forth in this monitoring plan, develop a “road map” for completing and implementing the first set of protocols, and to make adjustments if needed.

At the end of the fifth fiscal year of Vital Signs monitoring, and every five years thereafter, the network will undertake a comprehensive program review. The review shall be conducted by National Park Service specialists at the national and regional levels, and may involve qualified independent specialists from other agencies and organizations. The purpose of these reviews is to evaluate accomplishments, products, and protocols used for gathering data, data management, fiscal management, and staffing. Program reviews provide the basis for any significant changes in program direction or reassignment of resources to any park or office with the approval of the SECN Board of Directors.

Chapter 9. Schedule

This chapter describes the plan for implementing the SECN Vital Signs Monitoring program. For the ten protocols under development in the next three to five years, we present both the development and implementation schedule (Table 9-1) and the annual field sampling schedule (Figure 9-1). The SECN plans to fully implement thirteen protocols by the end of FY 2010, with all protocols to be phased in by the five-year review.

Table 9-1.
Deployment schedule of monitoring protocols to be implemented by the Southeast Coast Network.
[Protocol Development & Field Trials, Site Selection & Establishment, Full Implementation].

Protocol Name	Network Vital Signs (where different)	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012
Coastal Shoreline Change						
Stream Habitat Assessment						
Salt Marsh Elevation						
Marine Water Quality						
Fixed-Station Water Quality	Marine Water Quality and Stream Water Quality					
Amphibians	Amphibians and Fire & Fuel Dynamics					
Breeding Forest Birds						
Plant Communities	Plant Communities and Invasive/ Exotic Plants					
Wintering & Migratory Shorebirds						
Landscape Change Detection						

As we progress through FY 2009 and beyond the network will reevaluate the implementation schedule. This evaluation will take place on a protocol by protocol basis, but we will also evaluate how implementation as a whole is going and use that evaluation to help us adjust annual work plans as necessary.

Protocol Implementation Schedule

Similar to the phased process each network takes to develop a monitoring plan, the SECN is taking a phased approach to the implementation of Vital Signs monitoring (Figure 9-1). The ten protocols will be phased in between FY2007 and FY2011, primarily to ensure that the Network's data management capacity can keep pace with data collection (Figure 9-1). Also, several protocols require the deployment and installation of permanent equipment, modifications to existing structures (docks, piers), or post-deployment calibration periods. In such cases deployment of stations and equipment will likewise be phased in due to spread out deployment expenses.

By taking this approach we will be able to use experience learned from initial deployments to improve those conducted in later years.

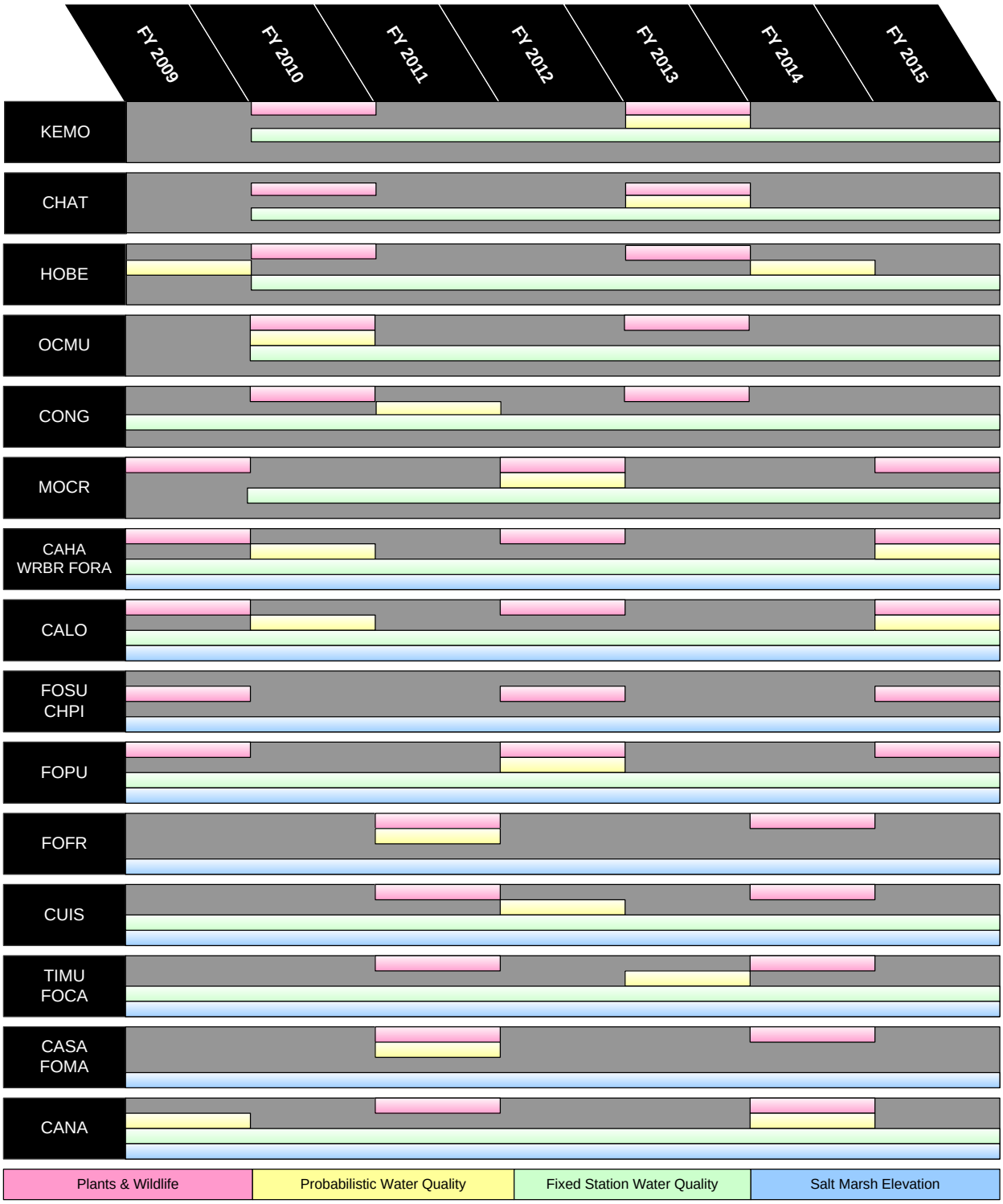


Figure 9-1. Annual protocol implementation schedule for Southeast Coast Network Vital Signs monitoring protocols that require field work.

Annual Sampling Schedule

In any given year, 1/3 of the parks will be selected for intensive sampling (Figure 9-1); those parks will undergo an assessment of landscape dynamics to ensure that landscape-scale Vital Signs are collected concurrently with field sampling. During any given fiscal year, at least one and as many as three types of monitoring protocols will be implemented at any given park (Figure 9-1):

- *Continuous / Fixed Station Monitoring.* Continuous monitoring stations are central to many of the SECN protocols, particularly for those relating to air quality, weather, water quality, and water quantity. Although data are collected in regular intervals (ranging from minutes to days), acquisition and integration of those data sets will likely occur much less frequently (monthly to annually). Although data collection is not automated, sediment elevation readings in coastal wetlands will be conducted at a minimum of annually.

- *Probabilistic Water Quality Monitoring.* Due to the number of sites and the associated costs of laboratory analyses, park-wide assessments of water quality will only be conducted once every five years. Water quality monitoring will included chemical, biological, and physical measurements as appropriate to the ecosystem (mainstem rivers, tributaries, or marine / estuarine systems) being monitored. To the extent possible, protocols currently adopted by State agencies will be used to allow for integration of ancillary data collected during interim sampling periods.

- *Probabilistic Terrestrial Monitoring.* Due to higher travel costs associated with field sampling, plant and animal communities will be sampled on a once per three-year schedule. Groups of parks are selected to minimize travel costs, and plant and animal communities will be sampled at the same parks during any given year to allow for collocation of sample sites.

Each year, monitoring data are synthesized for all Vital Signs. Park-wide assessments are conducted following intensive terrestrial monitoring.

Chapter 10. Budget

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Glossary

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

Adaptive monitoring design: An iterative process that refines the specifications for monitoring over time as a result of experience in implementing a monitoring program, assessing results, and interacting with.

Area Frame: A sampling frame that is designated by geographical boundaries within which the sampling unites are defined as subareas.

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

Biological Significance: An important finding from a biological point of view that may or may not pass a test of statistical significance.

Co-location: Sampling of the same physical units in multiple monitoring protocols

Conceptual Models: purposeful representations of reality that provide a mental picture of how something works to communicate that explanation to others.

Degradation: An anthropogenic reduction in the capacity of a particular ecosystem or ecosystem component to perform desired ecosystem functions (e.g., degraded capacity for conserving soil and water resources). Human actions may degrade desired ecosystem functions directly, or they may do so indirectly by damaging the capacity of ecosystem functions to resist or recover from natural disturbances and/or anthropogenic stressors.

Disturbance: "...any relatively discrete event in time that disrupts ecosystem, community, or population structure and changes resources, substrate availability, or the physical environment." In relation to monitoring, disturbances are considered to be ecological factors that are within the evolutionary history of the ecosystem (e.g., drought). These are differentiated from anthropogenic factors (*stressors*, below) that are outside the range of disturbances naturally experienced by the ecosystem.

Disturbance Stimuli: Non-lethal, human-caused events that change an animal's behavior from patterns occurring without human influence; analogous to predation risk.

Driver: The major external driving forces that have large-scale influences on natural systems. Drivers can be natural forces or anthropogenic.

Dynamic soil Properties: Soil properties that vary in relation to management activities, climatic fluctuations, or natural disturbances (e.g., bulk density, infiltration capacity, soil-surface roughness, organic-matter content, soil aggregate stability, biological soil crust cover and composition).

Ecological Indicator: See *Indicator*.

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

Ecological Site: A kind of land with specific physical characteristics which differs from other kinds of land in its ability to produce distinctive kinds and amounts of vegetation and in its response to management.

Ecological Sustainability: The tendency of a system or process to be maintained or preserved over time without loss or decline.

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

Ecosystem Functioning: The flow of energy and materials through the arrangement of biotic and abiotic components of an ecosystem. Includes many ecosystem processes such as primary production, trophic transfer from plants to animals, nutrient cycling, water dynamics and heat transfer. In a broad sense, ecosystem functioning includes two components: ecosystem resource dynamics and ecosystem stability.

Ecosystem Health: A metaphor pertaining to the assessment and monitoring of ecosystem structure, function, and resilience in relation to the notion of ecosystem “sustainability.” A healthy ecosystem is sustainable (see *Sustainable Ecosystem*, below).

Ecosystem Integrity: See *Ecological Integrity*.

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

Ecosystem Sustainability: See *sustainable ecosystem.*

Endpoints: Ecosystem attributes of ecological and/or societal importance. Endpoints may or may not be indicators of overall ecosystem condition (also referred to as *assessment endpoints*).

Focal Ecosystems: Ecosystems that play significant functional roles in landscapes by their disproportionate contribution to the transfer of matter and energy, or by their disproportionate contribution to landscape-level biodiversity.

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

Functional Groups: Groups of species that have similar effects on ecosystem processes – frequently applied interchangeably with *functional types*.

Functional Types: Sets of organisms sharing similar responses to environmental factors such as temperature, resource availability, and disturbance (= functional *response* types) and/or similar effects on ecosystem functions such as productivity, nutrient cycling, flammability, and resistance / resilience (= functional *effect* types).

Hydrologic Function (upland systems): Capacity of a site to capture, store, and safely release water from rainfall, run-on, and snowmelt, to resist a reduction in this capacity, and to recover this capacity following degradation.

Hydrologic function (lotic and lentic systems): Capacity of an area to:

- dissipate energies associated with (1) high stream flow (lotic); or (2) wind action, wave action, and overland flow (lentic); thereby reducing erosion and improving water quality;
- filter sediment, capture bedload, and aid floodplain development;
- improve flood-water retention and groundwater recharge;
- develop root masses that stabilize streambanks against cutting action;
- develop diverse ponding and channel characteristics to provide the habitat and the water depth, duration, and temperature necessary for fish production, waterfowl breeding, and other uses;
- support greater biodiversity

Indicators: A subset of monitoring attributes that are particularly information-rich in the sense that their values are somehow indicative of the quality, health, or integrity of the larger ecological system to which they belong (Noon 2003). Indicators are a selected subset of the physical, chemical, and biological elements and processes of natural systems that are selected to represent the overall health or condition of the system.

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

Landscape: A spatially structured mosaic of different types of ecosystems interconnected by flows of materials (e.g., water, sediments), energy, and organisms.

Landscape Diversity: The number of ecosystem types and their spatial distribution.

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

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

Metric: Metrics are those *Measures* that respond consistently to environmental stressors or gradients within an ecosystem and to which scoring criteria are applied. Typically, *Measures* are quantified with different units and have different absolute numerical values (e.g., numbers of taxa might range from 0 to 100 and relative species abundances would be reported as percentages). Additionally, some metrics might increase with response to disturbance while others might decrease. To resolve such differences, metrics are assigned scores based on expectations for that metric at minimally disturbed sites in similar systems, representing a degree of deviation from those reference conditions. *Metrics* are the building blocks of *Multimetric Indexes* (modified from Karr and Chu, 1997).

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

Multimetric Index: An assessment tool that systematically combines scores from two or more *Metrics* to provide a qualitative summary value judgment about the condition of a monitored resource (i.e., “Good,” “Fair,” or “Poor”).

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

Resilience: The capacity of a particular ecological attribute or process to recover to its former reference state or dynamic after exposure to a temporary disturbance and/or stressor. Resilience is a dynamic property that varies in relation to environmental conditions.

Resistance: The capacity of a particular ecological attribute or process to remain essentially unchanged from its reference state or dynamic despite exposure to a disturbance and/or stressor. Resistance is a dynamic property that varies in relation to environmental conditions.

Soil Quality: The capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation. From an NPS perspective, soil quality is defined by a soil's capacity to perform three ecological functions: 1) regulate hydrologic processes, 2) capture, retain, and cycle mineral nutrients, and 3) support characteristic native communities of plants and animals. Soil quality can be regarded as having an inherent component defined by the soil's inherent soil properties as determined by the five factors of soil formation, and a dynamic component defined by the change in soil function that is influenced by human use and management of the soil.

Soil/ Site Stability: The capacity of a site to limit redistribution and loss of soil resources (including nutrients and organic matter) by wind and water.

State: As applied to state-and-transition models, a *state* is defined as "a recognizable, resistant and resilient complex of two components, the soil [or geomorphic] base and the vegetation structure." These two ecosystem components interactively determine the functional status of the primary ecosystem processes of energy flow, nutrient cycling, and hydrology. States are dynamic and "... are distinguished from other states by relatively large differences in plant functional groups and ecosystem processes [including disturbance and hydrologic regimes] and, consequently, in vegetation structure, biodiversity, and management requirements" (Also see *threshold* and *transition*).

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

Sustainable Ecosystem: An ecosystem "...that, over the normal cycle of disturbance events, maintains its characteristic diversity of major functional groups, productivity, and rates of biogeochemical cycling."

Threshold: As applied to state-and-transition models, a *threshold* is a point "...in space and time at which one or more of the primary ecological processes responsible for maintaining the sustained [dynamic] equilibrium of the state degrades beyond the point of self-repair. These processes must be actively restored before the return to the previous state is possible. In the absence of active restoration, a new state ... is formed" (Stringham et al. 2003:109). Thresholds are defined in terms of the functional status of key ecosystem processes and are crossed when capacities for resistance and resilience are exceeded. (Also see *state* and *transition*.)

Transition: As applied to state-and-transition models, a *transition* is a trajectory of change that is precipitated by natural events and/or management actions which degrade the integrity of one or more of the primary ecological processes responsible for maintaining the dynamic equilibrium of the state. Transitions are vectors of system change that will lead to a new state without abatement of the stressor(s) and/or disturbance(s) prior to exceeding the system's capacities for resistance and resilience. (Also see *state* and *threshold*.)

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

Vital Signs: 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. Vital signs may occur at any level of organization including landscape, community, population, or genetic level, and may be compositional (referring to the variety of elements in the system), structural (referring to the organization or pattern of the system), or functional (referring to ecological processes).

The 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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