National Park Service
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Natural Resource Program Center

Gulf Coast Network Vital Signs Monitoring Plan

Natural Resource Report NPS/GULN/NRR–2007/015

ON THE COVER
Top: (1) Great blue heron (*Ardea herodias*), Padre Island National Seashore. (2) Naval Live Oaks Reservation, Gulf Islands National Seashore. (3) Texas tortoise (*Gopherus berlandieri*), found in San Antonio Missions National Historical Park and Palo Alto Battlefield National Historic Site. (4) Natchez Trace Parkway (NPS photo).

Middle: (1) Dunes in November, Padre Island National Seashore. (2) Large ranid frog, Jean Lafitte National Historical Park and Preserve. (3) Vicksburg National Military Park.

Bottom: (1) Big Thicket National Preserve (NPS photo). (2) Acequia at San Antonio Missions National Historical Park.

All photos in this document are courtesy NPS/R. Woodman unless otherwise noted.

Gulf Coast Network Vital Signs Monitoring Plan

Natural Resource Report NPS/GULN/NRR–2007/015
Version 1.1

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Acronyms

AARWP	Annual Administrative Report and Work Plan
BITH	Big Thicket National Preserve
BOD	Board of Directors
BP	Barataria Preserve
CBNC	Chalmette Battlefield and National Cemetery
CESU	Cooperative Ecosystem Studies Unit
CIR	color infrared
CUPN	Cumberland Piedmont Network
DMP	Data Management Plan
ENSO	El Niño/Southern Oscillation
EPA	U.S. Environmental Protection Agency
EPA-CCA	U.S. Environmental Protection Agency Coastal Condition Assessment
FY	fiscal year
GEM	general ecosystem model
GIS	Geographic Information Systems
GPRA	Government Performance and Results Act
GRTS	General Random Tessellation Stratified
GUIS	Gulf Islands National Seashore
GUIS-FL	Gulf Islands National Seashore–Florida section
GUIS-MS	Gulf Islands National Seashore–Mississippi section
GULN	Gulf Coast Network
GULN WQMP	Gulf Coast Network Water Quality Monitoring Plan
HTLN	Heartland Network
I&M	Inventory and Monitoring
IT	information technology
JELA	Jean Lafitte National Historical Park and Preserve
LiDAR	Light Detection and Ranging
NASA	National Aeronautics and Space Administration
NATR	Natchez Trace Parkway
NBII	National Biological Information Infrastructure
NCBN	Northeast Coast and Barrier Network
NOAA	National Oceanic and Atmospheric Association
NPS	National Park Service
NPS-ARD	National Park Service Air Quality Division
NPS-GRD	National Park Service Geologic Resources Division
NR	natural resource
NWS	National Weather Service
OMB	President's Office of Management and Budget
PAAL	Palo Alto Battlefield National Historic Site
PAIS	Padre Island National Seashore
PDS	Protocol Development Summary
PI	principal investigator
POMS	portable ozone monitoring station
QA	quality assurance

QC	quality control
SAAN	San Antonio Missions National Historical Park
SAV	submerged aquatic vegetation
SCA	Student Conservation Association
SECN	Southeast Coast Network
SERO	Southeast Regional Office
SOPs	standard operating procedures
STAC	Scientific and Technical Advisory Committee
T&E	threatened and endangered
TCEQ-CRP	Texas Commission on Environmental Quality Clean Rivers Program
USGS	U.S. Geological Survey
USGS NAWQA	U.S. Geological Survey National Water Quality Assessment
VCP	variable circular plot
VICK	Vicksburg National Military Park
VSCMP	Vegetation Structure and Composition monitoring protocol
WASO	Washington Area Service Office

Executive Summary

Chapter 1: Introduction and Background

The Gulf Coast Network (GULN) is one of 32 networks included in the Servicewide Inventory and Monitoring program. The GULN includes eight units of the National Park System: Big Thicket National Preserve, Gulf Islands National Seashore, Jean Lafitte National Historical Park and Preserve, Natchez Trace Parkway, Palo Alto Battlefield National Historic Site, Padre Island National Seashore, San Antonio Missions National Historical Park, and Vicksburg National Military Park. The total area of land managed within the network is more than 440,500 acres.

Three general properties broadly affect the integrity of ecosystems and natural resources in GULN parks: (1) parks are generally surrounded by altered landscapes, and thus present the suite of challenges isolated ecosystems face; (2) the Gulf Coast region experiences storm events that have the potential to cause impacts to both environments and biota; and (3) the Gulf Coast region is increasingly subject to human development, resulting in diverse anthropogenic effects on park resources.

The network is committed to establishing the foundation of a monitoring program that will continue in the long term. We expect that the information gained will provide valuable data to aid appropriate management decisions in network parks and provide landscape-scale information that can also form the foundation of other, targeted, shorter-term, research projects in the parks. Issues of management concern are an important component of the monitoring program, but the focus is on landscape- and regional-scale issues shared by the network parks.

The following major objectives of the of the GULN monitoring program are associated with the landscape-scale issues that many of our parks have in common: (1) to monitor changes in land use outside of park boundaries; (2) to monitor changes in structure and community composition of terrestrial vegetation; (3) to monitor changes in water quality; (4) to monitor changes in common amphibian species abundance and distribution; (5) to monitor coastal dynamics, or the large-scale changes in landscape features in our coastal parks; and (6) to monitor weather and climate as a driver of larger ecosystem change across the network.

Chapter 2: Conceptual Ecological Models

The GULN 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 three dominant ecosystem types in GULN parks: the uplands/forest-dominated zone, the river-dominated wetlands/riparian zone, and the coastal/near-shore marine zone. Each model depicts a set of agents of change, stressors, ecosystem responses, and possible measures or indicators, along with some of the major links between levels. Each system model is applicable to multiple network parks, and several parks contain examples of multiple ecosystems represented by different system models.

Chapter 3: Vital Signs

Vital signs, as defined by the NPS, are a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, 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.

There are 42 identified vital signs for the GULN, presented within the vital signs framework as developed by the National Park Service Vital Signs Monitoring Program. Of these vital signs, 19 are considered to be higher priority for implementation under the scope of the current program. One of these vital signs refers to air and climate, one refers to geology and soils, three refer to water, two refer to ecosystem pattern and process, and twelve refer to biological integrity.

Chapter 4: Sampling Design

An overall sampling design has been proposed for the GULN. The GULN will use a design-based approach to monitoring that relies on the use of probability-based samples to extrapolate results to non-sampled units. In some cases, monitoring on GULN parks will use “panels” to spatially and/or temporally allocate sampling effort as a way to more effectively use limited monitoring resources. Monitoring of freshwater resources will rely on synoptic sampling, in which samples are taken on fixed calendar dates, regardless of flow and weather conditions. All sites within a park will be sampled in rotation. As we are in the early phases of development for most of our monitoring protocols, specific sampling designs are still largely conceptual. Once complete, each protocol will include a detailed sampling design, together with appropriate definitions and rationale, as part of its formal documentation.

Chapter 5: Sampling Protocols

Protocol Development Summaries for the four protocols currently being developed are located in Appendix N. These include the network-wide protocols for monitoring vegetation structure and composition, amphibian communities, adjacent land-use change, and water quality in the five predominantly freshwater parks. Because some of these protocols address more than one vital sign, we anticipate the development of eight separate protocols for the 19 high-priority vital signs. Additional development efforts anticipated to start later in FY2007 include a protocol for monitoring coastal and estuarine water quality, an all-parks bird monitoring protocol, a coastal geomorphology and landform protocol, and a submerged aquatic vegetation protocol. Each summary explains which vital signs are addressed by the protocol and the reasons why the vital sign was selected, sets forth specific monitoring objectives, and describes how the network plans to monitor the vital sign. Where possible, we are addressing multiple vital signs with one protocol. A draft freshwater monitoring protocol is located in Appendix M.

Chapter 6: Data Management

The data management plan for the GULN serves as the network’s overarching strategy to ensure that data collected by the program are subjected to rigorous quality assurance and control procedures and are made available to others for decisionmaking, 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 full Data Management Plan is located in Appendix O of this report. 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.

Chapter 7: Data Analysis and Reporting

The GULN approach to the analysis, interpretation, and reporting of monitoring data is based on three factors that contribute to the success of the program: (1) quality and timeliness of information; (2) rigorous data analysis; and (3) effective communication to address different audiences with diverse information needs. Formal reports and publications to be produced include, but are not limited to, annual administrative reports and workplans; 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 that will be an opportunity to present and discuss monitoring data. This will be an opportunity for 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 of the Monitoring Program

The network has developed a near-term (three-to-five-year) plan under which monitoring will begin and the development of additional protocols will be initiated. This plan includes a staffing plan, a plan to integrate network and park operations, key partnerships, and the periodic review process for the program. The network is planning to rely on key partnerships with federal and state agencies as well as 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. For the protocols under development in the next three to five years, we describe the key events or issues that must be addressed for each. Monitoring of water quality for freshwater resources will begin in 2007.

Chapter 10: Budget

Annual funding from the National Park Service's Vital Signs Monitoring Program for GULN is $929,800, with an additional $89,000 coming from the National Park Service Water Resources Division for water quality monitoring. During the first year of implementation (FY2008), we expect that 45% of the budget will be spent on personnel and 55% will be spent on operations (equipment, cooperative agreements, and travel). Overall, we will expend approximately 33% of our budget (calculated in both time spent and direct operational costs) on data management.

Acknowledgements

We would like to gratefully acknowledge the hard work of others who were involved during the many years of effort that went into developing this monitoring plan: Network Intern Luis German, for his diverse contributions to the completion of the draft plan; retired Network Coordinator Paul Conzelmann, for his leadership during the early phases of our program development; Southeast Coast Network Wildlife Ecologist Mike Byrne, for his initial development of park conceptual models and contributions to an earlier draft of the document; Writer-Editor Alice Wondrak Biel, for her skillful work in converting our draft materials into a polished professional document; and especially the superintendents and staff from the eight network parks who made time to develop and debate conceptual models, vital signs, and management priorities for the network parks.

Chapter 1
Introduction and Background

The Gulf Coast Network (GULN) is one of 32 networks included in the Servicewide Inventory and Monitoring (I&M) Program. The network approach facilitates collaboration, information sharing, and economies of scale in natural resource monitoring, and will provide parks with a foundational infrastructure for initiating natural resource monitoring that can be built upon in the future. The GULN is located in portions of six states, spanning from Brownsville, Texas, to Pensacola, Florida, and north to Nashville, Tennessee (Figure 1.1). The network includes eight National Park Service (NPS) units: Big Thicket National Preserve (BITH), Gulf Islands National Seashore (GUIS), Jean Lafitte National Historical Park and Preserve (JELA), Natchez Trace Parkway (NATR), Palo Alto Battlefield National Historic Site (PAAL), Padre Island National Seashore (PAIS), San Antonio Missions National Historical Park (SAAN), and Vicksburg National Military Park (VICK).

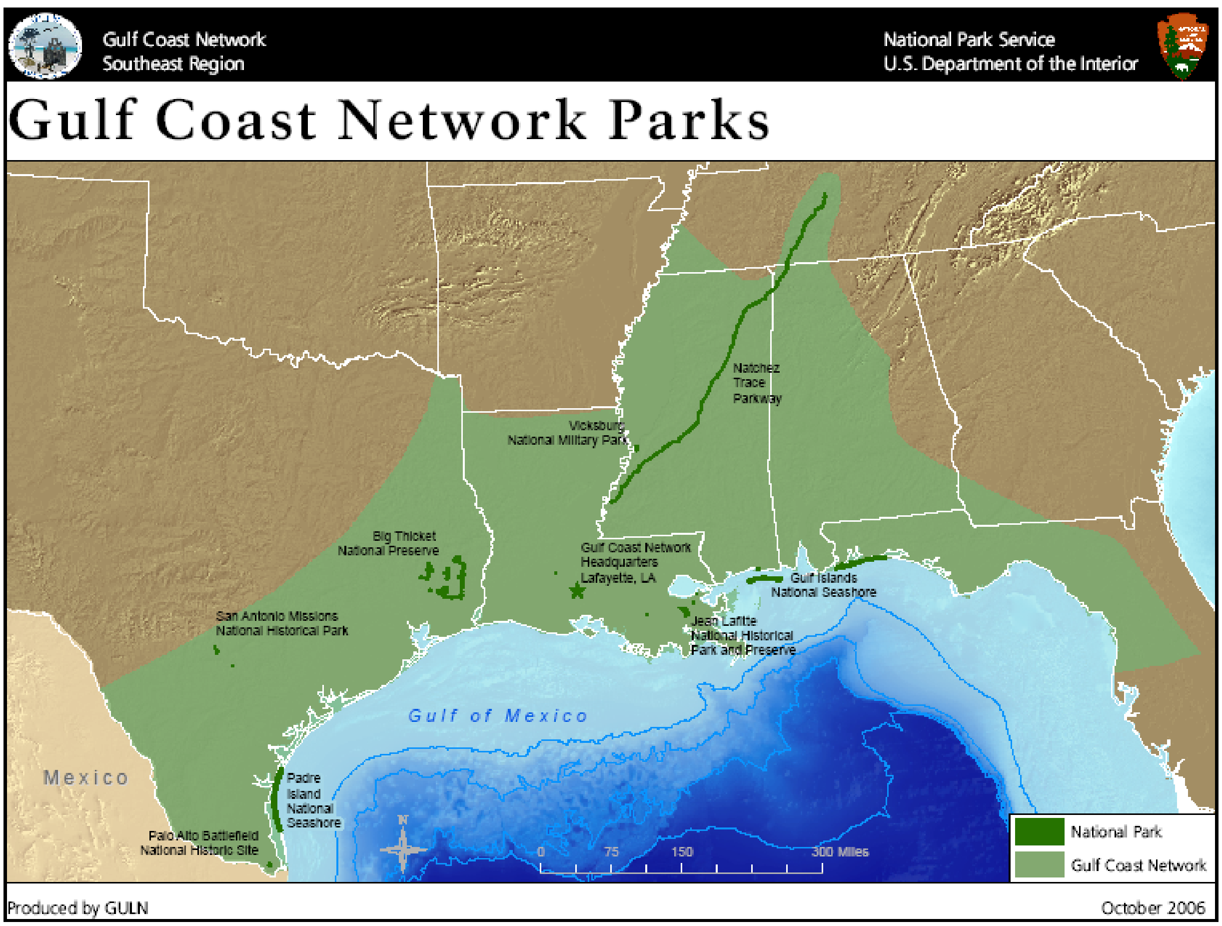

Figure 1.1. Map of the Gulf Coast Network parks.

1.1. Park Stewardship and Natural Resource Monitoring

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 working with other agencies and the public. The challenge of protecting and managing a park's natural resources requires a multi-agency, ecosystem-based approach because most parks are open systems, with many threats, such as air and water pollution or invasive species, originating outside of park boundaries. An ecosystem-based approach is further needed because no single spatial or temporal scale is appropriate for all system components and processes. The appropriate scale for understanding and effectively managing a resource might be at the population, species, community, or landscape level, and in some cases may require a regional, national, or international effort. National parks are part of larger ecosystems, and must be managed in that context.

Natural resource monitoring provides site-specific information needed to understand and identify changes 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 characterized by complexity, variability, and surprises. Monitoring data help to define the normal limits of natural variation in park resources and provide a basis for understanding observed changes; monitoring results may also be used to determine what constitutes impairment and to identify the need to initiate or change management practices. Understanding the dynamic nature of park ecosystems and the consequences of human activities is essential for management decisionmaking aimed to maintain, enhance, or restore the ecological integrity of park ecosystems and to avoid, minimize, or mitigate ecological threats to these systems (Roman and Barrett 1999).

Vital signs, as defined by the NPS, are a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, 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. Because of the need to maximize the use and relevance of monitoring results for making management decisions, vital signs selected by parks may include elements selected because humans have assigned them important value (e.g., harvested or charismatic species) or because of some 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 decisionmaking, 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 and research, provides the information needed for effective, science-based managerial decisionmaking and resource protection (Figure 1.2). 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 may trigger a management action, or it may generate a new line of inquiry. Research is generally defined as the systematic collection of data that produces new knowledge or relationships and usually involves an 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.

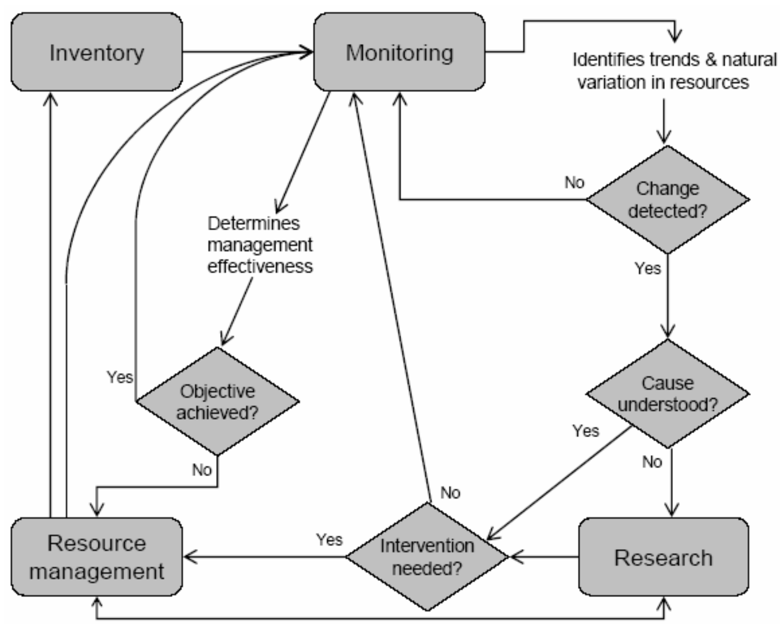

Figure 1.2. Relationships between monitoring, inventories, research, and natural resource management activities in national parks. Modified from Jenkins et al. (2002).

1.1.1. Servicewide monitoring goals

The overall goal 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 GULN monitoring program is designed around the five broad, servicewide monitoring goals common to all networks within the Vital Signs Monitoring Program:

1. Determine status and trends in selected indicators of the condition of park ecosystems to allow managers to make better-informed decisions and to work more effectively with other agencies and individuals for the benefit of park resources.
2. Provide early warning of abnormal conditions of selected resources to help develop effective mitigation measures and reduce costs of management.
3. Provide data to better understand the dynamic nature and condition of park ecosystems and to provide reference points for comparisons with other, altered environments.

4. Provide data to meet certain legal and congressional mandates related to natural resource protection and visitor enjoyment.
5. Provide a means of measuring progress toward performance goals.

Network-specific monitoring goals and objectives relate to the network-wide and park-specific ecosystems and management concerns of the network parks, and are presented in Section 1.6. Monitoring objectives were developed based on the process used to develop the conceptual models (see Chapter 2) and are presented and discussed in more detail in Chapter 3.

1.2. Legislative Mandates

The enabling legislation establishing the National Park Service and its individual park units clearly mandates, as its 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 (Appendix A). 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 FY2000 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 2001 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 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 its 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 to provide reference points for comparison with other environments and time frames.*
- *Use the resulting information to maintain-and, where necessary, restore-the integrity of natural systems" (*2001 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 A.

1.2.1. GULN monitoring plan and performance management

The Government Performance and Results Act (GPRA), passed by Congress in 1993, directs federal agencies to ensure that daily action and expenditures of resources are guided by long- and short-term goal-setting in pursuit of accomplishing an organization's primary mission, followed by performance measurement and evaluation. A list of the national GPRA goals relevant to the Monitoring Plan for GULN parks is located in Table 1.1; a complete list and descriptions of GPRA goals are located in Appendix A. This list of goals includes cultural resource goals, because many GULN parks have significant cultural resources. Management of those cultural resources needs to be coordinated with natural resource management. Goals concerning visitor understanding are also included on the assumption that information gathered through the monitoring program will increase the general level of understanding of park resources. Linking this knowledge into visitor understanding is an important aspect of a long-term monitoring program. In addition to the national strategic goals, each park unit has a five-year plan that includes park-specific GPRA goals. Many of these park-specific goals are directly related to natural resource monitoring needs.

Table 1.1. Summary of selected 2007–2011 GPRA goals in Gulf Coast Network parks relevant to natural resource monitoring.

GPRA goal summary	Goal	Parks with this goal
Acres disturbed lands restored	1a1A	BITH, JELA, NATR, PAIS, VICK
Invasive plants contained	1a1B	BITH, GUIS, JELA, NATR, PAIS, SAAN, VICK
Species of special management concern	1a2B	BITH, GUIS, NATR, PAIS, SAAN
Invasive animals	1a2C	BITH, GUIS, JELA, NATR, PAAL, PAIS, SAAN, VICK
Water quality (miles rivers and streams)	1a4A	BITH, NATR, SAAN
Water quality (acres lakes, reservoirs, etc.)	1a4B	BITH, GUIS, NATR, PAIS
Cultural landscapes	1a7	JELA, NATR, PAAL, SAAN, VICK
Vital signs identified (2004–2008)	1b3A	BITH, GUIS, JELA, NATR, PAAL, PAIS, SAAN, VICK
Vital signs monitoring implemented (2004–2008)	1b3B	BITH, GUIS, JELA, NATR, PAAL, PAIS, SAAN, VICK
Visitor understanding	2b1	BITH, GUIS, JELA, NATR, PAAL, PAIS, SAAN, VICK

1.2.2. GULN park unit enabling legislation

The GULN includes two national seashores (GUIS and PAIS), two national preserves (BITH and JELA's Barataria Unit), two national historical parks (JELA and SAAN), one national military park (VICK), one national historic site (PAAL), and one parkway (NATR). In 1970, Congress elaborated on the 1916 Organic Act, clearly stating that all of these designations have equal legal standing in the National Park System.

The enabling legislation of an individual park provides insight into the natural and cultural resource value for which it was created (Table 1.2). Along with national legislation, policy and guidance, a park's enabling legislation provides justification and, in some cases, specific guidance for the direction and emphasis of resource management programs. For parks where the enabling legislation is based on cultural rather than natural resources, those cultural resources are often tied directly to an historic natural resource setting that may be managed to reflect that historic condition.

Table 1.2. Summary of the enabling legislation for each Gulf Coast Network park unit.

Park	Summary content
Big Thicket National Preserve	PL 93-439—Act established the preserve to ensure the preservation of numerous representative areas typical of the Big Thicket region and to protect and preserve the natural values that make it unique.
Gulf Islands National Seashore	PL 91-660—Act established the Gulf Islands National Seashore, in the states of Florida and Mississippi, for the recognition of certain historic values at Fort San Carlos, Fort Redoubt, Fort Barrancas, and Fort Pickens in Florida, and Fort Massachusetts in Mississippi, and for other purposes.
Jean Lafitte National Historical Park and Preserve	PL 95-625—Act established the preserve for the education, inspiration, and benefit of present and future generations significant examples of natural and historical resources of the Mississippi Delta region and to provide for their interpretation in such manner as to portray the development of cultural diversity in the region.
Natchez Trace Parkway	48 Stat. 791—Act established the parkway to preserve the old Indian trail known as the “Natchez Trace,” with a view of constructing a national road on this route to be known as the “Natchez Trace Parkway.”
Padre Island National Seashore	PL 87-712—Act established the Padre Island National Seashore, approved September 28, 1962, in order to save and preserve, for purposes of public recreation, benefit, and inspiration, a portion of the diminishing seashore of the United States that remains undeveloped (76 Stat. 650).
Palo Alto Battlefield National Historic Site	PL 102-304—Act established the national historic park In order to preserve for the education, benefit, and inspiration of present and future generations the nationally significant site of the first battle of the U.S.–Mexican War (1846–1848), and to provide for its interpretation in such a manner as to portray the battle and the U.S.–Mexican War and its related political, diplomatic, military, and social causes and consequences.
San Antonio Missions National Historical Park	PL 95-629—Act established an 819-acre national historical park. The park preserves four 18th-century Spanish Colonial missions—Concepción, San José, San Juan, and Espada—and one ranch ruins in perpetuity, and makes this valuable part of America’s heritage available to approximately 1.2 million visitors each year for their experience, enjoyment, understanding, and appreciation.
Vicksburg National Military Park	30 Stat. 841—Act established a national military park to commemorate the campaign, siege, and defense of Vicksburg during the Civil War, approved February 21, 1899.

1.3. Overview of the Gulf Coast Network

1.3.1. Regional setting

The parks of the Gulf Coast Network are ecologically diverse islands situated in the ever-changing landscape and environment of the Gulf Coast region. Three general properties or forces broadly affect, and potentially threaten, the continued function and integrity of ecosystems and natural resources in GULN parks:

1. Parks are generally small patches of resources surrounded by altered landscapes, and thus present classic examples of "island biogeography" and the suite of challenges that isolated ecosystems, biological communities, and populations face;
2. The Gulf Coast region experiences frequent extreme storm events that have the potential to cause widespread impacts to both environments and biota; and
3. The Gulf Coast region is increasingly subject to human development, resulting in diverse anthropogenic effects on park resources and ecosystems.

These three factors pose a strong collective challenge to park resource managers and the GULN monitoring program.

The generally flat Gulf Coast landscape formed as a result of changes in sea level over the past 125 million years. Rising and falling sea levels, along with sediment-carrying water flowing in rivers, repeatedly eroded and built up land. The resulting combination of uplands (i.e., alluvial plains built from waterborne sediments, shoreline landforms, and the most extensive wetland areas in the United States) host a diversity of ecosystems. The eight network parks distribute across six ecoregions of the south-central and southeastern U.S.: the East Central Texas Plains (SAAN), Western Gulf Coastal Plain (PAAL, PAIS, BITH), Mississippi Alluvial Plain (VICK, JELA), Mississippi River Loess Plain (VICK, NATR), Southern Coastal Plain (GUIS), and Southeastern Plain to Interior Plateau (NATR) (Figure 1.3).

These parks represent and host important examples of a broad range of ecosystems. Functionally (and as presented in our ecosystem conceptual models), GULN park ecosystems may be effectively grouped into three major classes; upland, freshwater-aquatic, and coastal and near-shore ecosystems. Upland ecosystems include temperate hardwoods, pine flatwoods, (or barrens), scrub forests, loessal bluffs, dry scrub/grasslands of the Edwards Plateau, and coastal prairies. Freshwater wetlands and aquatic ecosystems include bottomland hardwoods and floodplain forests, freshwater marshes, lakes and rivers. Coastal and near-shore-marine ecosystems include barrier islands, salt marshes, seagrass beds, estuaries, and bays (Twilley and Rivera-Monroy 2005). The combination of upland, alluvial, and shoreline physical landscapes occurring in conjunction with the convergence of temperate and subtropical climates across the region creates enormous diversity in ecosystems and makes the region, the GULN, and its parks a center of biodiversity of great national value and interest (Twilley et al. 2001). Maintaining this biodiversity is a key management challenge for GULN parks through time.

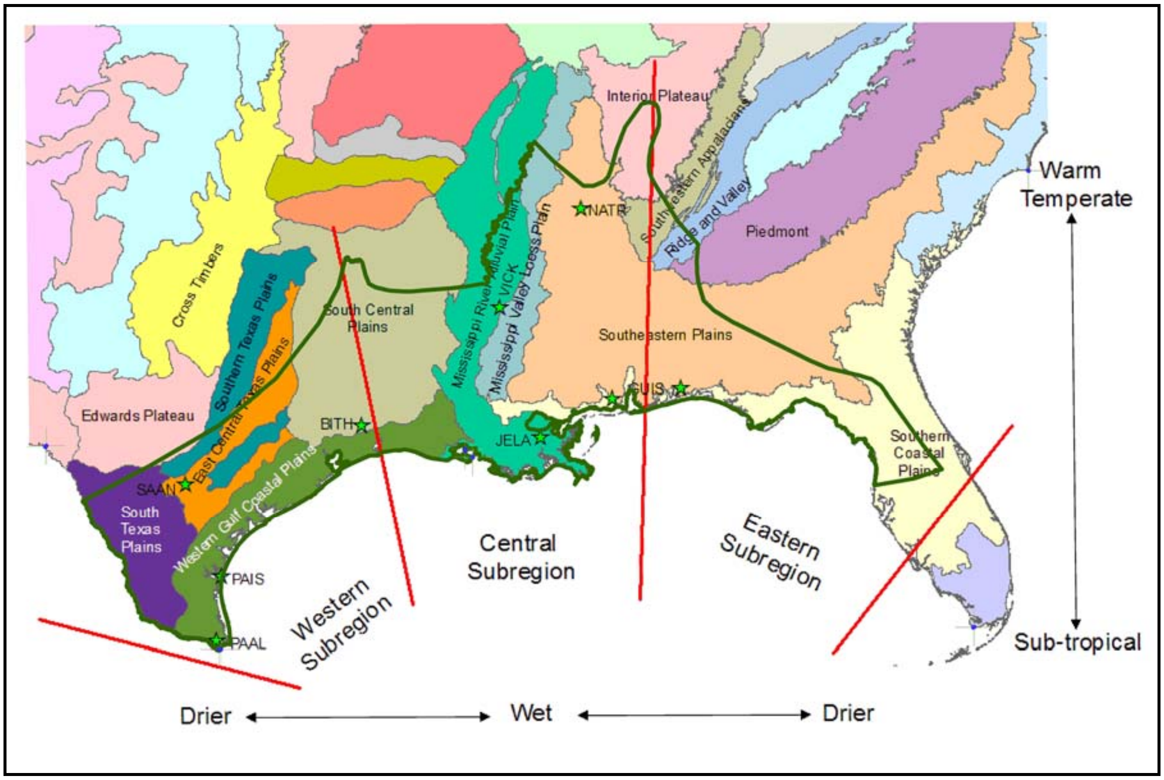

Figure 1.3. Ecoregions of the Gulf Coast Network. Adapted from the 2003 U.S. Environmental Protection Agency Level III Ecoregions of the Continental United States (revision of Omernik 1987).

1.3.2. Climate

The Gulf Coast climate results from the interplay of global factors, including the El Niño/Southern Oscillation (ENSO), and regional factors—specifically, its latitude and the influence of nearby oceans. El Niño years are typically characterized by lower temperatures in winter and spring and increased winter rainfall in the Gulf Coast. Fall and winter seasons are typically warmer in La Niña years, especially in Louisiana, followed by little change in spring and higher temperatures in summer. La Niña events are also associated with regional drought conditions, such as those that occurred in the central and western Gulf Coast from 1998 to 2000. Further, ENSO has a strong influence on the number of Gulf Coast hurricanes. During La Niña events, the average number of hurricanes coming ashore in the Gulf of Mexico is typically higher than during El Niño or non-ENSO years.

The interaction of regional climatic features creates notable climate gradients that divide the Gulf Coast into three climatic sub-regions, as shown in Figure 1.3. The western sub-region, from Texas to Louisiana, is warm–temperate to subtropical, and changes from semi-arid to humid from west to east. Precipitation ranges from 18 cm/yr at the Rio Grande River to 119 cm/yr near the Mississippi River. The central sub-region includes Louisiana, Mississippi, and Alabama, and is typically humid and warm. Rainfall in this sub-region ranges from 100 to 178 cm/yr, with little seasonal pattern. The eastern sub-region (i.e., the Florida panhandle) is humid; temperatures range from warm–temperate to subtropical. This sub-region is also characterized by a distinct summer wet season and winter dry season, with annual precipitation ranging from 84 to 230 cm (Table 1.3). Precipitation throughout the network typically comes in the form of rain from winter and spring storm fronts, thunderstorms, and tropical storms and hurricanes in the summer and/or early fall (Twilley and Rivera-Monroy 2005).

Table 1.3. Mean precipitation and temperature in Gulf Coast Network parks.

Park code	Park	Station location (years of data)	Mean annual precipitation (cm)	Mean annual temperature (°C)
SAAN	San Antonio Missions National Historical Park	San Antonio, Texas (48)	76.7	20.6
PAAL	Palo Alto Battlefield National Historic Site	Brownsville, Texas (48)	65.8	23.3
PAIS	Padre Island National Seashore	Rockport, Texas (30)	89.4	21.8
BITH	Big Thicket National Preserve	Beaumont, Texas (30)	141.5	19.7
VICK	Vicksburg National Military Park	Vicksburg, Mississippi (5)	123.2	18.3
JELA	Jean Lafitte National Historical Park and Preserve	New Orleans, Louisiana (48)	156.7	20.6
GUIS	Gulf Islands National Seashore	Pascagoula, Mississippi (21)	154.4	20.0
		Pensacola, Florida (39)	158.6	20.0
NATR	Natchez Trace Parkway (from north to south)	Nashville, Tennessee (48)	120.9	15.6
		Tupelo, Mississippi (13)	132.1	17.2
		Jackson, Mississippi (32)	141.0	18.3
		Natchez, Mississippi (30)	156.7	19.0

Order is approximately from west to east across the network.

Source: http://weatherbase.com, accessed August 1, 2005.

The Gulf Coast climate is uncharacteristic of its latitude, which typically hosts warm, arid, and semi-arid climates. The Gulf of Mexico, Caribbean Sea, and Atlantic Ocean all have a substantial influence on the region's climate. Winters are generally mild due to Gulf of Mexico waters, which moderate winter temperatures. Occasionally, however, these mild winters are punctuated by cold air masses reaching far south from the northern Pacific or the Arctic, bringing low temperatures and freezing conditions. Summers in the region tend to be hot and humid. The adjacent waters of the Gulf and the Atlantic are also major sources of atmospheric moisture, resulting in a greater rainfall than is typical for its latitude. Rainfall is brought to the region by a variety of processes, including seasonal storm fronts and events. Hurricanes and tropical storms, a frequent occurrence in late summer and fall (Figure 1.4), exert major influences on biota, geomorphology, and environmental conditions along the northern Gulf of Mexico, where they alter the shapes of coastlines and dramatically affect plant diversity and distribution (Guntenspergen 1998). Although the impacts of these storms are usually thought of as coastal phenomena, the disturbances they cause extend far inland as the systems track to the north.

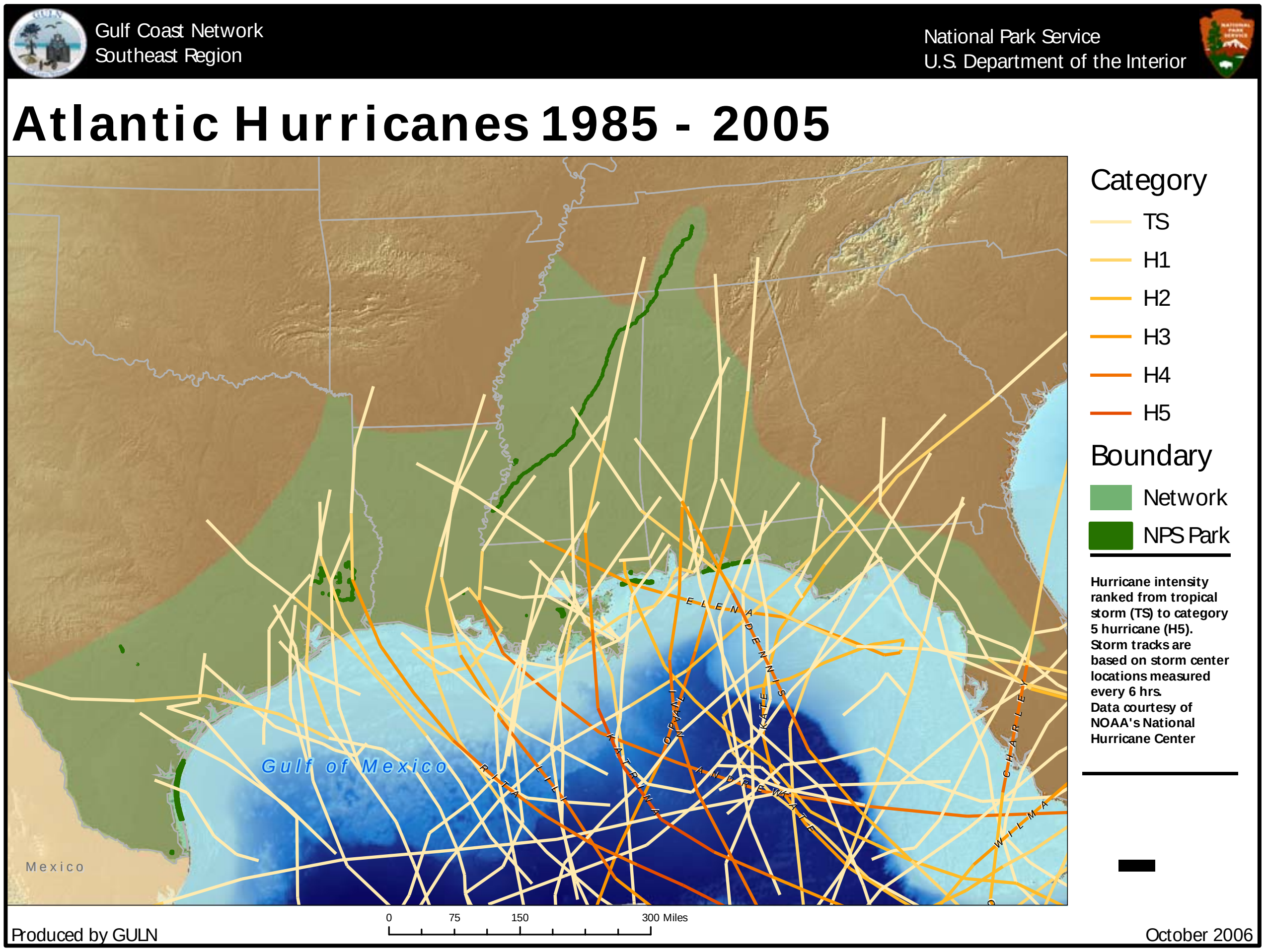

Figure 1.4. Map showing the tracks of tropical cyclones in the Gulf of Mexico during the last 20 years, from 1985 to 2005. Source: http://hurricane.csc.noaa.gov/hurricanes/viewer.html.

1.3.3. Anthropogenic change in Gulf Coast ecosystems

The Gulf Coast region is extremely impacted and altered by continued development, which exerts ever-increasing pressures, causing significant changes to regional and park ecosystems. Development includes population growth and associated land-use changes; engineering interference with natural water flows and coastal processes; habitat fragmentation; and water and air pollution. The population of the five Gulf Coast states increased over the past decade to more than 48.5 million in 2000, with the most significant population increases occurring in Florida and Texas (Twilley and Rivera-Monroy 2005). Population growth in coastal areas of the nation has been more rapid than elsewhere, with more than half the U.S. population now living within 80 miles of coastal land. Population growth significantly affects the distribution of surface and ground water, both of which are critical for Gulf Coast ecosystems.

Major physical features of the Gulf Coast have been engineered over the past century to meet demands imposed by the ever-growing population. Alterations to water flows through dams and impoundments, channelization, dredge and spoil operations, and diking all affect the quantity and quality of discharge as well as the sediment input into coastal waters. This affects ecological functions such as estuarine productivity that depend on freshwater discharge from rivers, wetlands in the alluvial basins, and sand supplies from barrier islands (Twilley and Rivera-Monroy 2005). Irrigation for agriculture is becoming increasingly important throughout the Gulf Coast to buffer effects of extreme droughts. Four of the five states in this region are ranked in the top 20 U.S. states in terms of irrigated land (Twilley and Rivera-Monroy 2005). Other significant draw on fresh water includes thermoelectric power production, industrial uses, and household uses. Removing fresh water for human uses from river and coastal habitats typically results in degradation of these aquatic ecosystems.

Human economic, land, and resource development activities in the region have also greatly reduced or fragmented natural habitats. For example, increased coastline development has reduced wetland and mangrove habitat. In the upland areas, agriculture and timber plantations have replaced natural prairies and forests.

Humans are also both directly and indirectly responsible for the movement and establishment of non-native invasive species that further degrade natural habitats and threaten native plants and animal species. Increasing human population, per-capita consumption, trade in the region, and human mobility have resulted in unprecedented levels of introduced, non-native species. When these introduced species become common, permanent residents, they can produce severe, often irreversible impacts on agriculture, recreation, and natural resources and threaten biodiversity, habitat quality, and ecosystem functioning.

In summary, while alterations of the landscape have enabled the human population of the Gulf region to grow and thrive, they have also caused widespread degradation of natural habitats, species invasions and displacement, and functional and structural shifts in ecosystems. Cumulatively, these human pressures on Gulf Coast water resources, ecosystems, biodiversity, and habitats are the most important drivers of ecosystem change in the region today (Twilley and Rivera-Monroy 2005). As a result, many ecosystems are vulnerable to additional stressors, such as those that will arise from a rapidly changing climate (Twilley et al. 2001).

1.4. Resource Management Issues of Gulf Coast Network Parks

1.4.1. Natural resource summaries

The GULN is composed of eight parks that encompass approximately 180,000 hectares (Table 1.4). As part of the planning for this monitoring program, the GULN produced individual natural resource summary reports for each of the network parks. Those reports include summaries of available information on biological communities, geology, hydrology, air quality, ecosystem studies, and management issues of importance to each park; a listing of local subject-matter experts; a database of scientific literature and topical bibliography; and a compilation of available digital maps, sources, and metadata. Resources and issues of management concern for each park are summarized below. The complete set of summary documents is located in Appendix B.

Table 1.4. Gulf Coast Network park locations, original rationale for establishment, approximate area, major natural resources, and major issues of management concern.

Park	Established primarily for:	Hectares (acres)	Major natural resources	Major management issues
BITH	Natural resources	39,323 (97,168)	Biological diversity Five forest types ranging from upland pine forest to river floodplain forest Globally Important Bird Area	Habitat fragmentation Water quality Land use (logging, oil and gas, development) Invasive species; disruption of natural fire regime
GUIS	Natural and cultural resources	55,843 (137,991)	Barrier islands Dunes Maritime forests Seagrasses Gulf and estuarine waters 80% of area is submerged land	Human use Beach nourishment Storm impacts (erosion and deposition) Invasive species Water quality
JELA	Natural and cultural resources	8,096 (20,005)	Upper freshwater zone of the estuary associated with the Mississippi River Hardwood forest Swamp "Flotant" freshwater marsh	Hydrologic alterations Bankline erosion Water quality Salt-water intrusion Large river diversion Invasive species
NATR	Cultural resources	21,037 (51,984)	Six major forest types and eight watersheds 470 miles; extends from Gulf Coastal Plain to Western Highlands	Invasive species Adjacent land use Roadway construction Water quality Air quality
PAAL	Cultural resources	1,379 (3,407)	Salt prairie Brushland Wetlands associated with resacas (abandoned river meanders)	Invasive species Adjacent land use Hydrologic alterations
PAIS	Natural resources	52,785 (130,434)	Gulf waters and hypersaline lagoon Seagrasses Freshwater ponds Undeveloped barrier island	Water quality Oil and gas development Human use Dredge spoil deposition Storm impacts (erosion and deposition) Historic overgrazing Marine debris
SAAN	Cultural resources	334 (826)	Riparian forests Acequias (historic irrigation ditches) Grassland Scrubland	Adjacent land use Invasive species Altered fire regime Water quality Historic grazing
VICK	Cultural resources	735 (1,815)	Mixed mesophytic forest Streams and associated vegetation Loess soils	Erosion Adjacent land use Invasive species Altered historic vegetation patterns

Although there is a large variation in climate, dominant ecosystems, and habitats, most network parks share a common set of management issues that are related to their relatively small size, habitat fragmentation, proximity to urban and/or industrial centers, and the shared characteristics of the Gulf Coast region in general. Although network-wide, endangered and threatened species are not a major focus of management concern, nor a focus of the monitoring program, several parks do have populations of either federal or state-protected species (Appendix C). Following is a brief description of the significant natural resources in each park and some of the predominant management issues each park faces. Individual park maps are located in Appendix D.

1.4.1.1. Big Thicket National Preserve

Big Thicket National Preserve was established in 1974, and consists of nine separate land units and six water corridors that lie in a region with a high biological diversity due to the convergence of three ecosystems: eastern hardwood forest, Gulf coastal plains, and Midwest prairies (Cooper et al. 2004a). Teale (1971) described the ecology of the area in and adjacent to BITH as one of the most diverse habitats in North America, due to the influence on the biological community of habitats from the north, south, east, and west. BITH has been designated an International Biosphere Reserve by the United Nations Education, Scientific and Cultural Organization Man and the Biosphere Program, and as a Globally Important Bird Area by the American Bird Conservancy. The park includes a diverse assemblage of wildlife and vegetative communities, geophysical features, and natural processes reflecting the complexity of the park ecosystems.

Big Thicket National Preserve.

BITH is composed of five main forest types, with subcategories within: upland pine forest (pine sandhill, pine forests, pine savanna wetland), slope forest (upper slope pine oak, mid-slope oak pine, lower slope hardwood pine), floodplain forest (stream floodplain forest, river floodplain forest, cypress-tupelo swamp), flatland forest (flatland hardwood pine, flatland hardwood), and bay galls (bog systems of dense forest canopy, shrub, and herbaceous layers created by local mound-and-intermound relief with unique spodosol soils).

Because of the park's proximity to multiple urban centers, including Beaumont and Houston, BITH is subject to many environmental problems, including reduced air and water quality, disturbed lands, hydrologic disruption, and non-native/invasive species. Current and past anthropogenic influences on BITH include logging and oil and gas operations, air and water pollution, alterations to flow and quality of rivers, fragmentation of habitat and the continued isolation of the individual park units, introduction of non-native/invasive species, and the disruption of the natural fire regime.

1.4.1.2. Gulf Islands National Seashore

Gulf Islands National Seashore consists of several units in Florida and Mississippi. The Mississippi section (GUIS-MS) consists of five islands and a small mainland headquarters area. The authorized boundary includes not only the barrier islands themselves, but also portions of the Gulf of Mexico and nearby bays. From the west to east, the islands of GUIS-MS are: Cat, West Ship, East Ship, Horn, and Petit Bois Islands. East and West Ship are separated by a small pass referred to as "Camille Cut" because it was created by Hurricane Camille in 1969, and are occasionally referred to singly as Ship Island. Horn Island is the largest and Cat the most recently acquired of the GUIS-MS islands. Davis Bayou is the only mainland area in the GUIS-MS park section.

The Florida section (GUIS-FL) consists of portions of two islands (Santa Rosa Island and Perdido Key) and two small mainland areas. Three park units are located on Santa Rosa Island: Fort Pickens, Santa Rosa Area, and Okaloosa Area. The Naval Live Oaks Reservation is on a peninsula forming part of the eastern mouth of Pensacola Bay. Unlike GUIS-MS, all areas of GUIS-FL, including the islands, are accessible to vehicles. The water bodies surrounding GUIS-FL include Santa Rosa Sound, Big Lagoon, Pensacola Bay, Choctawhatchee Bay, and the Gulf of Mexico (Cooper et al. 2005a).

Gulf Islands National Seashore.

There are a number of aquatic and terrestrial ecosystems in GUIS. including Gulf, bay, dunes, salt marsh, maritime forest, barrier islands, seagrass beds, and other marine systems. Hydrology and water-related issues are of central importance because 80% of the park is submerged land (Anderson et al. 2005). The mainland portion of GUIS-FL consists of live oak, sandhill, and marsh communities; the mainland portion of GUIS-MS consists of pine/palmetto flatwoods, mixed pine/hardwood, lowland hardwood, and tidal marsh.

Many of the park's management issues concern protecting natural resources and mitigating the effects of various types of disturbance, such as human use, beach nourishment, and storm impacts. Human use has caused both direct and indirect effects on the park. Direct effects include destruction of habitat by pedestrians and off-road vehicles, dredging, and development. Indirect effects include introduction of contaminants such as litter, oil, and pesticides; introduction of non-native/invasive species; and fire suppression. Due to the inaccessibility of the GUIS-MS barrier islands, most of the direct anthropogenic disturbance has occurred on GUIS-FL. Although GUIS-MS is largely uninhabited, increased urbanization near GUIS-FL has impacted water quality. GUIS-FL is accessible by various bridges connecting Santa Rosa Island to the mainland, while access to GUIS-MS is limited to private boats and one passenger ferry that operates between Gulfport, Mississippi, and Ship Island. Florida's Gulf Breeze peninsula is experiencing rapid urbanization. Most of the urban and commercial development is occurring on Santa Rosa Island and along U.S. Highway 98, adjacent to the park.

Hurricanes are one of the biggest concerns for the park, as they can have devastating effects on biological communities as well as park structures and facilities, and cause rapid morphological shoreline changes through erosion and overwash of the islands. Hydrologic alternations (e.g., jetties and navigation channels) alter sediment input and transport, limiting the ability of these systems to recover on their own between storms. To combat erosion, the beaches of GUIS have been regularly nourished with sand, which generally comes from the dredging of navigation channels. Although these nourishment projects are beneficial for the reduction of erosion, there is concern regarding the rates of revegetation, adverse effects on macroinvertebrates, and reduction of the vegetative seed bank (Cooper et al. 2005a).

1.4.1.3. Jean Lafitte National Historical Park and Preserve

Jean Lafitte National Historical Park and Preserve, established in 1978, consists of six separate units in the Mississippi Delta region, including the Barataria Preserve (BP) and the Chalmette Battlefield and National Cemetery (CBNC), which are the only two units included in the I&M program. The 8,000-hectare Barataria Preserve is located in the upper freshwater zone of the Barataria Basin, one of the most productive estuarine wetlands in North America. It contains a portion of an abandoned delta of the Mississippi River and associated ecological zones. The natural communities of the preserve fall into three broad types, reflecting their underlying geological structure: hardwood forest, swamp, and marsh. The backbone of the preserve is an abandoned distributary channel of the Mississippi River and its flanking natural levees. The levees are ribbons of relatively firm alluvial soils—the only ground above sea level—on which grows a hardwood forest of ridge and bottomland species. On the back slopes of these natural levees, where the soils are inundated much of the year, grows a bald cypress (*Taxodium distichum*) and water tupelo (*Nyssa sylvatica*) swamp forest. The preserve's marshes occur beyond the swamps where alluvial soils have subsided well below sea level. Above this sunken surface, lies a layer of peat, often many feet thick (Muth 1997). The peat supports a unique type of floating marsh locally known as "flotant."

Jean Lafitte National Historical Park and Preserve.

The BP consists of six dominant ecosystems: natural levee; live-oak forest; ridge and swale bottomland hardwoods; backslope transitional red-maple swamp forest; bald cypress (*T. distichum*) and tupelo (*N. sylvatica*) swamp; fresh and intermediate marshes, including large expanses of floating marsh (flotant) and shrub communities; and bayous, ponds, and estuarine lakes.

The CBNC is a smaller unit that marks the site of the 1815 Battle of New Orleans in the War of 1812, and is one of the only undeveloped pieces of land on the east side of the Mississippi River close to metropolitan New Orleans (Bretting 1975, Cooper et al. 2005b). The habitats described there were grouped into six types: ditch, field and pasture, batture (which is flooded during part of the year), thicket, levee, and lawn. The vegetation consists primarily of low, grassy fields maintained by mowing, subjecting the area to a high rate of invasion by non-native species.

One critical issue of management concern in the park concerns hydrologic alterations due to the virtually complete confinement of the Mississippi River by artificial levees, spillways, and training devices. The result has been that the sediment and fresh water that historically flooded the wetlands of the preserve have been cut off. Restoration of natural hydrology is not feasible; however, BP is in the outfall area of a large, controlled river diversion constructed by the U.S. Army Corps of Engineers. Monitoring the effects of that diversion on the habitats of the preserve will be critical. Other issues include high rates of bankline erosion along lakes and other waterways, high local rates of subsidence, extensive human-made canals, and associated spoil banks that interrupt sheetflow and allow accelerated rates of salt-water intrusion by amplifying tidal effects. Development around the park introduces pollutants through urban run-off, provides a source for the introduction of non-native and invasive species, and has resulted in the disruption of natural fire regimes and loss of habitat.

1.4.1.4. Natchez Trace Parkway

The Natchez Trace Parkway is a 470-mile roadway that extends from Natchez, Mississippi, through the northwest corner of Alabama to Nashville, Tennessee, and crosses through six forest types and eight major watersheds. The parkway connects the southern Mississippi River to central Tennessee, and commemorates the historic route that was traveled by various American Indian tribes throughout early American history. Within Tennessee, most of the parkway lies on the Western Highland Rim province of the Interior Low Plateau. The portion within Mississippi and Alabama exists mostly on the Southeastern Plains and the northern portion of the Gulf Coastal Plain. A small portion of NATR crosses the Black Belt Prairie in northern Mississippi (Cooper 2004b). Because the shape of this park is long and narrow, much of what is known about its natural resources is inferred because of studies conducted on nearby national forests or state parks.

Natchez Trace Parkway.

The history of land use has shaped the vegetative communities that currently exist along the parkway. Due to disturbances caused by American Indians (e.g., use of fire) followed by the Europeans (e.g., timber harvesting followed by agriculture, then abandonment of agriculture and fire suppression), the landscape along the parkway is generally at least third- or fourth-growth forest.

The park currently contends with four major management issues, which are all related to the fact that the park is subject to many outside influences: non-native/invasive species, adjacent land-use impacts, nuisance native species, and parkway construction. Because of the parkway's shape and proximity to multiple large cities with increased suburbanization of the landscape, portions of it are subject to air and water quality issues, disturbed lands, and hydrologic disruptions.

1.4.1.5. Palo Alto Battlefield National Historic Site

Palo Alto Battlefield National Historic Site (PAAL) exists in the Matamoran district of the Tamaulipan biotic province. This area is a unique blend of northern, coastal, and tropical, and western desert characteristics. PAAL is located 10 miles north of the Rio Grande River in the southern tip of Texas, and preserves the 3,400-acre site of the first major battle of the U.S.–Mexican War (1846–1848).

Palo Alto Battlefield National Historic Site.

Three general habitat types or zones have been described in PAAL: brushland, salt prairie, and wetlands (Cooper et al. 2004c). Brushland habitat covers about 23% of the park and exists primarily on the area adjacent to meandering resacas, or old river bed/oxbows, created as the former channels of the Rio Grande were naturally cut off from the river as it shifted over time. These areas, slightly higher in elevation than the neighboring salt prairie, have better drainage, allowing soils to have lower salinity. Therefore, they support a different plant community. Brushlands are generally found from the southwest corner of the park, along its western side, and curving along the northern boundary. They are characterized by dense, woody, and usually thorny vegetation.

Salt-prairie habitat is the largest system on the PAAL, covering 75% of the park's land area. Salt prairies occur in low-lying areas with poorly drained soils. These areas are dominated by Gulf cordgrass (*Spartina spartinae*). Natural depressions within the salt-prairie systems, which once were frequently flooded, are typically dry most of the year due to excavation of cattle tanks and disruption of the resacas. These areas, also known as Borrichia or salt flats, are characterized primarily by sea oxeye (*Borrichia frutescens*) and succulents among the bare patches of soil. Wetlands compose approximately 2% of the park and consist primarily of abandoned channels and tributaries of the Rio Grande and human-made waterholes for cattle. Many resacas gradually filled with sediment from erosion and now support wetland species. Salinity levels of the groundwater in the park have been described as moderately to very saline (Cooper et al. 2004c). Lacking streams, much of the surface water (largely from hurricanes or other storm events) travels across PAAL in sheets. Surface water in much of the Lower Rio Grande Valley is transported through human-made ditches, which are a dominant feature in the landscape there.

However, because salt prairie dominated the area and row-crop agriculture was not successful, PAAL is generally free of scars caused by major irrigation and drainage ditches.

The park currently has two major management issues: non-native species and adjacent land-use impacts. Although PAAL has largely escaped the dramatic alterations seen in much of the Lower Rio Grande Valley due to its high-salinity soils, the area does show effects of previous land use. Vegetation has changed across the park due to previous landscape modifications including clearing of brushland and attempts to introduce non-native plants for grazing. Erosion resulting from agricultural activities within the park has dramatically increased the speed by which the resacas filled with sediment, which has resulted in a change in vegetation. Hydrologic alterations have reduced flooding to an infrequent occurrence limited to rainwater, so that it no longer reflects the historic hydrologic regime. If Brownsville's rapid growth rate continues, then PAAL could become an urban park in the future, with increased management problems due to changes in land use outside of the park.

1.4.1.6. Padre Island National Seashore

Padre Island National Seashore was established in 1962, and consists of approximately 130,000 acres of land and water. At 70 miles, it is the longest stretch of undeveloped barrier island in the world, and ranges in width from 0.5 to 3 miles (Cooper et al. 2005c). The authorized boundary of the seashore includes not only the barrier island itself, but also portions of the Gulf of Mexico and the Laguna Madre. The Laguna Madre extends the whole length of the South Texas coast, from Corpus Christi Bay to the Mexican border. It is 200 kilometers long and is one of the few hypersaline lagoon systems in the world. The Laguna Madre supports 75% of Texas's seagrass meadows (Chapman et al. 1998), which are some of the most productive estuarine systems as well as valuable nursery areas for a variety of wildlife. Due to the pressure from growing development along coastal Texas, the habitat in the park has become an increasingly important resource for many resident and migrating species.

Padre Island National Seashore.

There are a number of aquatic and terrestrial ecosystems on PAIS. Beginning on the Gulf side and going west to the Gulf Intracoastal Waterway, the park includes the nearshore waters, the foreshore (swash zone) and backshore (from high-tide line to dunes) on the beach, foredunes, vegetated flats behind the dunes with shallow fresh- or brackish-water ponds and marshes, back-island dunes in some areas, wind-tidal flats, and shallow, hypersaline seagrass beds in the lagoon. The interplay of climate, physiography, and geomorphology results in a landscape that is largely shaped by wind (Withers et al. 2004). The underlying formation of Padre Island is an ancient barrier bar deposited during the Pleistocene period. The sediments deposited on this barrier primarily consist of sand and shell. The sediment along Padre Island varies down its length due to multiple sources and the way in which deposition occurred. Sand along the southern end is coarse and was deposited by the Rio Grande. The finer sand in the north was deposited by rivers such as the Nueces and Colorado.

Very little surface freshwater is available from terrestrial sources adjacent to the Laguna Madre or on Padre Island. On Padre Island, freshwater sources are limited and generally confined to ponds that form in swales and depressions in the vegetated flats. These ponds are an extremely important source of both drinking water and food for many terrestrial vertebrates and birds. However, most are ephemeral, and many become brackish or dry up, particularly during dry periods.

Padre Island is relatively undeveloped due to its remote location and lack of permanent roads. The major population centers in the vicinity are Corpus Christi, in the northernmost upper Laguna Madre; Port Mansfield, along the south-central western shore in lower Laguna Madre; and Laguna Vista, Laguna Heights, Port Isabel, and South Padre Island, along the southernmost lower Laguna Madre. The lack of development on the mainland adjacent to the Laguna Madre is largely a result of large landholdings in Laguna Atascosa National Wildlife Refuge, and privately owned ranches such as the King, Kenedy, and Yturria ranches. Currently, recreation is the primary land use of the undeveloped areas of Padre Island, including PAIS. Public use and recreational activities have a significant effect on natural resources of barrier islands. The primary attraction of barrier islands is their natural settings, abundant wildlife, and frequently remote locations.

Many of the park's management issues concern protecting natural resources and mitigating the effects of various types of disturbance such as human use, cattle grazing, oil and gas exploration and production, fire, and storm impacts. Human use has caused both direct (e.g., destruction of habitat by pedestrians and vehicles, dredging, and development) and indirect (e.g., contamination from trash, oil spills, and pesticide use) management concerns for the park. Multiple studies have found that areas with heavy traffic display a decline in species density and richness (Cooper et al. 2005c), and cause areas to be less stable during storm events. Hurricanes are one of the biggest concerns for the park, as they can have devastating effects on biological communities as well as park structures and facilities, and cause morphological shoreline changes. Beach erosion is also a prevalent management issue at PAIS, and many efforts have been made to study and manage this problem. Grazing had occurred continuously on the island for 150 years until 1971, when cattle were removed. Overgrazing and drought previously denuded a once largely vegetated island and increased the accumulation of sand in the Laguna Madre. Since grazing has been phased out on the island, vegetation has rebounded.

Due to the number of oil tankers in Corpus Christi Bay, and seeps from the floor of the Gulf of Mexico, threats of oil spills remain a concern for the park. Other forms of contamination, such as trash and pesticides, have also been monitored in the park to determine the amount, type, and possible effects on the park and its inhabitants. There has been a decline in the level of organochloride pesticides, such as DDE, detected in park fauna since the 1970s, but chemicals such as polychlorinated biphenyls (PCBs) are now being detected (Cooper et al. 2005c).

1.4.1.7. San Antonio Missions National Historical Park

San Antonio Missions National Historical Park is an 826-acre unit that consists of several non-contiguous units along the San Antonio River. The park was created in 1978, and originally consisted of the major mission community sites of Concepción, San José, San Juan, and Espada; Espada Dam; and aqueduct sites in San Antonio. Rancho de las Cabras, a grazing ranch for Mission Espada located approximately 25 miles south of San Antonio in Wilson County, was transferred to SAAN from the State of Texas in 1995. The missions exist on the upper edge of the Gulf Coastal Plain, just south of the Edwards Plateau. The two physiographic regions are separated by the Balcones Escarpment, a series of subparallel faults that allowed the Gulf Coast Plain to sink (Cooper et al. 2005d).

San Antonio Missions National Historical Park.

The general appearance of the missions and surrounding area during the years of their greatest use (late 18th century) included lands between the missions that were crossed by the San Antonio River. The missionaries had built dams at various points on the river, and from the ponds that formed behind these dams, water flowed down the acequia, or irrigation system. At points along the acequia line, intermittent tributaries of the river were crossed.

Three major habitats exist within or in close proximity to the park: forested riparian corridors, old agricultural field, and scrubland. The habitat at the missions was formally a major riparian forest community composed of vegetation communities from both Blackland Prairie and South Texas Plains. Remnants of the old river channel have become riparian oases, creating habitat for many wildlife species. Paralleling the river on both sides was a series of wide ditches, or acequias, that supplied water to the mission irrigation systems. Prior to European settlement, the landscape of South Texas was primarily grassland with small patches of brush (Cooper et al. 2005d). Those scrubland and grassland habitats have been the focus of studies that examined the effects of overgrazing or abandonment of farms coupled with a lack of historic fire on plant succession (Van Auken and Bush 1984, Bush and Van Auken 1987). The combination of fire reduction and increased grazing allowed extensive brushlands, or huisache savannas, to replace grasslands and abandoned farms. Overgrazing reduced the fuel for fires and created open patches, which allowed brush species to become established. Because cattle do not generally feed on brush, and fire was eliminated from the system, brush species were able to outcompete grasses and dominate the system.

Because of the park's proximity to San Antonio, it currently contends with two major, related management issues: exotic species and adjacent land-use impacts. Park managers are currently concerned with several species of non-native plants and animals, including stray pets. Unchecked, they can become feral populations, which have an unknown impact on native animal populations and are a safety concern for visitors. Neighboring businesses or industries have also caused several occurrences of environmental hazards, including an underground plume of Trichloroethene from a local air-force base, a possible leak of hydrocarbons from a refinery, and the demolition of a garage built from automobile casings. Additionally, managing the park for both cultural landscapes and biological integrity is a challenge for resource managers in this urban setting (Cooper et al. 2005d).

1.4.1.8. Vicksburg National Military Park

Vicksburg National Military Park was established to commemorate the 1863 Siege of Vicksburg. This 1,815-acre park commemorates one of the most decisive campaigns of the Civil War. The vegetation in the park has changed greatly from the 1863 historical open landscape, and now consists of a mix of forested and open grassy areas, along with stream and river habitats. Early photos show a landscape of open fields largely devoid of trees. However, attempts to protect the area from erosion and a lack of maintenance funds over the years have created a very different vegetation community than originally existed at the park (Cooper et al. 2004d). The extant forest has been described as mixed mesophytic, although the dominant trees in the park consist of southern red oak (*Quercus falcata*) and white oak (*Q. alba*) instead of the typical beech (*Fagus grandifolia*) and cucumber tree (*Magnolia acuminata*) found in this habitat type (Walker 1997). VICK is located on the only major southward extension of this forest type, which stretches down through Mississippi to Louisiana and exists in an area known as the Blufflands. The variation in species composition has been attributed to the relative infancy of the forest in VICK. Vegetation type mapping is currently underway as part of the I&M program.

Vicksburg National Military Park.

The surface soils of VICK consist of Pleistocene-age loess. The advancement and recession of the Pleistocene glaciers in northern North America created a fine rock powder that was carried down the continent in many tributaries, including the Mississippi River. As the fine particles were deposited in flood plains and the water from glacier melt receded, these particles were swept up by the wind and deposited on the bluffs of the Mississippi and surrounding areas, creating varying depths of what is known as loess soil. Loess soil has the unique characteristic of allowing vertical cuts in the soil without support. However, because the soil was deposited by wind rather than water, it is highly susceptible to erosion when exposed (Cooper et al. 2004d).

The park currently contends with four major management issues, many of which are interconnected: erosion, change in vegetation, exotic species, and adjacent land-use impacts. The presence of highly erodible loess soils in the area has created problems for the park due to the loss of soil and alterations to vegetation in attempts to reduce this loss. The drastic change in vegetation across the park since the Battle of Vicksburg has been partly due to efforts designed to reduce erosion. In addition, the close proximity of the city of Vicksburg has influenced the park's natural resources by negatively impacting the air and water quality, destroying viewsheds, increasing vandalism, and allowing for the transfer of exotic-plant and feral-animal species. Walker (1997) found that 28% of the species in the park were not native to Mississippi. Higher water temperatures have been documented in Glass Bayou and Mint Springs Creek, due in part to increased sedimentation caused by urban development (Dibble 2003).

1.4.2. Non-native species in GULN parks

Non-native and invasive species pose a serious threat to the ecological integrity of all GULN park ecosystems. Most of the network parks are located close to urban centers or other developed areas, which increases the likelihood of presence and invasion by non-native species. The subtropical climate characteristic of the GULN, and subsequent long growing period, increases the likelihood of non-native species establishment. Although many non-native plant species exist in GULN parks, many are not invasive (e.g., *Desmodium triflorum*, *Murdannia nudiflora*), and thus do not necessarily threaten park ecosystems or warrant treatment and control. However, those species that do alter ecosystem function often necessitate treatment, control, and monitoring. For example, cogongrass (*Imperata cylindrica*) can establish mono-specific stands in undisturbed areas, thus reducing species diversity and habitat quality. Other species, such as Japanese climbing fern (*Lygodium japonicum*) or kudzu (*Pueraria montana*), can serve as ladder fuels during a fire event, carrying fire into the canopy and increasing fire intensity.

Non-native animals can adversely impact native species directly through consumption or indirectly through competition. For example, interspecific competition from the non-native house mouse (*Mus musculus*) may be associated with decreased abundance of the native Perdido Key beach mouse (*Peromyscus polionotus trissyllepsis*). Further, feral cats (*Felis domesticus*) likely pressure populations of beach mice, other small mammals, and native birds. Rooting activities from feral hogs (*Sus scrofa*) create large disturbances that cause habitat fragmentation, reduce habitat quality, and increase site vulnerability to non-native/invasive species establishment. See Appendix E for more detail on non-native/invasive species.

1.4.3. Water resources in GULN parks

Many GULN parks have significant and extensive areas where surface waters play a key role in the occurrence and distribution of associated natural resources. BITH and the Barataria Preserve of JELA contain major forested and emergent wetlands that are directly influenced by the surface water found there. GUIS and PAIS are barrier-island complexes with inshore shallow bays that support extensive seagrass beds, as well as interior ponds that provide important freshwater habitat in an otherwise marine system. BITH, VICK, and NATR contain abundant stream and river corridors or stream crossings that support aquatic communities and interact with broad floodplains and meanders. SAAN is located along a river within a major urban center. PAAL contains salt prairie and remnant meander lakes called resacas. Occurrence of surface water is usually associated with rainfall and accompanied by dramatic changes in habitat and species composition that are otherwise not apparent.

The designated uses, impairments, and threats to the network parks are as varied as the parks themselves, and the amount of historic water quality data available for each park varies widely, which makes comparisons difficult. In preparation for the development of a water quality monitoring plan, the network worked with the U.S. Geological Survey (USGS) to prepare a scoping report summarizing the water quality issues for each park, identifying all 303(d)-listed waters in the parks, and identifying existing monitoring stations and/or programs in and near network parks (Swarzenski 2006; Appendix F). In addition, coastal watershed condition assessments have been completed for both PAIS (Withers et al. 2004) and GUIS (Anderson et al. 2005). All GULN parks are located near urban settings and have been negatively impacted by residential and industrial anthropogenic activities. All network parks, except PAAL, have one or more water bodies listed on their corresponding state's 303(d) list of impaired water bodies due to air deposition of toxics and inputs associated with land-use practices. Listing under the 303(d) program is not applicable to PAAL because of the lack of predictable surfacewater source. Based on the differing issues highlighted in the scoping report, the network will develop two separate plans for monitoring water quality. The five predominantly freshwater parks (BITH, NATR, PAAL, SAAN, and VICK) will be combined into one plan (see Chapter 5 and Appendix M for details), and the three coastal/marine parks (GUIS, JELA, and PAIS) will be combined into a separate plan. Each plan will include basic water quality parameters and use techniques and protocols already in use by other agencies. The network will coordinate with existing programs to ensure that the data can be interpreted in a broader watershed or regional scales.

The NPS Air Resources Division has prepared a review of existing data on persistent organic pollutants (POPs) and heavy metals in the network parks (Gallaher et al. 2005; Appendix F). These contaminants largely enter the parks' waterways through atmospheric deposition. Therefore, they are most likely to be captured in water quality monitoring, rather than measured directly as part of air quality monitoring. This report also compiled any available data into a searchable Microsoft Access database. These data were collected by many different agencies, universities, and private companies. Many of the data were too old to be useful for an analysis of current conditions, or were not collected in a consistent way from site to site. However, because of the proximity of industrial sources and oil and gas activity on or near several parks, the authors suggest that a more systematic inventory of these pollutants may be warranted. The network will continue to coordinate with existing monitoring programs in the various states, but will not pursue this issue on a network-wide scale because of the costs involved.

1.4.4. Air resources in GULN parks

Several GULN parks are impacted by air pollution. BITH, SAAN, and portions of NATR are located in areas designated non-attainment for ozone; their respective states are required to develop plans to eventually comply with the standard. Under the Clean Air Act, park managers have the responsibility to protect air quality and related values from the adverse effects of air pollution. The National Park Service's Air Quality Division (NPS-ARD) has implemented monitoring efforts in many Class 1 areas, areas that are subject to the most stringent standards under the Clear Air Act. No GULN parks are designated Class 1 areas. However, as part of the Natural Resource Inventory and Monitoring Program, the NPS-ARD has conducted an inventory of the location of U.S. Environmental Protection Agency (EPA) air quality monitoring stations within close proximity (50–100 km) to park boundaries. Data from these stations were used to obtain a rough assessment of air quality within individual park units.

Of primary concern to the network is the deposition of air toxics (as discussed above in water quality) and some concern for potential of ozone damage. Vegetation in BITH and portions of NATR is considered at high risk of injury from high levels of ozone. Vegetation in SAAN, JELA, and other portions of NATR are considered at moderate risk (see Appendix G or http://www2.nature.nps.gov/air/Permits/ARIS/networks/ozonerisk.cjm). Consequently, through coordination with the NPS-ARD, the GULN has purchased two portable ozone monitoring stations (POMS) that are currently in use in network parks. The stations are located in areas where there is some uncertainty about whether existing stations accurately represent in-park conditions, and they are relocated to other network parks after sufficient data (usually two summer seasons) have been collected. Comparing the data to that from existing stations will allow the network to confirm which existing stations can be used for long-term monitoring of ozone in the parks. We will use data from those existing stations to track ozone over time, and do not expect to implement a separate air quality monitoring protocol in the network. The NPS-ARD has made access to the data available at http://www2.nature.nps.gov/air/studies/portO3.cfm, and interpolated estimates of air quality data at http://www2.nature.nps.gov/air/Maps/AirAtlas/index.cfm. At this time, the NPS-ARD does not intend to fund additional monitoring at GULN park units.

1.4.5. Geologic resources in GULN parks

The soils and geology of the GULN represent a broad spectrum. The soils include highly erosive loess (VICK), various muck soils (JELA), clayey soils (PAAL, SAAN), sandy soils (GUIS, PAIS), and loam soils (BITH, NATR) (Appendix H). However, the majority of the network parks, located in the Gulf Coastal Plain, can be geologically characterized as alluvial. As part of the Geologic Resource Inventory, the NPS Geologic Resources Division (NPS-GRD) is producing digital geologic resource maps for all parks included in an I&M network. The first step in that process is to conduct geologic resource scoping meetings, including park staff, NPS-GRD staff, and other experts in local geologic issues. To date, scoping meetings have been conducted at PAIS and GUIS. The products for PAIS are expected to be completed during FY2007, GUIS in FY2009. Assessments of coastal vulnerability of these two barrier-island parks (Pendleton et al. 2004a, b) indicate that large parts of these systems are highly vulnerable to the impacts of sea-level rise. The severe impacts that GUIS and JELA experienced during the hurricane seasons of 2004 and 2005 confirm that network parks are vulnerable to such impacts as shoreline erosion, saltwater intrusion, inundation of wetlands and estuaries, and threats to cultural and historic resources and park infrastructure. The dynamic geomorphologic features of GUIS and PAIS are directly linked to the other natural resources in those parks, making this the only high-priority geological issue in the network.

Vegetation helps stabilize the dunes on Santa Rosa Island, Gulf Islands National Seashore.

1.5. Existing Monitoring Programs in Gulf Coast Network Parks

We conducted a survey of current and historical monitoring efforts within the network parks to identify opportunities to continue, modify, or expand existing programs. In-park monitoring efforts are summarized in Table 1.5, and additional details for historical and current monitoring efforts are presented in Appendix I. Table 1.5 includes only those monitoring/research projects that were conducted on park property. Regional monitoring programs, such as air or water quality monitoring, which will be used to aid in assessing park resources, are not included in this summary. We will make full use of existing monitoring programs, particularly air and water, outside of the parks, if the data are appropriate. In the case of water quality, the network's monitoring program will be designed to augment existing efforts and place park resources in a broader, watershed- or regionwide context. We are planning no in-park, long-term air quality monitoring, but will use data from existing programs to track changes that may begin to impact park resources. Also not included in the table are park-based inventories, which are designed to document presence/absence of species rather than trends in populations over time. The results of those inventories are available in NPSpecies, the NPS database designed to house inventory data. Overall, little long-term, comprehensive monitoring has been conducted in GULN parks. Some parks, such as JELA, have a long history of research conducted in the park; others have very little baseline information or monitoring data. Where work has been done, most is not long-term or currently ongoing.

Table 1.5. Summary of existing and prior park-based monitoring efforts conducted in Gulf Coast Network parks presented in the framework of the NPS I&M program.

Level 2 Category	Level 3 Category	BITH	GUIS	JELA	NATR	PAAL	PAIS	SAAN	VICK
Air Quality	Ozone				C		C		
	Visibility and Particulate Matter				C				
	Air Contaminants						C		
Weather and Climate	Weather and Climate			C	C		C		
Geomorphology	Coastal/Oceanographic Features and Processes		C	C			H		
	Stream/River Channel Characteristics								
	Hillslope features (erosion)								C
Soil Quality	Soil Function and Dynamics			H					
Hydrology	Groundwater Dynamics					C			
	Surface water dynamics			H					
Water Quality	Water Chemistry			C,H			H		C
	Nutrient Dynamics			C,H					
	Toxics			C		C	H	C	
Invasive Species	Invasive/Exotic Plants	C	C	C,H	C		C		C
	Invasive/Exotic Animals			C					C
Focal Species or Communities	Wetland Communities			C,H					
	Riparian Communities			C,H					
	Aquatic Vegetation			C					
	Forest/Woodland Communities			C,H					
	Marine Invertebrates								
	Freshwater invertebrates								C
	Terrestrial Invertebrates			C,H					
	Fishes		C	C					C
	Amphibians and Reptiles			H					
	Birds		C	C,H	C?			C	C
	Mammals			C					
	Terrestrial Communities							H	
At-risk Biota	Threatened and Endangered Species and Communities	C	C			C	C		

Level 2 Category	Level 3 Category	BITH	GUIS	JELA	NATR	PAAL	PAIS	SAAN	VICK
Point-source Human Effects	Point source human effect (oil and gas)	C		H			C		
Non-point-source Human Effects	Non-point source human effect (Marine Debris)						H		
Visitor and Recreation Use	Visitor Usage		C				C	C	
Fire and Fuel Dynamics	Fire and Fuel Dynamics	C					C		C
Landscape Dynamics	Land Cover and Use			C,H					
Soundscape	Soundscape						H	C	

C = data collected within the last five years (2000–2005).

H = historical data collected prior to 2000.

1.6. Developing an Integrated Monitoring Program

1.6.1. GULN monitoring objectives

There are several challenges associated with developing a truly integrated monitoring program for the Gulf Coast Network: the large range and variation in ecosystems and their associated functions, processes, and characteristics; the large geographical distance between parks (the greatest distance between park units is more than 1,200 miles from north to south); the division of the network across a major NPS administrative boundary (half of the parks are in the Southeast Region, half in the Intermountain Region); and the combination of large parks with significant natural resources and associated staff and expertise, and smaller cultural parks with locally significant natural resources that may not have been the focus of previous management activities. Nevertheless, thanks in large part to park staff and its Technical Committee members, the GULN has taken to heart the operational model for the development of this program: the network is thought of as one park with multiple units. The focus has been to search for the common characteristics and needs of the parks, rather than the differences. Consequently, the network has created a few common conceptual models, rather than attempting to model each of the many types of systems found across the network (see Chapter 2). Vital sign selection was driven by issues of common concern, rather than each park-specific issue (see Chapter 3). Protocols with network-wide application potential are given highest priority (see Chapter 5).

The GULN recognizes that the NPS I&M program offers a unique opportunity to monitor trends in natural resources that are pervasive across network parks and that individual parks would find difficult to accomplish due to high cost or magnitude of scale. Our intention is to analyze network-wide changes in the status of selected vital signs, recognizing that the monitoring data need to be collected, analyzed, interpreted, and reported in such a way as to be relevant for individual park managers. Additionally, our intent is to develop a monitoring program that is complementary to those of other I&M networks in the Southeast Region, so that the data can ultimately be used to evaluate larger, regional trends.

The GULN monitoring program will not exclusively focus on the general ecological function of network ecosystems, because no network park can be considered to be in a "pristine" condition. Most network parks are already highly impacted by a variety of anthropogenic stressors and may be less resilient to natural disturbances due to their small size and location in a largely altered system outside of park boundaries. Several have a relatively small acreage compared to boundary length (i.e., are long and linear), or are made up of many discrete units. Consequently, many of the impacts to park resources are beyond the control of park managers, but have large impacts on the ecosystems found there. Given the rapidly changing landscape in which these parks are found, new issues will arise that may be difficult to predict today.

A landscape-scale approach will provide valuable data that will assist parks with these emerging issues. The major objectives of the of the GULN monitoring program are associated with the landscape-scale issues of management concern that many of our parks have in common:

1. *Monitor changes in land use outside of park boundaries*. At the request of park managers, our approach is to provide real-time, early warning of permitted development within areas of concern identified by park staff. The goal is to allow the parks to plan for impacts to resources (e.g., visitor access, watershed issues, viewscape, or introduction of invasive species) before those changes occur.
2. *Monitor changes in structure and community composition of terrestrial vegetation*. Vegetative-community types and habitats, and their associated structural characteristics, are closely linked to other species of interest found in an area. Several associated issues of concerns may be wholly or partially addressed by this approach: control or expansion of invasive species; increase or decrease of natural and anthropogenic disturbance (e.g., frequency or intensity of tropical storms, fire suppression); and changes in weather patterns and climate (e.g., droughts, global climate change).
3. *Monitor changes in water quality*. Surface waters play a key role in the occurrence and distribution of the associated natural resources in network parks and are highly important to visitor experience. Monitoring of water quality will be coordinated with other state and federal efforts in order to place changes identified within the parks in larger regional context.
4. *Monitor changes in common amphibian species abundance and distribution*. Amphibians are indicators of general ecological health, and are common to all network parks. They are subject to regional- and global-scale environmental changes, but are less mobile than other species (such as birds), and are therefore better indicators of in-park conditions that may be under management control.
5. *Monitor coastal dynamics, or the large-scale changes in landscape features in our coastal parks*. Geomorphic change along the coast can lead to sudden and dramatic changes, not only in natural resources, but also in park infrastructure. Consistent, quantifiable measurements of coastal change will inform park managers for such issues as park planning, and participation in regionwide efforts of other federal agencies, such at the Army Corps of Engineers. Coordination with other coastal monitoring in the northern Gulf of Mexico will put in-park changes into a regionwide perspective.
6. *Monitor weather and climate as a driver of larger ecosystem change across the network*. High-quality, correlative weather data will be important for the interpretation of all other vital signs datasets. Particular issues of concern are global climate change and sea-level rise.

The GULN is committed to establishing the foundation of a monitoring program that will continue in the long term. We expect that the information gained will provide valuable data to aid appropriate management decisions in network parks and provide landscape-scale information that can also form the foundation of other, targeted, shorter-term, research projects in the parks. Issues of management concern are an important component of the monitoring program, but the program focus is on landscape- and regional-scale issues shared by the network parks.

1.6.2. Process used to identify vital signs

The process for choosing and prioritizing vital signs has largely followed that recommended by the national I&M program, consisting of a series of scoping workshops, compilation of park issues and concerns, development of conceptual models, Scientific/Technical Advisory Committee (STAC) meetings, use of prioritization ranking criteria, and park visits to ensure the linkage between monitoring data and park management (details are provided in Chapter 3). The process for choosing and prioritizing vital signs began 2002, with a combined Board of Directors and STAC meeting. The final list of 42 vital signs was prioritized in April 2005, at a STAC meeting, where 19 of the vital signs were determined to be of highest priority. At that time, it was understood that given budget and time limitations, the network would likely not be able to immediately begin monitoring all of those vital signs. As protocol development has progressed, we have been working to address as many of the identified vital signs in common protocols as possible (see Chapter 5). We consider this monitoring plan to be dynamic and subject to frequent review and evaluation.

Chapter 2
Conceptual Ecological Models

This chapter presents and discusses the conceptual models we developed to guide and support the GULN monitoring program. Experience from the NPS prototype program, as well as from many other monitoring programs, indicates that successful monitoring programs are based on an underlying understanding of how the ecosystem(s) in question work. This programmatic understanding forms a mental model that guides and influences program development. For effective programmatic use, these models need to be explicit and available for discussion and refinement (Maddox et al. 1999). Conceptual models, and the modeling process, contribute to development of program monitoring objectives, prioritization of possible vital signs, selection of useful specific indicators for effective ecological monitoring, and clarification of meaningful monitoring strategies, thus enabling programs to progress from general to more-specific monitoring questions (Gross 2003). Conceptual models are part of an integrated information system to provide scientifically valid information to park managers, and may be revised as monitoring data are interpreted and findings reported (Figure 2.1).

Figure 2.1. Ecological monitoring as an integrated information system to provide scientifically valid information to park managers. Figure adapted from National Water Quality Monitoring Council (2003).

2.1. Introduction

Conceptual models are simplified visual or narrative summaries that present selected important components and interactions of complex systems (Starfield 1997). They help synthesize current knowledge so that scientists can make defensible decisions about what to monitor with a better understanding of how indicators are linked to the larger ecosystem (DeAngelis et al. 2003). They also serve as heuristic devices to help program developers communicate and understand ecological complexity by organizing available information, simplifying component relationships and processes, and illustrating how components may affect one another and other systems. For the GULN program, conceptual models are (1) communication devices that support effective decisionmaking during continued program development; (2) tools intended to present a simplified digest of complex information that allows us to place our monitoring efforts within a context that relates indicators to major ecosystem components, processes, and anthropogenic threats of interest to network parks; and (3), dynamic, living documents that are expected to change over time as we acquire new information and understanding about the ecosystems we monitor.

The GULN program has developed diverse conceptual models representing a broad array of issues, resources, and ecosystems. These models range from process-outline “box-and-arrow” depictions of major ecosystems to park-specific diagrams of resources and monitoring interests. This chapter includes the following:

1. A description of the GULN conceptual-modeling process;
2. A GULN general ecosystem conceptual model that introduces the ecosystem levels and symbology used in GULN system models; and
3. The three specific models created to summarize the major ecosystem types regarded as being broadly applicable across GULN parks.

GULN ecosystem conceptual models follow the general form of “stressor models” as described in Gross (2003). They identify major agents of change, stressors, ecosystem responses, possible measures and indicators, and some of the major causative links between these entities. Our emphasis is on showing the linked relationship between the natural and anthropogenic drivers affecting network ecosystems, system structure and function responses, potential vital signs and indicators, and monitoring efforts.

2.2. Gulf Coast Network Model-Development Approach

Developing conceptual models is an iterative process of creating and revising models as we gain understanding of GULN ecosystems, issues, and approaches to monitoring. In cooperation with stakeholders and expert scientists, models have been developed to summarize, in a “holistic overview,” our conceptual understanding of network ecosystems and park resources. These models communicate, in a graphical way, the important physical, chemical, and biological components and processes of major network ecosystems, serve as diagrammatic illustrations of the conceptual basis for monitoring, and support the identification and selection of ecological vital signs. The general and type-specific ecosystem models presented here serve to mark current waypoints in our ongoing programmatic development.

Our general strategy for model development was to gather information on network park ecosystems and identify significant examples of and linkages among agents of change, stressors, and responses in these systems, followed by drafting of initial models. A workshop was held on April 21–22, 2004, to develop the basic background information needed to develop both ecosystem and park-specific conceptual models. Participants included specialists in Gulf Coast ecosystems, GULN staff, and park natural resource management specialists. For purposes of discussion, the eight network parks were grouped into river-dominated coastal parks, marine-dominated coastal parks, and upland parks, based on the general types of major ecosystems present in each park. For each group of parks, workshop participants developed and discussed lists of likely stressors and ecosystem responses. Details of the stressors and ecosystem responses generated for each park group, a list of workshop participants, the resulting final report (Twilley and Rivera-Monroy 2005), and a collection of previously published conceptual models representing the ecosystems found in the network (Twilley 2005) are presented in Appendix J. Following discussion of the assembled ecological and resource information, selected specialists and program staff drafted diverse initial ecosystem models and park-specific diagrams to visually represent system structures and linkages as well as resources and issues thought to be important to individual parks and park management. Initial models were reviewed and discussed by specialists, NPS program personnel, and GULN and park staff in several forums, including in-house staff meetings, consultation with experts, and multiple park-based meetings involving program staff and park management teams. Outcomes of reviews and continuing discussion include increasing understanding of park ecosystem structure, function, and components; refining understanding of park resource issues and of what park managers need in terms of monitoring information; and revising the conceptual models to reflect these changes in understanding.

2.3. Gulf Coast Network Ecosystem Conceptual Models

The GULN recognizes and responds to the reality that its ecosystems are subject to natural environmental processes that occur in conjunction with anthropogenic activities, and that anthropogenic forces and activities, natural processes and events, and ecosystem processes and components are best viewed as an interwoven supersystem. This holistic perspective emphasizes that park ecosystems are broadly subject to, and influenced by, natural and anthropogenic forces (Figure 2.2). Effective ecological monitoring can best be developed in a context that takes both system function and interactions and external influences and drivers into account.

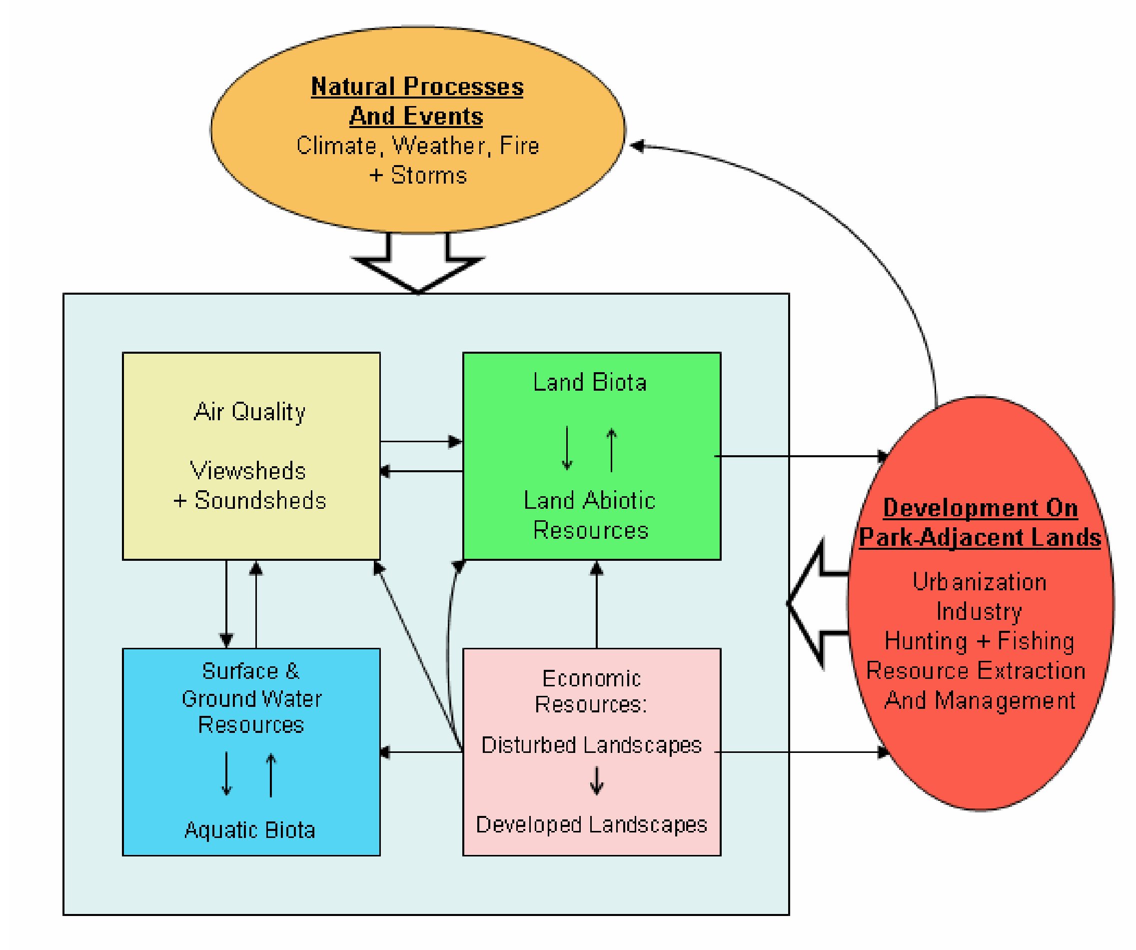

Figure 2.2. Environmental system drivers that affect the complex linkages of air, water, land, and biological resources within park units, together with how economic resources impact the structure and function of these natural resources. Adapted from Twilley and Rivera-Monroy (2005).

In general, natural and anthropogenic processes and activities are viewed as being environmental system drivers. These drivers create or result in stressors that lead to linked changes that alter, in diverse ways, ecosystem function and structure, resulting in measurable changes in component properties and interactions. The GULN has chosen a hierarchical, stressor-response model format to represent this conceptual picture of monitoring ecosystem responses to system drivers. Our models emphasize two aspects of our programmatic understanding and approach to ecosystems and their monitoring: (1) ecosystems have a hierarchical structure, and (2) levels within systems are linked, allowing us to link specific measures of ecosystem response to natural and anthropogenic drivers. For example, processes, disturbances, events, and actions affect the amount and type of light arriving at a plant's surface. Light drives photosynthesis, and photosynthesis supports biosynthesis, resulting in plant growth. Measures of growth and incident light correlate back to drivers affecting available light quality and intensity.

Our ecosystem models share a common structure and symbology, presented in Figure 2.3. Models depict four distinct hierarchical levels with text-filled boxes. Major causative links between these levels are indicated by directional lines and arrows.

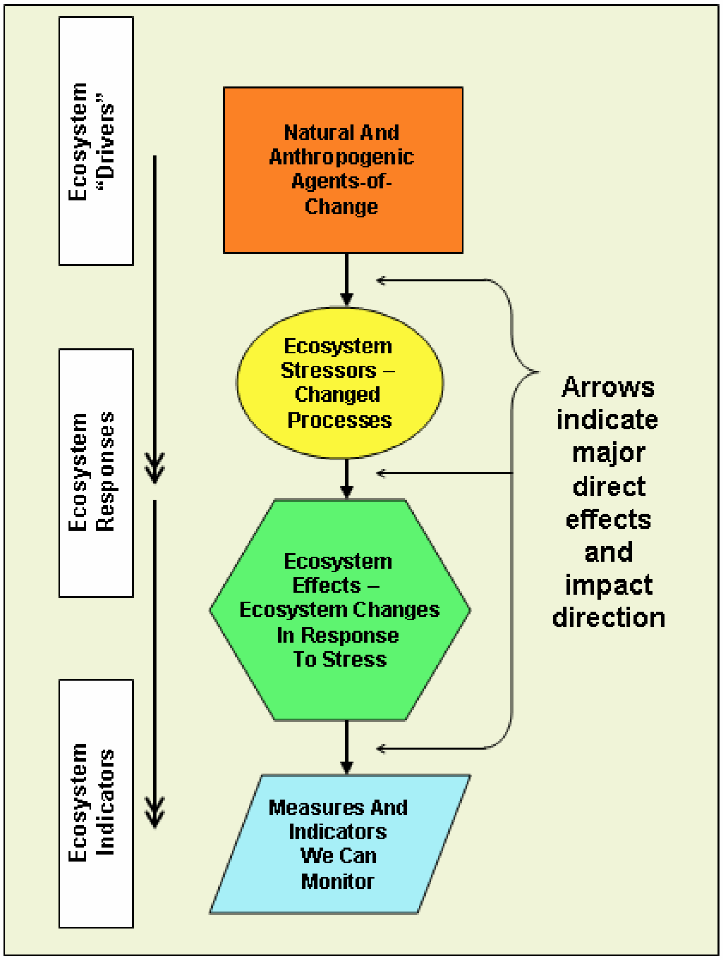

Figure 2.3. Diagram of the Gulf Coast Network conceptual modeling symbology. The four box types represent levels within the hierarchical ecosystem models. Text within the boxes identifies examples or specific cases of that level. Line-arrows represent (largely directional) superior-level forces or effect on subordinate levels and events. Vital signs for monitoring are mostly drawn from the set of ecosystem responses and indicators, but may be identified at any level within an ecosystem.

The general ecosystem model (GEM; presented in Section 2.4) was constructed to serve as a template for specific models that depict the three dominant ecosystem types in GULN parks: the uplands/forest-dominated zone, the river-dominated wetlands/riparian zone, and the coastal near-shore marine zone. The GEM depicts different levels and linkages with examples that are potentially applicable across all eight GULN parks and of all the major ecosystems found within those parks. The specific ecosystem models identify appropriate examples for each level and denote the likely linkages considered to be salient within that specific system type. Examples of ecosystem-specific agents of change, stressors, and ecosystem responses are presented in Table 2.1. Each system model is applicable to multiple network parks, and several parks contain examples of multiple ecosystems represented by different system models. The park-by-ecosystem model alignment is shown in Figure 2.4. The ecosystem models serve to support and guide selection and development of program monitoring protocols.

Table 2.1. Descriptions of Gulf Coast Network conceptual-model agents of change, stressors, and ecosystem effects (responses).

Model component	Description
Agents of Change	**Disturbance** is the overarching theme of the GULN models. GULN ecosystems tend to be very dynamic and are subject to both anthropogenic and natural disturbances. Disturbance is the key to maintaining diversity in GULN ecosystems.
Geomorphic processes	Geomorphic change affects and drives GULN ecosystems in many ways. Landform change, subsidence, coastal dynamics, erosion, and deposition all alter and restructure the physical base for system environments and habitats, and all are variably influenced by many natural and anthropogenic forces and events.
Weather and climate	Ultimately, all ecosystems are closely linked to weather and climate. Natural and anthropogenic changes in climate can lead to both biotic (e.g., habitat loss/alteration) and abiotic (e.g., increased beach erosion due to eustatic sea level rise) changes in ecosystem structure and function.
Extreme weather events	This category refers to weather that substantially deviates from the average, such as extreme drought, floods, hurricanes, extreme cold, tornadoes. Frequency and magnitude of these events vary due to natural causes and, potentially, anthropogenic climate change.
Major spills and disasters	GULN parks are subject to major anthropogenic disasters, such as shipwrecks and major petroleum spills that cause acute, large-scale impacts to ecosystems by altering system processes, affecting environmental quality, and destroying biotic components.
Anthropogenic forces and actions	GULN ecosystems exist in an extensively developed environment, and are subject to diverse impacts from changes in adjacent land use, resource extraction and consumption, urbanization, diverse recreation activities, and resource management actions both in and outside parks.
Stressors	
Altered chemical inputs to air and water	Contaminants and pollution include diverse materials (metals, hydrocarbons, pesticides, nutrients, etc.) discharged into the atmosphere and/or into drainage systems and urban run-off that are associated with altered survival, growth, reproduction, and/or metabolism.
Altered sedimentation processes	Transport and deposition of sediments are important processes that are altered by both natural and anthropogenic forces. Altered sedimentation processes lead to dynamic changes in physical and chemical environments.
Altered fire regimes	Fire is a key natural component in many GULN ecosystems. Control and alteration of fire regimes broadly affects both habitat properties and biota in many parks.
Hydrologic manipulation	Hydrologic manipulation connotes alteration of natural hydrologic processes, for instance, dams, levees, ditching/digging of canals, dredging/navigation, water withdrawal for irrigation or drinking, and river diversions.
Infestation and disease	This category includes both native and non-native pests, as well as plant and animal diseases. Disturbed or altered ecosystems are less resilient to disease and infestation.
Altered landscape dynamics	This category includes historic and ongoing changes in land use/land cover, both inside and outside park boundaries.
Invasive species	Invasive species are alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health. With respect to a particular ecosystem, an alien species is defined as any species, including its seeds, eggs, spores, or other biological material capable of propagating that species, that is not native to that ecosystem (Executive Order No. 13112 1999).

Ecosystem Effects	
Change in chemical and physical environment, as well as habitat availability and quality	Changes in air quality potentially impact plant growth and development, and may also impact various faunal components in ecosystems. Changes in water quality and hydrology broadly change habitat for aquatic system biota. Changes in fire regimes alter vegetation-based physical structure and directly impact system functions and biota. Changes in sedimentation processes lead to diverse habitat impacts in aquatic and marine systems, and, in severe cases, can lead to direct loss of habitat, such as when a portion of a barrier island is destroyed by an extreme storm event or altered by major anthropogenic actions, such as dredging and spoil deposition.
Change in biotic components and interactions	Introduction of invasive species, removal of organisms, direct and indirect chemical toxicity effects, disease and pests, and fire-regime alterations can all affect population size, distribution, age/sex structures, reproductive rates, and inter- and intraspecific interactions in various biota. Any and all of these changes may lead to changes in biotic community structure and composition and system trophic structure.
Change in ecosystem process and function	Functional aspects of ecosystems, including nutrient-cycling pathways and rates, energy-flow dynamics, and ecological succession, are all impacted by stressors that alter availability of energy and nutrients, and/or modify potential for interactions where trophic levels “hand off” matter during these flow and cyclic processes.

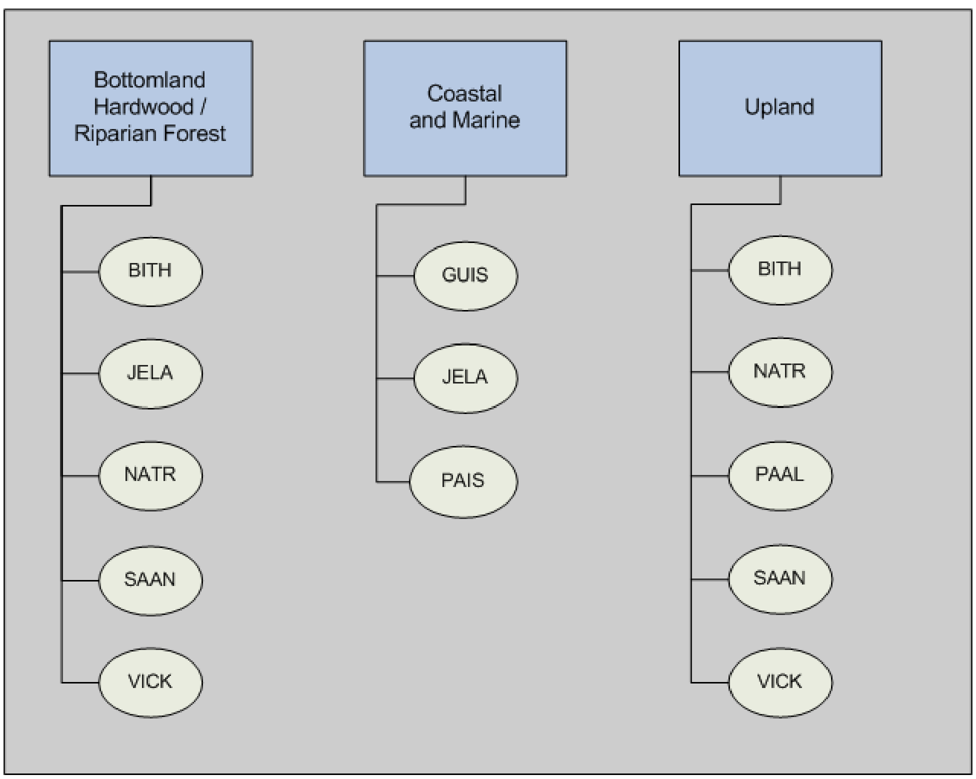

Figure 2.4. The applicability of the three major ecosystem models to Gulf Coast Network parks. Figure details which parks are addressed by which model.

2.4. Gulf Coast Network General Ecosystem Model

The GULN general ecosystem model is designed to illustrate a linked, hierarchical overview of an ecosystem subject to major systemwide drivers acting at the "top end," and monitored, using quantifiable responses (indicators), at the "bottom end." The emphasis in this general model is on showing a top-down stressor-response interaction between levels, ultimately resulting in measurable system change, subject to effective qualitative and quantitative assessment and monitoring. The GEM scheme places all systemwide drivers in an "agents of change" level that includes both anthropogenic activities and natural forces. Conceptually, these agents of change create or result in several discrete "stressors" that, in turn, act in specific ways on specific ecosystem functions and components represented in the "ecosystem responses" level. Stressor effects on the various ecosystem responses result in specific and measurable changes, such as altered physical and chemical environmental parameters. These measurable changes are the parameters and subjects that comprise the potential "indicators," or vital signs, targeted by program monitoring protocols. The model's hierarchical levels, with general examples, are defined in the following sections.

2.4.1. Agents of change

Agents of change are major forces or events (i.e., sources of disturbance) that have diverse and often large potential to affect and impact one or more ecosystem functions or structural properties by creating ecosystem stressors. The network's general ecosystem model (Figure 2.5) focuses on three broad categories of agents of change:

- **Natural forces and processes.** These include biotic processes, geomorphic processes, weather, and climate, for example, sea-level rise, ecological competition, pests and disease, succession, natural landform changes, and weather and climate cycles.
- **Acute events and disasters.** These include hurricanes and other extreme, stochastic natural events, as well as human activity-related disasters, such as major oil spills, shipwrecks, and dam breaks.
- **Anthropogenic actions and activities.** These include development and land-use change, urbanization, resource extraction and consumption, visitor and recreation activities, and park management actions.

Natural forces and processes are likely to apply broadly to all ecosystems across network parks, as all ecosystems experience ecological competition, weather effects, and relevant geomorphic processes—albeit to differing degrees and in sometimes different ways. All GULN parks also experience acute events and disasters in the form of hurricanes, which have potential for regionwide, severe impacts. Anthropogenic actions and activities are somewhat more park-specific in their type and scope, as will be noted in the specific ecosystem models and associated discussion.

In addition to these general categories, larger-scale factors, such as watershed condition and regional air quality, affect a variety of park resources and ecosystem functions. For example, inland watersheds drain into near-shore waters and serve as natural dynamic hydrologic systems that create and sustain estuarine and marine ecosystems. Impaired and altered watersheds convey pollutants and sediments into waters of coastal parks, impacting park resources and undermining critical coastal habitat. Many water quality issues and ecosystem problems derive from watershed conditions at scales beyond specific water sources. Although these larger-scale factors are generally outside of park regulatory influence and are not detailed on GULN network models, the impacts from these higher-level threats are recognized.

2.4.2. Stressors

Stressors are direct changes of process or components that result from agents of change. Stressors directly affect ecosystem structure and function, processes, and specific system components, and result in ecosystem responses. Each type of agent of change may cause one or more stressors. Seven general classes or categories of stressors are identified in the GEM: altered hydrologic processes and properties, altered fire regimes, invasive species and feral animals, altered sediment inputs, altered chemical inputs, changes in land use, and altered landscape/landform dynamics. Most of these stressors apply, as categorical types, across most or all GULN parks and ecosystems. In each park and ecosystem, there may be specific differences in detail that will be noted in the system models and supporting discussion narratives.

Depending on the type of ecosystem being discussed, the agents of change can lead to and form a wide array of links to stressors. For example, increasing human development and urbanization leads to changing land-use patterns, which may lead to increased invasive-species impacts, changes in hydrologic processes, and altered chemical inputs to local air and water. These stressors may, in turn, directly affect biological populations, trophic structure, and chemical and physical environments, which will affect population distributions and abundances. When a woodland area is converted to a housing development, for example, the woodland ecosystem responds as wildlife habitat is destroyed, food resources and supply are altered, invasive species are introduced, and soil and groundwater chemistry are altered by pollution.

2.4.3. Ecosystem responses

Ecosystem responses are changes in ecosystem processes and structure that result from stressor impacts within the system. Three general categories of ecosystem responses are identified in GULN system models:

- **Ecosystem function changes,** including changes in ecological productivity, nutrient cycling, energy flow, and the overall process of succession.
- **Biotic structure changes,** including changes in trophic structure, biological populations and communities, diversity, and species interactions.
- **Chemical and physical environment changes,** including changes in air quality, water quality and quantity, sediment properties, soil structure and composition, and topography.

As all ecosystems typically exist in environments with chemical and physical properties, all include some range of biodiversity, and all exhibit functional processes, these ecosystem response categories are broadly applicable to all systems and models. While the labels will remain the same, it should be noted that system function pathways, processes, environmental conditions, and biota are specific to the system of interest. Relevant details appear in system narratives, and are reflected in the specifics of selected indicators and monitoring protocols.

The three GULN ecosystem-specific conceptual models use the format, arrangement, and symbology found in the GEM. Sections 2.5, 2.6, and 2.7 will describe the models and discuss examples of agents of change, stressors, ecosystem responses, and measures or indicators being considered for the major GULN system types. It should be noted that the models and descriptions present some of the many likely examples possible for each level and category depicted. The intent here is not to exhaustively list all possible factors and connections; rather, it is to provide a useful set of some that are considered salient to effectively selecting and developing monitoring directions and protocols.

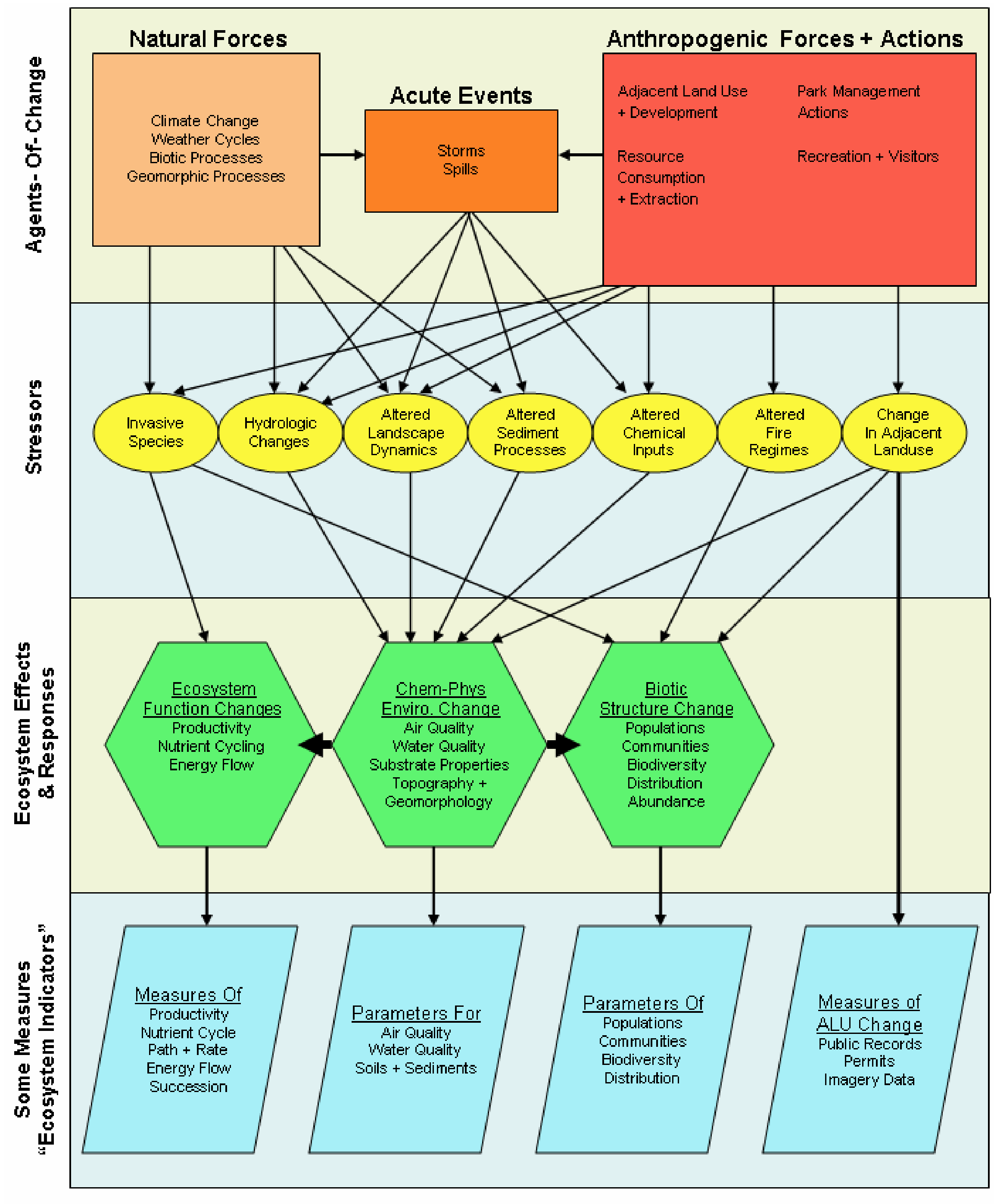

Figure 2.5. The Gulf Coast Network general ecosystem model. For ecological processes and various stressors, labels represent factors (i.e., ecological competition, altered fire regimes) that are widely recognized to be common natural processes and/or anthropogenic events. Vital signs for monitoring may be identified at any level in the model.

2.5. River-Dominated Wetlands/Riparian Zones Ecosystem Conceptual Model

2.5.1. General description

The riparian zone of a river, stream, or other body of water is the land adjacent to that body of water that is, at least periodically, influenced by flooding. Riparian zones are important features at BITH, JELA, NATR, SAAN, and VICK. Bottomland hardwood forests are a major riparian ecosystem type in the United States (Mitsch and Gosselink 1993). These systems play a crucial role in the watershed by providing areas to store floodwater, thereby reducing the risk and severity of flooding to downstream communities. Further, these wetlands improve water quality by filtering and flushing nutrients, processing organic wastes, and reducing sediment before it reaches open water. The Barataria Preserve of JELA provides one of the southernmost examples of bottomland hardwood forests in North America (Swanson 1991). Harris (1989) listed characteristics of these ecosystems that are beneficial to wildlife: hard mast production and a phenology (periodic biological phenomena, such as flowering) that is asynchronous with surrounding upland communities, frequent cavity trees, high abundance of invertebrate wildlife, and a linear distribution through 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. These characteristics increase in importance in the more arid western subregion. A collection of published models of riparian and bottomland hardwood forests are included in Appendix J and in the GULN Phase II Report (2005).

2.5.2. Agents of change and stressors

Major agents of change acting on these ecosystems include both the common suite of natural disturbances and drivers and the diverse anthropogenic forces resulting from major human development shown in Table 2.2. The anthropogenic agents of change result in several categories of stressors that impact park ecosystems in significant ways, altering system function and impairing system environments as well as biological structure and integrity (Figure 2.6).

Table 2.2. Major agents of change and stressors for river-dominated wetlands/riparian zones.

Category	Agent of change/Stressor
Natural forces and processes	• Climate patterns and effects • Major natural geomorphic and hydrologic patterns and processes
Acute events and disasters	• Extreme coastal storms and hurricanes that broadly impact the entire Gulf Coast region
Anthropogenic actions and activities	• Extensive urbanization and development in lands adjacent to river–riparian corridors • Drainage and development of wetlands • Management activities involving river and other hydrologic alterations

Bottomland hardwood forests and riparian zones in network parks are influenced by several stressors, including altered hydrology (e.g., changes resulting from dredging of canals, dams, saltwater influx, river diversions), erosion, contaminants, non-native/invasive species, and historical land use (e.g., timber extraction, oil and gas exploration/extraction). Ecosystem processes and plant-community composition and structure are driven, in part, by gradients of flooding frequency, duration, and timing. The biotic community, in turn, influences the hydrology of the wetland. Consequently, these systems are sensitive to landscape dynamics within their watershed that alter hydrology and/or water quality. Altered hydrology has increased lakeshoreerosion rates at JELA (Michot 1984, Taylor et al. 1988). The influx of saltwater into these systems can have dramatic effects on extant vegetation (Harrel 1975, Michot 1984, Taylor et al. 1988, Mendelssohn and McKee 1989), as freshwater hydrophytic species are not adapted to increased salinity levels. Increasing mercury levels in predatory fish are also a concern (Swarzenski et al. 2004). Non-native/invasive plants and animals can rapidly spread over large areas and are often difficult to treat due to logistic issues, treatment effectiveness, and seed/propagule influx (Tipping and Hulslander 2003). Burrowing by nutria (*Myocastor coypus*) damages levees, thus altering hydrology, and feral hogs (*Sus scrofa*) create large disturbances that fragment habitats and make the areas susceptible to non-native/invasive plant establishment (Conner and Day 1987, Harcombe and Van Kley 1996). Although no logging presently occurs on GULN parks, timber-harvesting activities on adjacent lands may adversely affect park faunal communities (Irwin and Dixon 1996). Oil and gas exploration and extraction currently occur in both JELA and BITH. Oil and gas extraction is linked to subsidence (Denslow and Battaglia 2002, Morton et al. 2001), and creating access for extraction activities (e.g., excavation of canals) alters hydrology (Taylor et al. 1988). Further, exploration and extraction activities cause localized disturbance that may result in increased susceptibility of plants to disease (Fountain and Rayburn 1987) and non-native/invasive species establishment. Oil spills can also have dramatic long-term consequences on aquatic flora and fauna (Harrel 1985).

2.5.3. Potential measures and indicators

Potential measures and indicators (vital signs) for river-dominated and wetland-riparian zone systems include

- measures of plant and animal species diversity and population abundance, structure, and distribution for selected species;
- changes in terrestrial and aquatic plant and animal community composition and structure;
- changes in vegetation-based habitat structure;
- zonal ecological succession (changes in vegetation community composition and structure, aerial coverage and distribution over time);
- changes in quantity and quality of running and groundwater resources; and
- changes in adjacent land use.

Protocols relevant to river-dominated wetlands/riparian zones are shown in Table 2.3.

Table 2.3. Protocols relevant to river-dominated wetlands/riparian zones.

Relevant protocols	Goal(s)
Freshwater	To provide chemical and physical parameter assessment on all network parks with freshwater resources.
Vegetation Structure and Composition	To detect and track a variety of vegetation structural and distributional parameters at parkwide and landscape levels, to address a range of park-specific vegetation questions in each sampled park, including • distribution, health, and coverage of key vegetation communities; • changes in park vegetation characteristics; • tracking of some invasive species; and • assessment of ecological succession seen in spatial changes in plant community coverage and composition patterns. To assess geomorphic structure in sampled parks.
Amphibian Communities	To assess and track amphibian assemblages, including measures of community structure and diversity, occupancy, reproductive success, and taxon distribution within parks.
Adjacent Land-use Change	To provide ongoing assessment of specific and general types of human development occurring in nearby adjacent lands.

Future protocol development may include:

- monitoring of benthic macroinvertebrates in conjunction with water quality monitoring,
- potential ozone impact assessment and monitoring, and
- support for other biotic assessment, such as targeted plant-species monitoring and monitoring of park bird communities.

See Chapter 4 and Protocol Development Summaries in Chapter 5 for monitoring questions, objectives, and possible measures being developed for monitoring protocols.

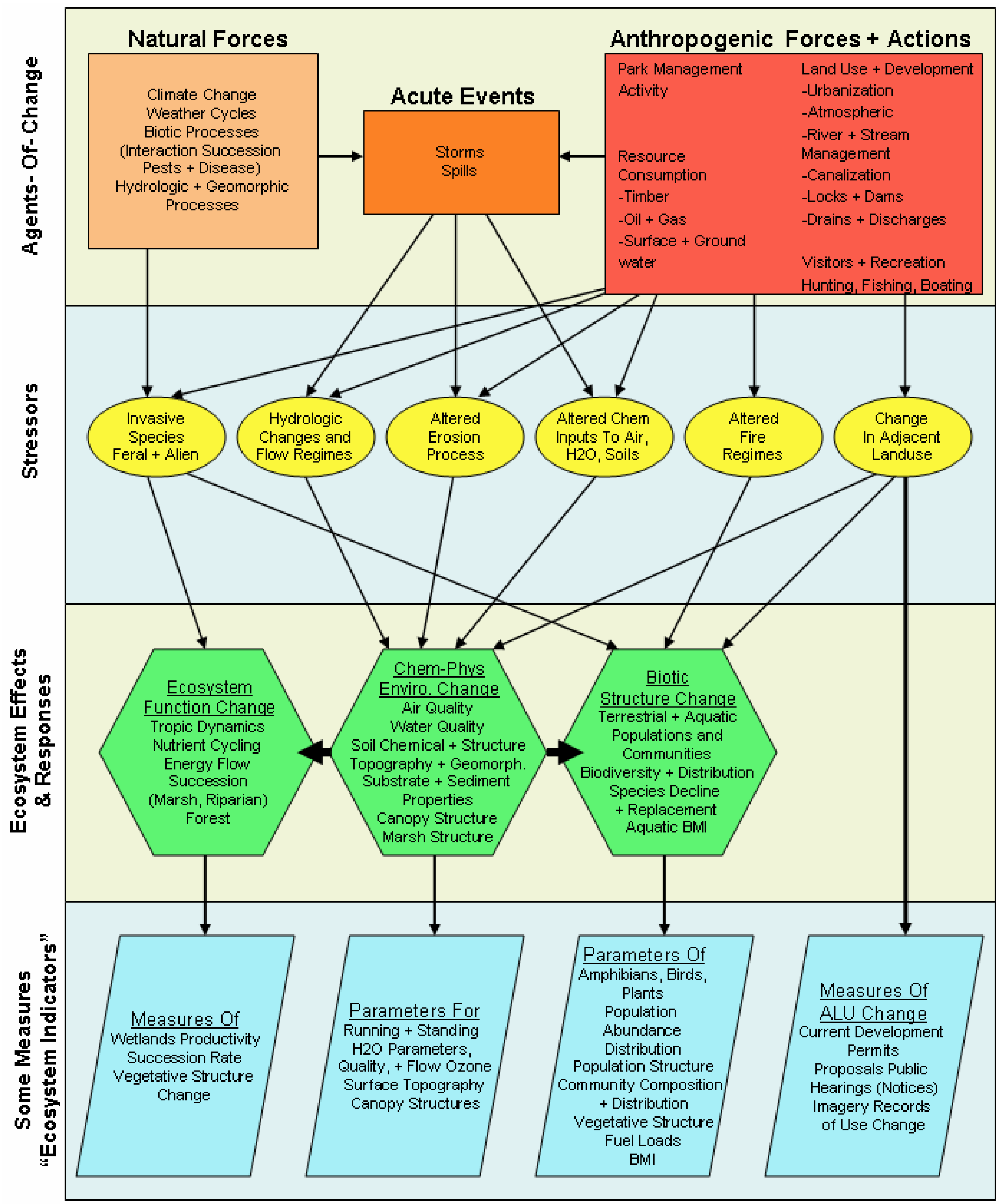

Figure 2.6. The Gulf Coast Network River-Dominated Wetlands/Riparian Zones conceptual model.

2.6. Coastal and Marine Ecosystems Conceptual Model

2.6.1. General description

There are two distinct coastal and marine ecosystems represented in network parks: the riverine-dominated (deltaic) coastal wetlands system (JELA) and the barrier-island systems (GUIS and PAIS). Although these systems are distinct from each other, they share a common set of agents of change, stressors, and ecosystem responses because of their coastal locations. Therefore, they are combined into one conceptual model.

JELA is located in the deltaic plain of the Mississippi River. As such, it is historically a river-dominated system, yet its location in the upper estuary of the Mississippi delta makes it distinct from other riparian areas in the network. The variety of wetland habitats and the stressors that influence those wetlands gives it characteristics more similar to the marine-dominated, barrier-island systems. Deltaic plant communities and associations are determined by the cyclical nature of delta lobe development and degradation (Gagliano and Van Beek 1975); overlapping environments develop and decline as the lobe ages. As delta lobes grow and decay, habitat and biodiversity peak in the early stages of degradation. Vegetation is closely tied to the unique landforms of the delta and proximity of those areas to either continued riverine or marine influence. Coastal wetlands are influenced by the natural processes involved in delta degradation such as subsidence, shoreline erosion, changes in salinity, and changes in availability of sediment. In addition, stressors include altered hydrology, sea-level rise, extreme weather events, recreation, oil and gas exploration and extraction, and contaminants. Coastal wetlands provide storm-surge abatement, water purification, recreational opportunities, and critical habitat for a variety of nesting, wintering, and migrating wildlife species.

Barrier islands are geologically young features; the vast majority are less than 7,000 years in age, and most are probably less than 3,000 years old. Barrier-island formation is dependent upon the complex interaction between waves, sea-level change, and the availability of sediment (http://www3.csc.noaa.gov/beachnourishment/html/geo/barrier.htm). They are a vital part of the coastal and estuarine habitats found in GULN parks. Barrier islands are composed of three general zones: beach, dune, and back dune (Figure 2.7). Each zone provides critical habitat for several state- and federally listed species. These systems serve as key stopover areas for migratory birds (Weber 1983, Moore et al. 1990, Blacklock et al. 1998, Fuller et al. 1998, Cooper et al. 2005c), nesting sites for sea turtles (Nicholas and Jacks 1996, Shaver 2000), year-round habitat for the Perdido Key beach mouse (Oli et al. 2001), and shorebird nesting (Simersky 1972, Mitchell and Custer 1986) and wintering habitat (Nichols 1989, Garza 1997, Gorman and Haig 2002).

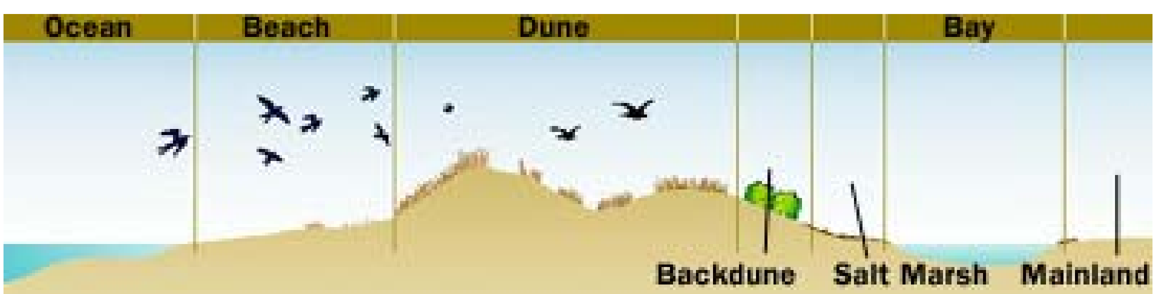

Figure 2.7. Typical zonation of a barrier island. Source: U.S. Air Force.

Changes in coastal geomorphology are normal processes; however, human-made structures (e.g., jetties) may alter offshore sediment transport and increase shoreline-erosion rates (Williams

1999). Extreme weather events are also normal coastal processes, but increased fragmentation and/or reduced system integrity prior to any given event will likely adversely affect system resilience and subsequent recovery. In response to events that cause substantial beach erosion, beach nourishment is often conducted. However, beach nourishment is linked to a decrease in species richness and density, shifts in the assemblage structure, and greater instability of these indices (Rakocinski et al. 1993, 1994, 1996). Excess foot traffic and off-road vehicle use disrupts natural dune processes and has adverse consequences on dune integrity by destabilizing the vegetation (Shabica and Shabica 1978; Shabica et al. 1979; McAtee and Drawe 1981; Blum and Jones 1985; Cousens 1988). However, a balance in recreation and preservation is necessary to fulfill the multiple purposes of designation (Psuty 1988). Oil and gas extraction is linked to subsidence (Denslow and Battaglia 2002, Morton et al. 2001), disturbance, and possible contamination of the activity site. Although contaminants have been detected in bird eggs and tissue, levels do not exceed those known to adversely affect survival and reproduction (Michot et al. 1994, Mora 1996). However, contaminants are associated with decreasing macrobenthic trophic diversity (Rakocinski et al. 1997, Brown et al. 2000) and could have cumulative effects in higher organisms (Carls et al. 1995). In the absence of extreme weather events (i.e., prolonged period since large disturbance), fire maintains barrier-island plant structure, specifically in the back-dune/maritime forest zone. Reduced fire frequency and fire suppression results in the loss of the herbaceous component to a woody overstory of shrubs and trees (Sheaffer 1998).

2.6.2. Agents of change and stressors

In addition to the common suite of natural disturbances and drivers and anthropogenic forces shown in Table 2.4, storm events, coastal/near-shore shipwrecks, and fuel spills pose threats to park ecosystem integrity. Storm surges can substantially scour away biotic components and impact park cultural resources and infrastructure. The anthropogenic agents of change include extensive dredge-and-spoil operations that alter availability of sediment, coastal armoring and modification, water extraction, and coastal drainage modifications. These result in several categories of stressors that impact these ecosystems in significant ways, alter system function, and impair system environments and biological structure and integrity (Figure 2.8).

Table 2.4. Major agents of change and stressors for coastal and marine ecosystems.

Category	Agent of change/Stressor
Natural forces and processes	• Climate patterns and effects • Major natural geomorphic and hydrologic patterns and processes
Acute events and disasters	• Extreme coastal storms and hurricanes that broadly impact the entire Gulf Coast region
Anthropogenic actions and activities	• Extensive urbanization and development on coastal barrier islands—including those that directly comprise GUIS and PAIS—and on lands adjacent to coastal wetlands • Management activities involving river and other hydrologic alterations

Stressors such as near-shore land subsidence, non-native invasive species, hydrologic manipulation, fire-regime modification, and pollution events result in habitat loss, loss of species diversity, and decreased water quality. Barrier islands in network parks are influenced by several stressors, including shoreline erosion, extreme weather events, beach nourishment, recreation, oil and gas exploration and extraction, contaminants, and fire suppression.

Restoration of these systems is often costly and controversial. Water diversions, rock revetment, and revegetation projects are strategies implemented to protect shorelines and interior marshes from erosion and degradation. Hydrocarbon extraction from oil and gas activities has expedited land subsidence and compounds natural geological processes. While fire plays an important role in maintaining ecological integrity of marsh systems, the historic fire regime at JELA is not known. Depending on the role fire historically played at JELA, the exclusion of fire may be fostering the spread of invasive species and disrupting natural plant and animal communities.

2.6.3. Potential measures and indicators

Potential measures and indicators (vital signs) for coastal and near-shore marine zone systems include

- measures of terrestrial and marine plant and animal species diversity, population abundance, structure, and distribution;
- quantity and quality of running and groundwater resources;
- quality of estuarine and near-shore waters;
- geomorphic dimension and properties; and
- changes in adjacent land use.

Protocols relevant to coastal and marine ecosystems are shown in Table 2.5.

Table 2.5. Protocols relevant to coastal and marine ecosystems.

Relevant protocols	Goal(s)
Freshwater	To provide chemical and physical parameter assessment of freshwater resources, along with monitoring of near-shore estuarine and marine waters.
Vegetation Structure and Composition	To detect and track a variety of vegetation structural and distributional parameters at parkwide and landscape levels, to address a range of park-specific vegetation questions in each sampled park, including • distribution, health, and coverage of key vegetation communities; • changes in park vegetation characteristics, community, succession, and invasive species. To assess of geomorphic structure in sampled parks.
Amphibian Communities	To assess and track amphibian assemblages, including measures of community structure and diversity, occupancy, reproductive success, and taxon distribution within parks.
Adjacent Land-use Change	To provide ongoing assessment of specific and general types of human development occurring in nearby adjacent lands.

Future protocol development may include

- monitoring of benthic macroinvertebrates (in conjunction with freshwater monitoring),
- support for targeted plant species monitoring and monitoring of park bird communities, and
- future development of SAV monitoring for coastal parks.

See Chapter 4 and Protocol Development Summaries in Chapter 5 for monitoring questions, objectives, and possible measures being developed for monitoring protocols.

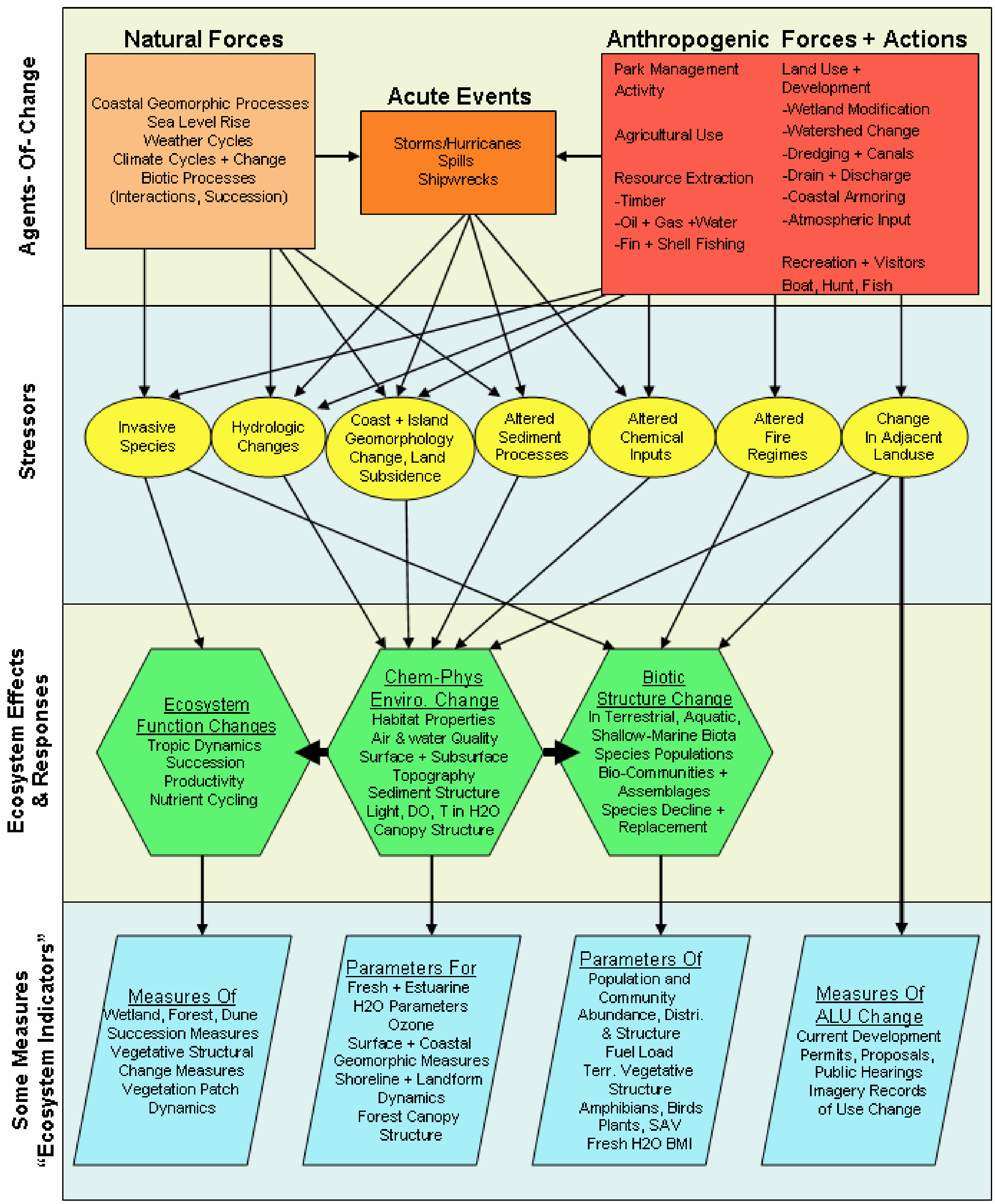

Figure 2.8. The Gulf Coast Network Coastal and Marine Ecosystems conceptual model.

2.7. Upland Ecosystems Conceptual Model

2.7.1. General description

Upland systems in the GULN are diverse, ranging from slash pine stands at GUIS to more xeric brushlands at PAAL and SAAN. Fire is the primary disturbance mechanism in the systems; however, the increasing wildland–urban interface makes fire management increasingly difficult and often results in fire suppression. Ecosystems respond differently to fire suppression. Temperate ecosystems where frequent, low-intensity wildfires had occurred in the past are more likely to have been adversely affected by fire suppression (Agee 1993). Because of altered fire regimes (i.e., fire return interval), many fire-adapted upland systems in the GULN have shifted from herbaceous-dominated to woody-dominated (Table 2.2), thus altering structure and species dominance and reducing species diversity and overall site viability. Overgrazing has further facilitated an increase of woody components in fire-adapted GULN systems.

Table 2.6. Fire-adapted upland systems in Gulf Coast Network parks.

Park	System	Estimated fire return interval	Citation(s)
BITH	Longleaf pine (*Pinus palustris*)	1–6	Frost 1998, Stout and Marion 1993, Ware et al. 1993
GUIS	Slash pine (*Pinus elliotii*)	3–8	Frost 1998, Wade et al. 2000
NATR	Loblolly pine (*Pinus taeda*)	1–6	Frost 1995
NATR	Shortleaf pine (*Pinus echinata*)	2–15	Wade et al. 2000
PAAL	Coastal prairie	~10	Paysen et al. 2000
SAAN	Blackland prairie	~10	Paysen et al. 2000
VICK	Oak-hickory/Mixed mesophytic	3–15	Buell et al. 1954, Cutter and Guyette 1994, Van Lear and Waldrop 1989

The greatest effect of fire suppression on biological diversity is not on the diversity within a particular habitat (Whittaker 1977), but on the diversity of habitats across a landscape. Landscapes with high diversity resulting from fire perpetuate high species diversity by providing opportunities for the establishment and maintenance of early successional species and communities (Connell 1978, Reice 1994). Fire suppression, on the other hand, increases uniformity in habitats as competition eliminates early successional species, leaving only shade-tolerant understory plants to reproduce (Stuart 1998).

Fire suppression has helped change the ecosystem dynamics of communities adapted to frequent, low-intensity wildfire. Complex landscapes are made simpler, some early and midsuccessional plants and animals are extirpated, shade-tolerant tree populations rapidly expand, and the relative importance of fire as a disturbance agent is reduced, while the importance of insects and pathogens as agents of disturbance is elevated (Covington et al. 1994). During droughts, for example, excessively dense forests become further stressed, enabling pathogens and insects to reach high population levels (Johnson et al. 1994). Trees killed by drought, insects, or pathogens create abundant fuel that exacerbates fire hazard. When fire occurs in such a system, it is often larger and more severe than one expected in areas with a natural fire regime (Stuart 1998). Southern pine beetle (*Dendroctonus frontalis*) invasions often result in habitat loss and altered forest structure while further increasing fuel loads in fire-suppressed areas, possibly resulting in catastrophic fires.

Previous land use has permanently altered the upland habitats of GULN parks. Water withdrawals, agriculture, and forest clearing are examples of the types of land uses that continue to impact these systems. Disruptions of native habitats make these areas susceptible to invasion by non-native species, further altering the biotic community.

Erosion is a concern at VICK, where surface soils consist of highly erodible loess soil.

2.7.2. Agents of change and stressors

Although upland systems vary across the network, agents of change and stressors are relatively consistent across most examples of these systems in network parks. Major agents of change acting on these ecosystems include both the common suite of natural disturbances and drivers and the diverse anthropogenic forces resulting from major human development shown in Table 2.7.

Table 2.7. Major agents of change and stressors for uplands ecosystems.

Category	Stressor
Natural forces and processes	• Climate patterns and effects • Major natural geomorphic and hydrologic patterns and processes
Acute events and disasters	• Extreme coastal storms and hurricanes that broadly impact the entire Gulf Coast region
Anthropogenic actions and activities	• Extensive urbanization and development on lands directly adjacent to parks • Extensive historical and current petroleum extraction activities • Management activities involving vegetation, park viewscape, and cultural resource management

Storm events and fuel spills pose additional threats to park ecosystem integrity. The impacts of coastal storms extend far inland and have large-scale impacts on forest vegetation, including stand condition, tree-fall damage, and increased major-bole fuel loads. Park cultural resources and management infrastructure can also be impacted. Agents of change result in several categories of stressors on upland systems in the GULN, including fire-regime modification, southern pine beetle invasions, previous land-use impacts, erosion, non-native/invasive species, urbanization, agricultural development, and oil and gas exploration and extraction—all of which impact ecosystems in ways that alter system function and impair system environments and biological structure and integrity (Figure 2.9).

2.7.3. Potential measures and indicators

Potential measures and indicators (vital signs) for upland systems include

- measures of terrestrial plant and animal species diversity, population abundance, structure, and distribution;
- zonal ecological succession (shifts in aerial coverage, distribution, structure, and composition of key plant communities over time);
- forest-pest outbreaks and forest health or condition indicators;
- quantity and quality of running and groundwater resources;
- geomorphic dimension and properties; and
- changes in adjacent land use.

Protocols relevant to upland ecosystems are shown in Table 2.8.

Table 2.8. Protocols relevant to upland ecosystems.

Relevant protocols	Goal(s)
Freshwater	To provide chemical and physical parameter assessment of freshwater resources in upland systems.
Vegetation Structure and Composition	To detect and track a variety of vegetation structural and distributional parameters at parkwide and landscape levels, to address a range of park-specific vegetation questions in each sampled park, including • distribution, health, and coverage of key vegetation communities; • changes in park vegetation characteristics, community and vegetation succession, and some invasive species. To assess of geomorphic structure in sampled parks.
Amphibian Communities	To assess and track amphibian assemblages, including measures of community structure and diversity, occupancy, reproductive success, and taxon distribution within parks.
Adjacent Land-use Change	To provide ongoing assessment of specific and general types of human development occurring in nearby adjacent lands.

Future protocol development may include

- monitoring of benthic macroinvertebrates (in conjunction with freshwater monitoring),
- support for targeted plant species monitoring and monitoring of park bird communities, and
- future development of ozone impact assessment.

See Chapter 4 on Sampling design, and Protocol Development Summaries in Chapter 5 for monitoring questions, objectives, and possible measures being developed for monitoring protocols.

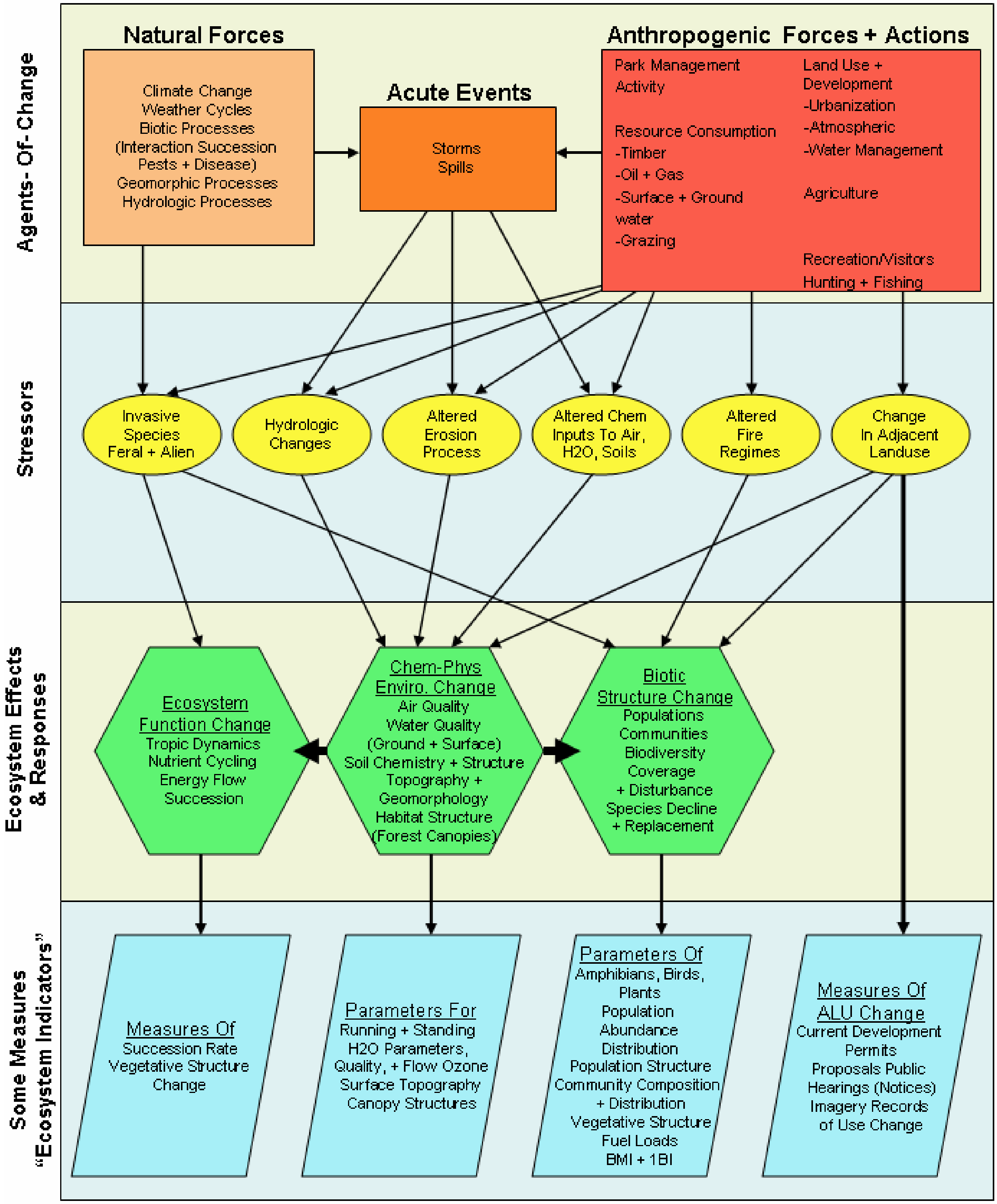

Figure 2.9. The Gulf Coast Network Upland Ecosystems conceptual model.

2.8. Conclusion and Park-Specific Conceptual Diagrams

Conceptual models are iterative. Although they should be based on fundamental and enduring principles of ecology, they should also be sufficiently flexible to allow refinement as the results of monitoring or other empirical or theoretical advances improve our understanding of the elements and processes of park ecosystems. In the development of these conceptual models, our primary goals were to illustrate some major influences (i.e., disturbances) on park ecosystems, identify important ecosystem functional links and processes, facilitate communication between the monitoring program and its parks, and identify potential vital signs for monitoring. We anticipate modifications to our conceptual models once vital signs monitoring begins and our understanding of system dynamics increases.

In addition to the ecosystem-based models presented in this chapter, we created conceptual diagrams for each individual GULN park (Appendix K). The goal of these diagrams is to illustrate and communicate our current understanding of the ecological setting and major sources of disturbance for each park. These diagrams are being developed for parks to illustrate how park resources relate to a variety of challenges from off-park events and activities. They are intended to be dynamic and easily changed to help communicate the role of monitoring in park management and meet the needs of a variety of audiences. One common theme that emerged from the conceptual modeling effort was that GULN parks are highly disturbed systems. Although the focus tends to be on the current level of human disturbance, these systems have historically been subjected to major disturbances such as fires and severe weather events. These diagrams combine the system-specific ecological models with park-specific management goals and concerns, with a focus on sources of stress and/or disturbance to the natural system.

Chapter 3
Vital Signs

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" (http://science.nature.nps.gov/im/monitor). 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, animals, and the various ecological, biological, and physical processes that act on those resources. This chapter describes the vital signs for the Gulf Coast Network and the process used to select and prioritize those vital signs.

The GULN has identified 42 vital signs that represent a systems approach to our monitoring program. The network developed this list through a process of meetings and ranking exercises to produce a list of 19 vital signs we plan to implement or develop protocols for in the next three-to-five years.

3.1. Process for Choosing Vital Signs

The process for choosing and prioritizing vital signs began with a Board of Directors meeting in October 2002, and concluded in April 2005, with an STAC meeting where the final list of 42 vital signs was prioritized. The process consisted of a series of scoping workshops, STAC meetings, and the use of prioritization ranking criteria. During this process, the list of potential vital signs was developed in conjunction with the network conceptual models. Table 3.1 summarizes the major steps in the GULN process of selecting vital signs.

Table 3.1. Summary of the process used in the Gulf Coast Network to choose and prioritize vital signs.

Date	Event	Vital signs milestone	Product
October 2002	GULN combined Board of Directors/Scientific/Technical Advisory Committee meeting	Begin compilation of network and park-specific issues of management concern for the purpose of developing background information.	See Table 1, Appendix L
October 2002–February 2003	Natural resource (NR) specialists for each park fill out table of issues of management concern	First-draft table of issues of concern as identified by the NR specialists.	See Table 2, Appendix L
February–October 2003	Scoping meetings at each GULN park	New issues included in larger table of park-specific issues.	See Table 2, Appendix L

Date	Event	Vital signs milestone	Product
October 2003	Scientific/Technical Advisory Committee meeting	NR specialists review, as a group, the compilation of issues of concern for accuracy and across network relevancy.	See Table 3, Appendix L
April 2004	Conceptual modeling workshop	Table of NR issues used to frame the discussion of stressors and ecosystem responses for the conceptual ecological models.	See Chapter 2 of this report
August 2004	Scientific/Technical Advisory Committee meeting	List of potential vital signs created based on the results of conceptual modeling scoping meeting and table of park issues. Initial narrowing to final list of vital signs.	See Table 4, Appendix L
August–November 2004	Parks score vital signs individually according to the ranking criteria	Database of park-specific prioritization of potential vital signs created.	See Table 5, Appendix L
November 2004	Scientific/Technical Advisory Committee meeting	Group scoring of the potential vital signs, with network, not park-specific, emphasis.	See Table 5, Appendix L
April 2005	Scientific/Technical Advisory Committee meeting	"Park-specific" and "network" rankings reconciled to finalize vital sign prioritization.	Current vital sign list (Table 3.2)
Spring 2006	Individual park-level visits with NR staff and superintendents, when available	Final meeting with parks to confirm vital sign list and relevance of proposed data to park-level management needs.	Table 3.2 and identification of specific protocols (Chapter 5)

To initiate the discussion of vital signs, the park natural resource specialists were asked to fill out a table with both network-wide and park-specific issues of management concern. This discussion began at a combined Board of Directors and STAC meeting. Following this meeting, GULN staff traveled to each network park to continue this scoping process. Any issues that had not already been identified were then included in the master table of natural resource issues (Appendix L). Upon completion of the individual park scoping meetings, the STAC reconvened to review the compilation of issues of concern for accuracy and across-network relevancy.

The next stage of vital signs development was the conceptual modeling workshop, where experts in Gulf Coast ecosystems and park staff came together to assist in the development of the GULN conceptual models (See Chapter 2). The table of natural resources issues that had been compiled earlier was presented to all the workshop participants, and helped to frame the discussion of the network conceptual models. Following this meeting, a vital signs workshop was held in August 2004, at Vicksburg National Military Park, to generate a list of potential vital signs for the network. This list was derived from a combination of (1) issues previously identified by the park natural resource specialists, (2) issues discussed at the conceptual modeling workshop, and (3) a list of vital signs being used by other networks in the NPS I&M program. A database developed by the Washington Area Service Office (WASO; National_vs_Summary.mdb) was modified and used to develop a list of potential vital signs and to document justifications for selection, along with likely measures. After two days of constructive discussion, the STAC agreed on a list of 42 potential vital signs, as well as justifications and measures for each (Appendix L).

The first step in prioritizing those 42 vital signs was to apply the vital signs ranking criteria recommended by WASO. Those criteria are based on a weighted score of “management significance,” “ecological significance,” and “legal mandate,” with a suggested weighting of 40%, 40%, and 20%, respectively (Appendix L). During round one, each park independently scored the vital signs according to those ranking criteria. The scores were compiled into a database (GULN_VS_Park_Prioritizer.mdb), creating a “combined score” for the network based on individual park responses. In November 2004, the STAC convened for round two and decided to score each vital sign as a group using the same criteria, creating a group consensus referred to as “GULN score.” At this meeting, the STAC visualized all the GULN parks as separate units of one larger park. This fostered valuable discussions concerning the importance of the wide range of habitats found in the network. In this way, upland and coastal parks, for example, were able to acknowledge the mutual importance of their various issues from the perspective of the network and in the context of the larger Gulf Coast ecosystems. These discussions, and the good working relationship among the network parks, contributed greatly toward the network-wide approach to protocol development that the network has taken.

In April 2005, the STAC met again to review and discuss the results of the two different methods of applying the ranking criteria to the vital signs. During this meeting, the results of both rounds of prioritization were presented to the group in the form of spreadsheets showing the rankings of the vital signs as both “combined score” and “GULN score.” The results were also shown for different weighting of the criteria to show more clearly how each vital sign ranked in terms of management significance, ecological significance, and legal mandate. The spreadsheets were color-coded to show how the vital signs ranked out in quartiles (top ¼, second ¼, third ¼, and bottom ¼) using each approach. At the meeting, the group decided to add the ranked scores from the combined approach and the GULN approach to give a new ranked score combining the two techniques. The resulting spreadsheet is what guided the final discussion and prioritization of the vital signs (Appendix L, Table 7).

Participants discussed the idea of eliminating the legal mandate criterion, focusing instead on prioritizing the vital signs based only on ecological and management significance. The assumption was that if there were an actual legal mandate to monitor a certain taxon (such as an endangered species), that monitoring was probably already underway. However, after reviewing the spreadsheets (Appendix L, Table 6), the group consensus was to use the recommended 40/40/20 weighting of the ranking criteria, because the legal mandate criterion included legal issues, such as GPRA goals, whose mandate did not clearly require monitoring. Several of the vital signs ranked highly no matter how the criteria were weighted: Coastal Dynamics, Water Quality Issues, Non-native Plants and Animals, Marine and Estuarine Submerged Aquatic Vegetation, Migratory and Resident Birds, Terrestrial Vegetation, and Land Use/Land Cover. These high-priority vital signs corresponded directly with the major network-wide issues identified in the conceptual modeling workshop.

Several important considerations allowed the group to move forward with agreement on a prioritized list of vital signs:

- Although the group acknowledged that there would likely not be sufficient funding to develop lower-ranked vital signs, these vital signs were kept on the list in recognition of their continuing importance for the network. Initial program development over the next five years will focus on the 19 higher-ranked vital signs. Other vital signs will be addressed as opportunities and resources allow.

- Some vital signs will be combined into single protocols for the sake of efficiency. It is possible that a lower-ranked vital sign may be monitored if it can be combined into a protocol with a higher-ranked vital sign. An example is our approach to monitoring a combined suite of major multiple-park vegetation vital signs—including terrestrial, riparian, and salt marsh communities and forest health—using a single, network-wide Vegetation Structure and Composition monitoring protocol (see Chapter 5 and Protocol Development Summaries for further discussion). In addition to addressing these vital signs, this protocol may yield data for several other vital signs, including Fire and Fuel Dynamics, Coastal Dynamics, Non-native Vegetation, and Visitor Usage.

- Some highly ranked vital signs may not be monitored if the cost is too high, or if an existing monitoring program is already in place. In such cases, the role of the network will be to provide data management support. For example, migratory birds are both a high-priority vital sign and a focal resource of park and public interest for several network parks. Monitoring of birds is, however, cost-prohibitive for effective quantitative monitoring as a network vital sign. Consequently, the GULN will provide data management support and a suggested common sampling design and methodology to all network parks that wish to develop in-park monitoring efforts through local experts and volunteers.

- Individual water quality-related vital signs were removed from the prioritization process on the assumption that water quality in general is a high priority for the network. An overriding theme in the conceptual modeling workshop was that water is one of the main resources that impacts each network park in some way. The GULN has developed a split-plan approach to water resource monitoring, in which freshwater and estuarine/marine waters will be monitored using two separate protocols under control of the network's water quality monitoring program. Freshwater monitoring will follow the model previously developed for these resource types by other networks, such as the Cumberland Piedmont Network (CUPN). Estuarine and marine monitoring will be performed using a protocol adopted from the Southeast Coast Network (SECN) and the Northeast Coast and Barrier Network (NCBN), which are based on other existing estuarine monitoring protocols from the National Oceanic and Atmospheric Administration (NOAA)'s National Estuarine Research Reserves and the EPA. See Chapter 4 for sampling design discussion, and Chapter 5 for protocol discussion and Protocol Development Summaries.

- Weather and Climate came out low in the rankings, largely because it has low management significance (parks have no ability to change it) and there is no legal mandate to monitor weather and climate. However, the group agreed to move weather and climate into the top tier of vital signs because it is important to all ecological processes in the parks; should be relatively inexpensive to monitor (due to existing stations and a national Memorandum of Understanding between the NPS and the National Weather Service); and will provide important ancillary data for all other vital signs.

- Ozone was not determined to be a high-priority issue to the network, based on risk assessments conducted by the NPS Air Resources Division. However, the GULN will support limited air quality monitoring by utilizing its POMS and acquiring data from other monitoring programs. The network's primary role will be data management.

After much discussion, the group agreed to select any vital sign that was in the top quartile of either the combined or the GULN list to be on the list of highest-priority vital signs for the network as a whole. Nineteen vital signs were selected for protocol development after the individual park visits. These will be the vital signs the network begins to develop, keeping the above considerations in mind. The lowest-ranked vital signs were those in the bottom quartile in either the combined or the GULN columns.

3.2. Vital Signs for the Gulf Coast Network

The prioritized list of vital signs for the GULN is presented in Table 3.2. Vital signs are presented within the Ecological Monitoring Framework developed by the national vital signs monitoring program. Each vital sign is included in one of three prioritized groups: highest priority, medium priority, and lowest priority for the network as a whole. Table 3.2 also indicates which vital signs we anticipate developing over the next three-to-five years, shown by funding category. Category 1 (✚) vital signs are those for which the network is expected to develop protocols and implement monitoring using funding from the vital signs or water quality monitoring programs, including those for which the network will augment existing protocols. Category 2 (•) vital signs are those currently being monitored by an individual park using park base funds or some other funding source. Category 3 (◊) vital signs are those for which monitoring may be conducted in the future, but which can not currently be implemented due to lack of staffing or funding. The GULN's 19 high-priority vital signs, not ranked in any way, are:

1. Weather/Climate
2. Coastal Dynamics
3. Water Chemistry
4. Water Nutrients
5. Water Toxics
6. Non-native Vegetation
7. Non-native Animals
8. Salt Marsh Plant Communities
9. Riparian Communities
10. Marine and Estuarine Submerged Aquatic Vegetation
11. Forest Health
12. Amphibians
13. Migratory Birds
14. Resident Birds
15. Terrestrial Vegetation
16. Threatened and Endangered/Rare Small mammals
17. Threatened and Endangered/Rare Plants
18. Fire and Fuel Dynamics
19. Land Cover/Land Use

Table 3.2. Prioritized list of vital signs for the Gulf Coast Network.

Blue = highest priority; Green = medium priority; Yellow = lowest priority. Symbols associated with the monitoring categories are described below.

I&M Ecological Monitoring Framework											
Level 1 Category	**Level 2 Category**	**Level 3 Category**	**Network vital sign**	**BITH**	**GUIS**	**JELA**	**NATR**	**PAAL**	**PAIS**	**SAAN**	**VICK**
Air and Climate	Air Quality	Ozone	Ozone	•	•	•	•	•	•	•	•
		Air Contaminants	Air Contaminants	•	•	•	•	•	•	•	•
	Weather and Climate	Weather and Climate	Weather/Climate	•	+	•	•	•	+	•	•
Geology and Soils	Geomorphology	Coastal/Oceanographic Features and Processes	Coastal Dynamics		+				+		
			Subsidence/Relative Sea Level Rise		•	•			•		
		Stream/River Channel Characteristics	Stream/River Channel Dynamics and Geomorphology	--						--	--
	Soil Quality	Soil Function and Dynamics	Erosion and Deposition	--		•		--		--	•
			Soil Biota	--	--	--	--	--	--	--	--
			Soil Chemistry	--	--	--		--	--	--	
			Soil Compaction		--				--		
			Soil Structure and Stability	--	--	--	--	--	--	--	--
Water	Hydrology	Groundwater Dynamics	Groundwater Hydrology	--	--	--		--	--	--	--
	Water Quality	Water Chemistry	Water Chemistry	+	+	+	+	+	+	+	+
		Nutrient Dynamics	Water Nutrients	+	+	+	+	+	+	+	+
		Toxics	Water Toxics	+	+	•	•	•	+	•	•

I&M Ecological Monitoring Framework											
Level 1 Category	**Level 2 Category**	**Level 3 Category**	**Network vital sign**	**BITH**	**GUIS**	**JELA**	**NATR**	**PAAL**	**PAIS**	**SAAN**	**VICK**
Biological Integrity	Invasive Species	Invasive/Exotic Plants	Non-native Vegetation	+	+	+	+	+	+	+	+
		Invasive/Exotic Animals	Non-native Animals	◊	◊	•	◊	◊	◊	◊	◊
	Focal Species or Communities	Wetland Communities	Salt Marsh Plant Communities		+						
			Freshwater Wetland Communities	+	+	+	+	+	+		+
		Riparian Communities	Riparian Communities	+		+	+	+		+	+
		Estuarine Communities	Marine and Estuarine Submerged Aquatic Vegetation		+	•			+		
		Forest/Woodland Communities	Forest Health	+	+	+	+	+	+	+	+
		Marine Invertebrates	Marine Invertebrates		--				--		
		Freshwater invertebrates	Freshwater Invertebrates	--			•	--		--	•
		Terrestrial Invertebrates	Terrestrial Invertebrates	--	--	•	•	--	--	--	--
		Fishes	Freshwater Fish Communities	◊	◊	•	•			◊	•
			Marine and Estuarine Fish		•	•			•		
		Amphibians and Reptiles	Amphibians	+	+	+	+	+	+	+	+
			Non T&E Reptiles	--	--	--	--	--	--	--	--
		Birds	Migratory Birds	+	+	+	+	+	+	+	+
			Resident Birds	+	+	+	+	+	+	+	+
		Mammals	Non T&E Small Mammals	--	--	--	--	--	--	--	--

I&M Ecological Monitoring Framework			Network vital sign	BITH	GUIS	JELA	NATR	PAAL	PAIS	SAAN	VICK
Level 1 Category	**Level 2 Category**	**Level 3 Category**									
Biological Integrity	Focal Species or Communities	Terrestrial Communities	Terrestrial Vegetation	✚	✚	✚	✚	✚	✚	✚	✚
	At-risk Biota	T&E Species and Communities	T&E/Rare Birds	◊	◊	◊	◊	◊	◊	◊	◊
			T&E/Rare Small mammals		•		•				
			T&E/Rare Freshwater Fish	◊	◊		◊			◊	
			T&E/Rare Plants	•	◊		◊		◊	◊	◊
			T&E/Rare Reptiles	--	•		--	--	•	--	--
Human use	Visitor and Recreation Use	Visitor Usage	Visitor Usage	--	--	--	--	--	--	--	--
Landscapes (Ecosystem Pattern and Processes)	Fire and Fuel Dynamics	Fire and Fuel Dynamics	Fire and Fuel Dynamics	✚	✚	✚	✚	✚	✚	✚	✚
	Landscape Dynamics	Land Cover and Use	Land Cover/Land Use	✚	✚	✚	✚	✚	✚	✚	✚
	Soundscape	Soundscape	Soundscape	--	--	--		--	--	--	--

✚ Category 1: Vital signs for which the network will develop protocols and implement monitoring using funding from the vital signs or water quality monitoring programs.

• Category 2: Vital signs that are monitored by a network park, another NPS program, or by another federal or state agency using other funding. The network will collaborate with these other monitoring efforts.

◊ Category 3: High-priority vital signs for which monitoring will likely be done in the future, but which cannot currently be implemented because of limited staff and funding.

-- Vital sign for which there are no foreseeable plans to conduct monitoring.

Blank indicates that vital sign does not apply to park.

3.3. Relationships of Vital Signs to Monitoring Objectives and Conceptual Models

Disturbance, both natural and anthropogenic, is the overall theme of the GULN conceptual models. Consequently, the network selected stressor/response type models as the conceptual framework for selecting and prioritizing vital signs. The selected vital signs typically link directly either to one of the stressors identified in the models or to the ecosystem effects of those stressors. The monitoring objectives also reflect the focus of the network on internal and external stressors to the ecosystems in network parks. The monitoring objectives for the 19 highest-priority vital signs (indicated in blue in Table 3.2), and their links to the conceptual models, are presented in Table 3.3.

Table 3.3. Relationship of Gulf Coast Network vital signs to monitoring objectives and conceptual models.

Vital sign	Monitoring objective	Link to conceptual models
Weather/Climate	Understand the natural range and variation in weather patterns and climate trends across the GULN parks. Establish baseline conditions for all other vital signs.	Agent of Change: Weather and climate impact all ecosystem effects and potential vital signs.
Coastal Dynamics	Establish a current baseline condition and document changes in coastal barrier-island morphology, both gradual and storm-induced.	Ecosystem Effect: Measures the impacts of coastal geologic processes and extreme weather events on barrier-island morphology.
Water Chemistry Water Nutrients Water Toxics	Establish a baseline and document long-term changes in core water quality parameters and selected specific analytes on GULN parks.	Ecosystem Effect: Changes in water quality in GULN parks are linked to hydrologic manipulations, industrial contaminants from sources outside park boundaries, and resource extraction.
Non-native Vegetation	Document impacts on native vegetative communities, especially structural changes associated with habitat change.	Stressor: Non-native species were identified as a major stressor in every network park. Impacts species diversity, structure, and function of vegetative communities.
Non-native Animals	Document impacts on native plant and animal communities in conjunction with other vegetation monitoring.	Stressor: Non-native species were identified as a major stressor in every network park. Impacts species diversity and community structure and function.
Salt Marsh Plant Communities	Determine current extent and community composition/structure, and monitor changes over time.	Ecosystem Effect: May be impacted by multiple model stressors.
Riparian Communities	Determine current extent and community composition/structure and monitor changes over time.	Ecosystem Effect: May be impacted by multiple model stressors.
Marine and Estuarine Submerged Aquatic Vegetation	Determine current extent and community composition/structure and monitor changes over time.	Ecosystem Effect: May be impacted by multiple model stressors.

Vital sign	Monitoring objective	Link to conceptual models
Forest Health	Document trends in aspects of forest health as a component in GULN vegetation monitoring: pest infestation and disease impact on canopy structure.	Ecosystem Effect: May be impacted by multiple model stressors.
Amphibians	Document trends in species diversity, occupancy, reproductive success, and relative abundance in GULN parks.	Ecosystem Effect: May be impacted by multiple model stressors.
Migratory Birds	Document trends in species diversity and relative abundance in GULN parks (monitored by individual parks with network assistance).	Ecosystem Effect: May be impacted by multiple model stressors.
Resident Birds	Document trends in species diversity and relative abundance in GULN parks (monitored by individual parks with network assistance).	Ecosystem Effect: May be impacted by multiple model stressors.
Terrestrial Vegetation	Document trends in extent and community composition/structure.	Ecosystem Effect: May be impacted by multiple model stressors.
T&E/Rare Small Mammals	Document trends in extent and population estimates (no development of monitoring is anticipated for this vital sign during the first three-year protocol development period).	Ecosystem Effect: May be impacted by multiple model stressors.
T&E/Rare Plants	Document trends in extent and population estimates (monitoring efforts will be developed by individual parks with network assistance).	Ecosystem Effect: May be impacted by multiple model stressors.
Fire and Fuel Dynamics	Document trends in plant community structure and ground fuel loading in conjunction with network vegetation monitoring.	Ecosystem Effect: Linked to hydrologic manipulations, non-native species invasions, park management, fire-regime alterations, and landscape dynamics.
Land Cover/Land Use	Document changes in development, land conversion, and succession both inside and outside park boundaries.	Stressor: This is a primary stressor of GULN parks. Due to their small size, most are highly impacted by outside influences.

Chapter 4
Sampling Design

This chapter outlines the general sampling designs and approaches we will use for monitoring vital signs in GULN parks. The sampling design describes how spatial locations are chosen for sampling, and how sampling effort will be rotated among those spatial locations. The purpose of a sampling design is to ensure that data collected in a sampling effort are representative of the population in question and in sufficient amount to enable defensible conclusions about aspects of that population.

4.1. Introduction

The primary objective of the GULN monitoring program is to provide high-quality, reliable information to park managers. Sound sampling design is fundamental to our success, as it ensures data quality and, thereby, the quality of monitoring information we can deliver to GULN parks. Sampling design ensures data quality by providing the formal framework for spatially and temporally distributing and allocating typically limited sampling resources to accomplish effective and statistically robust resource monitoring in an efficient manner. Sound designs leading to effective resource monitoring help ensure the scientific merit of our monitoring program.

Several factors will guide and affect our sampling-design development:

- ***One size does NOT fit all.*** No single sampling design will adequately address or support all vital signs monitoring. The GULN program will emphasize broadly applicable sampling concepts and principles, such as probabilistic sampling to ensure ability for statistical inference, in all of its sampling-design development. Development of specific sampling designs tailored to a vital sign and its data requirements will be a critical early step in each protocol development project the network undertakes.

- ***"Do a few things well"*** describes our network philosophy. The GULN program will focus on a relatively small number of high-priority vital signs (see Chapter 3), allowing us to focus more effort on each to better ensure that quality information is obtained for park managers.

- ***Try to do it right the first time.*** We stress *a priori* development of high-quality sampling design as a key component of all protocol projects. We subscribe to the concept that putting more effort and attention into initial development and evaluation of those designs will result in better monitoring protocols and provide higher-quality information over the long term. Sampling-design development will involve appropriate subject-matter experts and statisticians, and all designs will be carefully reviewed to ensure statistical robustness and performance prior to implementation.

- ***The GULN is a large network.*** We recognize that logistics will affect our ability to effectively monitor vital signs across eight widespread parks. We emphasize careful logistical planning across the scope of the program. Development of effective sampling rotation, revisit schedules, and panel designs are key components of our protocol development efforts.

- ***Location, location, location.*** Our overall sampling designs stress the use of geospatial location in all monitoring efforts to facilitate articulation and combination of data among monitoring projects. Geospatial and temporal components in sampling and analysis will support effective multi-parametric, multiple-protocol ecosystem monitoring, facilitate articulation of monitoring information with other park data through GIS, and provide the basis for development of integrated predictive models for park ecosystems.

- ***Strive to get more "bang for the buck."*** The GULN program places strong emphasis on developing efficiency in monitoring through extensive co-location and co-visitation in sampling across multiple protocols and vital signs. Wherever possible, we will combine sampling for multiple protocols in each site visit, and sampling for multiple protocols at the same locations, even when sampling and subsequent analysis are following different designs. We utilize a two-part approach to maximize cost-efficiency: (1) whenever possible, we are developing single protocols with common sampling design and methodology across all parks to address each vital sign, and (2) we will maximize collection of data for multiple vital signs with one protocol. Using common designs among multiple parks and multiple datasets under one protocol will save on development, staff training, and implementation costs while increasing our program's scientific merit by ensuring comparable and consistent data at a variety of spatial and temporal scales. This approach is exemplified in our development of a protocol that will simultaneously collect large, detailed datasets for multiple vital signs in terrestrial systems at the parkwide level (see description of LiDAR-based sampling in Section 4.3.1).

- ***Cost matters.*** We will take cost into consideration in our sampling-design development by adjusting and refining sample size, revisit schedules and panel designs, and detection power. (See discussion in following section.)

- ***Do not reinvent the wheel.*** Wherever and whenever possible, we will use, and modify if needed, existing monitoring protocols and standard operating procedures (SOPs). This applies to protocols developed by other NPS I&M networks as well as monitoring programs developed by other federal or state agencies, organizations, or academia. Our protocols and sampling designs will incorporate, wherever possible, sampling structures and methods comparable to those used in other projects and programs.

The GULN monitoring program is primarily geared toward assessing status and trends of vital signs at the park level. Secondarily, the program will support limited effectiveness monitoring of park management projects, and will provide flexibility to adaptively address changes in focus and scope of monitoring across network parks. While there is no *a priori* intent to make statistical inference across the entire network for most vital signs, our approach is strongly geared toward providing consistent and comparable design, methodology, and intensity of sampling effort on every park for each vital sign. By so doing, we support effective between-park comparability and gain the potential to combine data among parks to support larger-scale analysis and assessment of ecosystem trends.

Technical sampling designs—specific to the questions, populations, and circumstances being addressed—support development of sample analysis approaches and models and, thus, ultimately affect the reliability and quality of the results and interpretation that will be reported. As we are in the early phases of developing most of our monitoring protocols (see Chapter 5), specific sampling designs are still largely conceptual and tentative. Once complete, each protocol will include a detailed sampling design, together with appropriate definitions and rationale, as part of its formal documentation. Currently proposed design ideas and approaches are available, in part, in the Protocol Development Summaries discussed in Chapter 5.

4.2. Concepts and Definitions

Discussion of GULN sampling designs involves a few underlying concepts and specific statistical terms. This section describes these concepts, provides some brief definitions, and describes some rotation, panel, and membership designs we plan to use.

4.2.1. Ecological monitoring and approaches to monitoring

Our protocols will be for long-term **ecological monitoring**, which may be described as "the measurement of environmental characteristics over an extended period of time to determine the status or trends of some aspect of environmental quality" (Suter 1993). Monitoring may also be usefully defined as the collection and analysis of repeated observations over time to document status and trends in ecological parameters. In general, monitoring is designed to provide unbiased, quantitative, and statistical estimates of status and trends. In contrast to cause-and-effect studies (focused research that tests specific, well-defined hypotheses within the context of carefully controlled experiments), monitoring focuses on collecting objective, scientifically defensible data to address wide-ranging and sometimes vaguely defined hypotheses in less controlled and more complex natural systems. Long-term monitoring may document correlation between management actions or natural events and system changes and patterns in ecological parameters. Monitoring can provide a complex, multi-parametric view of ecosystem changes over time. We should, however, not expect monitoring to provide clear statistical cause-and-effect relationships between external changes (drivers) and the status and trends of sampled ecological parameters. The important utility of ecological monitoring lies in its ability to detect changes in parameter status, provide parks with reliable information about status of their resources, and serve as an early warning system that can effectively alert parks to changes in resource conditions and support effective resource management decisions.

The GULN program will use **design-based approaches** in its initial development of monitoring. Such approaches emphasize objectivity and do not rely on detailed (but often unstated and not well-understood) assumptions about the structure and nature of parameters and responses being measured. Rather, design-based approaches rely upon rigorous, probability-based samples in developing estimates and extrapolating results to non-sampled units (McDonald 2003). Design-based analyses do not make many detailed assumptions about responses, but instead use mechanistic and procedural sampling methodology as the basis for replication and subsequent probability statements on estimates (confidence intervals). As only general and limited assumptions are made about responses, design-based analyses are extremely difficult to challenge (McDonald 2003); a property that makes these approaches well-suited for projects that could involve litigation or controversial public decisions.

It should be noted that design-based approaches are poorly suited for future prediction, and are descriptive in nature. Predictions of future system states call for **model-based approaches**, which require detailed functional information about the system and often employ a number of simplifying assumptions (see Olsen et al. 1999). The use of design-based analyses will thus be most appropriate during earlier phases of the monitoring program, as detailed information about system function is often not available. We anticipate that as our program progresses and data accumulate, development of model-based approaches will become feasible, and we will be able to effectively shift from descriptive to more explanatory and predictive modes.

The GULN program will emphasize the use of **probability-based sampling** wherever possible. Probability-based sampling uses some form of randomization, ensuring a reduction in the potential bias that occurs from **judgment** (selection of sample units based on expert knowledge) or **haphazard** (convenience-based selection of sampling units) sampling. Randomization increases the validity of extending inference from the sample out to the population of interest. Design-based analyses require use of probability-based sampling to provide unbiased estimators about population properties. Probability-based sampling will always be required for a monitoring plan or design to be defensible and statistically valid (McDonald and Geissler 2004).

4.2.2. Sampling concepts and terms

Our monitoring designs will rely on concepts of finite population sampling. In **finite population sampling**, the area or sample space for which inference is desired (e.g., a park) is generally viewed as a finite collection of sample units, which are the smallest entities upon which measurements are taken within a target population. A **population** consists of the entire collection of units, individuals, or elements for which inference is intended. Many sampling designs may divide or partition the total population into multiple subpopulations. A **subpopulation** is any subset of units that may be of particular interest, and may be denoted or bounded by use of strata in a sampling design. **Strata** refer to sample frames of subpopulations that are separated, identified, and defined prior to drawing a sample, such as by some geographical or other accepted criterion. It is assumed that strata are defined by criteria distinct from both the specific and general properties being measured in sampling. For example, a plant population may be reasonably stratified by elevation or soils types that form gradients or divisions across the area in which the plants are being sampled. Plant properties, such as height or separation distance, would not be valid stratification criteria in this case. **Stratification** is a fixed scheme for allocating effort within a sampling design, such as by distributing sampling sites among three areas defined by elevation.

A **sample** is a drawn subset of the available sample units and their contained elements located within the sampled population, subpopulation, or stratum sample frame. The **sample frame** is that area or defined subpopulation actually included within the sampling effort. For example, individual fish may be sample units to estimate average body size of fish in a pond. If fish are to be collected from anywhere within the pond, the entire pond would be the sample frame. The pond could also be a sample unit if, for instance, one were estimating the proportion of pond fish that are exotics in all ponds across a park. **Elements** are individual items that are counted or measured, such as individual fish in the pond (regardless of whether the fish or the pond is the designated sample unit). **Responses** are the measured values or quantifications being recorded or collected for elements and units during sampling (e.g., body lengths, pH values).

4.2.3. Sampling panels and revisit schedules (designs)

Monitoring in GULN parks may involve, in some cases, the use of “panels” to spatially and/or temporally allocate sampling effort as a way to more effectively use limited monitoring resources. A **panel** is a set of sampling units that will always be sampled during a single sampling occasion or period of time. Panels may consist of subsets of all the used sampling sites within a park, or some few parks within a larger group of parks; in either case, panel members would be sampled together. **Panel membership** is defined and fixed by a **membership design**, which defines or sets out how sample units are either included or excluded from being in any given panel (a unit may be a member of multiple panels, if so specified in the membership design). Once panels have been defined, a **revisit plan** is created to define how sampling effort will rotate or be distributed among the available panels over time (see McDonald 2003). Revisit plans may include both “rotating panel” and “split-panel” designs. A **rotating design** might consist of two 3-site panels in a river, with panels alternating in a sampling sequence over years. A **split-panel design** could consist of a four-site panel scheduled for sampling every year, along with another four-site panel scheduled for sampling every third year (thus resulting in different temporal density or intensity of sampling). Sampling panels and revisit schedules will be developed for each protocol, with careful consideration given to both statistical and data needs as well as the limitations imposed on monitoring by logistical concerns such as sampling staff availability, inter-site movement, and possible co-visitation opportunities. A schematic representation of several possible revisit designs appears in Table 4.1.

Table 4.1. Some possible revisit designs.

	Sample occasion							
Panel	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Design [1-0]								
1	X	X	X	X	X	X	X	X
Design [1-n]								
1	X							
2		X						
3			X					
4				X				
5					X			
6						X		
7							X	
8								X
Design [2-n]								
1	X							
2	X	X						
3		X	X					
4			X	X				
5				X	X			
6					X	X		
7						X	X	
8							X	X
Design [2-3]								
1	X	X				X	X	
2		X	X				X	X
3			X	X				X
4				X	X			
5	X				X	X		
Design [1-0,2-3]								
1	X	X	X	X	X	X	X	X
2	X	X				X	X	
3		X	X				X	X
4			X	X				X
5				X	X			
6	X				X	X		

The design notation ([n-n]) follows that proposed by McDonald (2003) and used by many NPS monitoring networks. The first digit represents the number of consecutive occasions that a panel will be sampled; the second digit represents the number of occasions it is not sampled before repeating the sequence. For example, if a single panel is visited on all occasions, its design would [1-0].

4.2.4. Spatial distribution of sampling sites

The GULN program will address a wide range of vital signs and ecological parameters in multiple ecosystems at multiple scales. Our protocols may use any of several major sampling themes to determine location and distribution of sampling sites and effort. The general sampling themes include simple and stratified random sampling, systematic sampling, cluster sampling, and in some cases, total census and targeted approaches. In **simple random sampling,** *n* units are probabilistically selected from a population of size N using a random process, such that every unit has an essentially equal probability of being chosen. A **stratified random sample** (stratified sample) is one in which the sampling frame has been partitioned into mutually exclusive subpopulations (strata), with *n* units being drawn from each stratum. Stratification can be used to increase either or both sampling efficiency and precision in information yielded. Both stratification and "blocking" in sampling designs are approaches to partitioning a sampled population, and are analytically similar. A **systematic sample** is one in which sampling units are collected, counted, or measured in some regular or systematic pattern (spacing), such as on a grid or at fixed intervals along a transect. Generally, systematic sampling involves some degree of randomization of the initial sampling point, followed by fixing or assigning a regularly spaced grid of sampling points relative to that initial point. Systematic grid sampling typically uses a temporally and spatially fixed, permanent grid of locations, such as marked points on a map.

In specific cases, GULN monitoring protocols will involve use of a virtual systematic grid—a temporary sampling grid generated by the sampling technology and method being used. This virtual grid is spatially implicit and covers the same area with the same sampling intensity and spacing, but not exactly the same point location, in each separate sampling event. This sampling grid is virtual because it is not fixed and marked on the map of the sampled area prior to sampling, but rather is generated during the sampling process and appears only in the collected location dataset generated after sampling is complete (see the discussion of LiDAR-based sampling for monitoring of vegetation structure and composition and coastal geomorphology and landforms in the following sections for description of virtual systematic grids and their generation). **Cluster sampling** is a grouping method in which a localized set of units is sampled within a larger sampling frame that may be difficult or impossible to randomly sample in an effective manner, such as when travel times are too great. Cluster sampling must be undertaken only with careful consideration of how such clustering effectively limits distribution of sampling effort and vacates assumptions of randomized sampling across an entire sample frame. Hence, it has potential to limit inference about the population.

Because bird monitoring is explicitly not intended to provide quantitative inference across any whole park, the GULN will support subjective-adaptive site location for monitoring of migratory and resident birds in network parks. Site selection will be discretionary and based largely on park interest, rather than statistical sampling constraints, as bird monitoring in GULN parks will be a park-based, park-specific, interest-driven effort for which the network will provide data management support and methodology guidance. The GULN will advise its parks on site selection with regard to sampling habitats and other aspects (the adaptive component). See Section 4.4.3 for further discussion.

Applications of different approaches for spatially distributing sampling sites will be explicitly developed in the standard operating procedures of all protocols. Aspects and types of sampling designs, with proposed revisit designs, are provided for nine network protocols in Table 4.2.

Table 4.2. Proposed aspects and types of sampling for nine Gulf Coast Network protocols.

Monitoring protocol	Overall sampling design approach*	Spatial allocation	Revisit design
Weather and Climate[a]	NA	NA	[3-n]; Continuous
Coastal Geomorphology and Landforms	Terrestrial two-dimensional	Systematic virtual grid; *a posteriori* stratified	[1-2]; Adaptive by event
Estuarine and Near-Shore Coastal Waters	Aquatic two-dimensional	GRTS (General Random Tessellation Stratified); Subjective-adaptive by park	[1-0]; Continuous
Freshwater	Aquatic one-dimensional	Various adaptive by park; GRTS	[2-3]; TBD by park and issue
Vegetation Structure and Composition	Terrestrial two-dimensional	Systematic virtual grid; *a posteriori* stratified; Various allocation schemes by vegetation module: Riparian Communities Wetlands Forest Health Fire and Fuel Dynamics Non-native Vegetation	[1-0]; Adaptive by event; TBD by module
Submerged Aquatic Vegetation[b]	Aquatic two-dimensional	Systematic grid; Stratified random	TBD
Amphibian Communities	Aquatic two-dimensional; terrestrial two-dimensional	Stratified random; GRTS; Various by park and issue	[1-0]; TBD
Landbirds[c]	Terrestrial two-dimensional	Subjective-adaptive by park; Systematic grid	TBD by park
Adjacent Land-use Change	Defined buffer; Databases	Total census of databases (exhaustive sampling)	Continuous; TBD by park

*Conceptually, surface sampling-site distributions may be viewed as either strings or chains of sampling points along a linear feature, or aerial distributions of points across a surface. These general site distribution designs are labeled as one-dimensional and two-dimensional, respectively.

[a] Follows NPS national guidelines.

[b] Adapted from NCBN.

[c] Adapted from HTLN; GULN provides guidance, data management assistance.

4.2.5. Sample size, power, and error considerations

Sample size and power are major concerns in monitoring efforts. In general, sample size should be large enough to gain probability of detecting changes of management or conservation importance, but not unnecessarily large (Fry 1992). Where appropriate, we will perform *a priori* power analyses and/or simulations to estimate sample sizes. *A priori* power analysis is a statistical calculation made prior to initiating monitoring using existing data (Thomas and Krebs 1997). Because these data provide an estimate of variability within the considered metrics, power analyses can be used to estimate sample sizes needed to detect trends in the data. An important interplay exists between cost, sample size, and sampling methodology. Different sampling methods differ in cost and yield data of varying quality and reliability. Variation within data reflects a combination of system, or true variation, and method error, or noise (e.g., imprecision in measurement, counting, data recording). Our program will take all of these into account when selecting both sampling methods and designs.

As with all scientific hypothesis testing, monitoring programs must weigh the relative costs and benefits of Type I versus Type II errors, and set alpha (*a*) and power (1-*a*) accordingly (see Fields et al. 2005). Type I errors involve detecting a trend or difference when, in fact, none exists, whereas Type II errors involve failure to detect real differences or trends. Traditionally, scientists focus on reducing Type I errors, and accordingly use smaller alpha levels in statistical tests. In monitoring with a strong resource-conservation mandate, it may be preferable to support an early-warning philosophy by increasing alpha and consequently increasing the power to detect differences or trends (see Sokal and Rohlf 1995). For example, where the possibility of obtaining large, high-quality samples may be limited, we will consider adopting a higher-alpha, higher-power strategy and adjust our sampling design accordingly.

4.3. Monitoring Coastal Geomorphology and Landforms

Geomorphology (primarily surface form, topography, and elevation) is a high-priority vital sign for two GULN barrier-island parks, GUIS and PAIS. Landform provides the physical foundation for all park surface ecosystems and natural resources, and changes dynamically in response to normal system processes, acute storm events, and anthropogenic actions. The primary objectives of the GULN Geomorphology and Landforms monitoring protocol are to detect and document substantial physical changes and displacement in the surface and near sub-surface geography of coastal parks, including recording land subsidence and landform changes occurring as a result of changes in climate, sea level, storm events, and ongoing anthropogenic activities such as dredging, canalization, water withdrawal, and flow modifications.

The beach and dune system at Padre Island National Seashore.

Development of this protocol will proceed in collaboration with the USGS, and be modeled after the Barrier Island Comprehensive Monitoring program currently being developed for monitoring barrier islands in Louisiana. We are interested in developing an approach that is consistent with other similar efforts in the northern Gulf of Mexico. Many technical aspects, including sampling design spatial resolution and coverage, are currently tentative and/or under development. Complete designs and discussion will be presented in the finalized protocol documentation.

The GULN approach to monitoring geomorphic change is based, in large part, on the airborne pulse LiDAR (Light Detection and Ranging) technology that we will use to address multiple vital signs across network parks. For geomorphic monitoring, LiDAR will be used to create a three-dimensional, bald-earth topographic model of the mineral and water surface of sampled coastal landscapes.

4.3.1. LiDAR technology

Airborne LiDAR collects elevation data on sample points in a landscape by bouncing red- or green-light laser pulses off of the sampled substrate and measuring changes in reflection intensity and return time to the sending unit aboard the aircraft. Key elements in the reflection signature from each laser pulse indicate the elevations of the first-return, or canopy-top elevation, and the underlying, bald-earth, mineral-ground (or, in some cases, water) reference surface relative to sea level. Sampling is performed by following a linear flyway at a fixed height (relative to sea level) over the landscape and taking readings (sample measurements) in a raster-scan design similar to that used to generate the image on a typical television screen. Pulse data are recorded simultaneously with GPS coordinates and sampling time that provides sampling location and order information.

LiDAR sampling involves two levels of sampling design. The actual LiDAR surveys generate a primary, or technology-generated, sampling design during the physical sampling event. This primary design is a dynamic, high-resolution, virtual systematic grid sampling of a flyway belt transect across the landscape. The flyway dimensions are set by aircraft altitude, arc of scan across the flyway, and length of flyway. For example, a typical flyway may be approximately 240 meters wide by *n* meters long (*n* = some discretionary length). In this primary design, the sample frame may be anything from one flyway to a combination of parallel flyways covering an entire park. For coastal geomorphic monitoring, the sample frame may include near-shore waters and directly-abutting adjacent lands. Sample units may range from one flyway to an entire park. Actual sampled area is determined by the cumulative length of parallel flyways flown during one sampling occasion.

The virtual grid is anchored on, or referenced to, fixed-location ground stations that are initially subjectively selected (locations permitted according to park management preference). Both ground stations and all sampled points in the virtual grid will have GPS coordinates, allowing the entire sample and database to be accurately georeferenced on the park map. As ground stations are permanent and fixed, the virtual grid can be relocated to cover the same sample frame each time (high degree of grid relocation for repeated measures), but individual sample points within the grid have a low probability of being re-sampled in any given subsequent sampling occasion.

Sampling points are distributed roughly evenly within the grid, with a user-defined, mean spacing that can be adjusted by changing the overflight altitude and pulse frequency of the laser. Typical sample spacing within the grid is about 1.5 × 2.0 meters, yielding large sample sizes (and high sampling intensity; approximately 25,000+ points per square kilometer) and consistent, reliable data.

After primary sampling is performed over the entire sample frame or park, the datasets—composed of all elevation data with geospatial locator and time records—are available for diverse secondary, or *a posteriori,* sampling-design development (Figure 4.1). For example, the total island sample may be stratified to analyze areas of interest (geospatial stratification) and elevation zones of interest (vertical stratification). It may also be sub-sampled to focus on select classes of features (targeted sampling). Large sample sizes also provide the ability to combine, *a posteriori,* adjacent sample points to create new sample-point sizes (footprints) with mean values and associated error terms. This allows one dataset to be used in a variety of sampling designs and analyses, addressing questions at different scales and resolutions. Such combined-footprint sample points are also more likely to be effectively re-sampled over time, as each footprint can assume the mean geospatial location of its several points. This feature will allow us to effectively track shapes, volumes, and locations of objects, such as small sand dunes, over time.

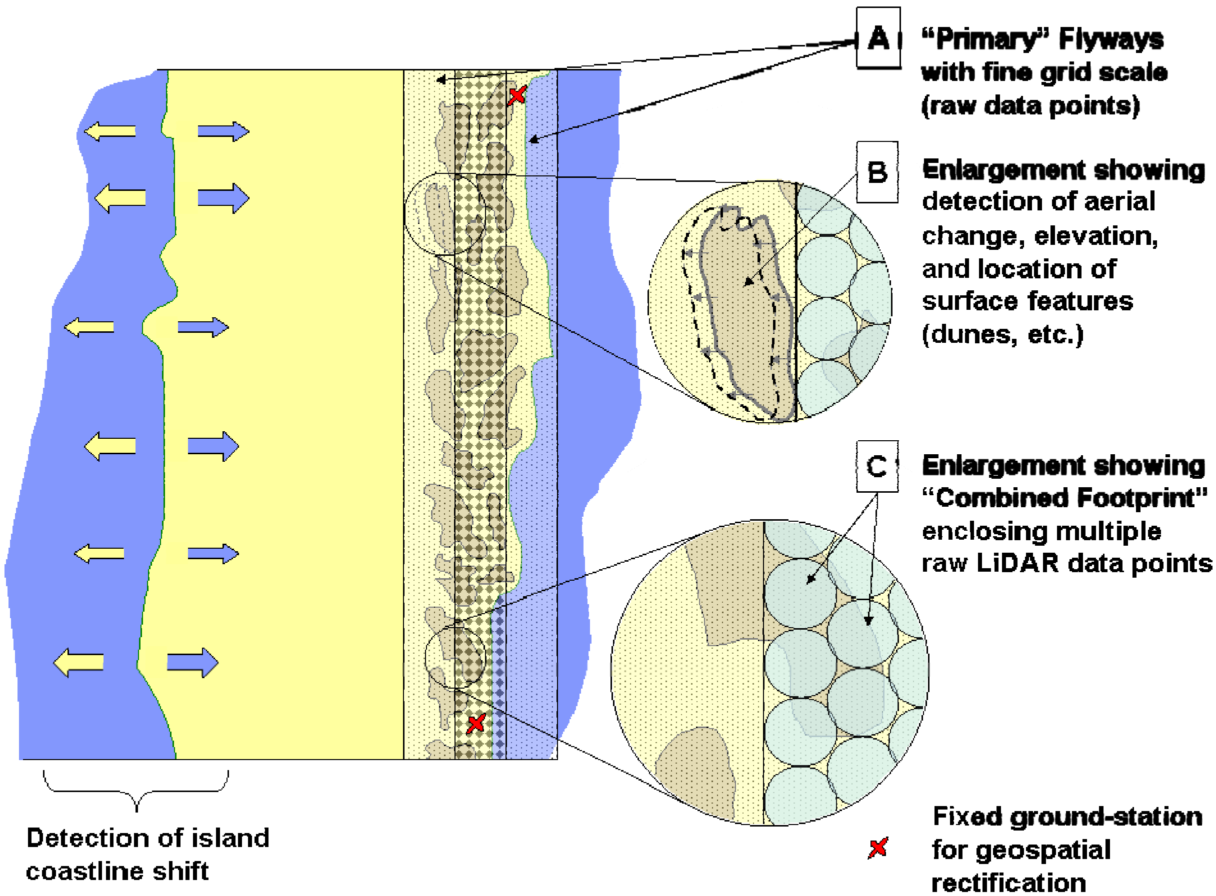

Figure 4.1. LiDAR sampling for geomorphic monitoring. Sampling generates a virtual systematic grid in the raw data (A). Details (B and C) include a secondary, or *a posteriori*, sampling design using combined-point footprints, tracking of surface features, and detection of coastline change.

4.3.2. Sampling intervals, revisit schedules, and panels

The GULN program has yet to finalize the sampling interval, frequency, and scheduling of geomorphic monitoring. One model currently under consideration would treat GUIS and PAIS as one panel to be sampled once every three years. Sampling dates would be approximate windows, determined by weather and flight availability, with a revisit design of type [1-2]. We further anticipate that one or both parks may receive additional sampling runs (adaptive sampling) following acute storm events if park managers request assessment of storm impacts on island geomorphology and resources.

4.4. Terrestrial Biological Integrity Monitoring

This section summarizes sampling designs for proposed monitoring of several high-priority biological and ecological vital signs associated with terrestrial ecosystems (see Chapter 3). These vital signs may be usefully divided into three major groups, each with a general type of sampling design: (1) terrestrial vegetation and related vital signs, (2) amphibians, and (3) birds, including both migratory and resident species. All three groups are important, to varying degree and detail, to all eight network parks.

4.4.1. Terrestrial vegetation and related vital signs

Terrestrial vegetation is a key monitoring focus in all GULN parks. In addition to the general condition of park vegetation, various parks are strongly interested in several other related vital signs, including Forest Health, Riparian Communities, Salt Marsh Communities, Fire and Fuel Dynamics, and Non-native Vegetation (see Chapter 3 for parks and vital signs).

The GULN is developing, in collaboration with the USGS, a technology-based, combined monitoring strategy that will simultaneously address all of these vital signs. Our combined vital signs approach is based on the recognition that vital signs related to vegetation involve similar questions about aerial and spatial dimension, location, condition of plant stands or patches, and species composition (Fire and Fuel Dynamics does not involve a species component). These general questions may be quantitatively addressed by measuring the structure, dimensions, and locations of vegetation patches or units as physical objects, without *a priori* consideration of species. As the questions may be answered, at least in large part, across vital signs and parks with like data (measurements), it appears reasonable that these vital signs may be effectively monitored using a common methodology and design. Accordingly, we are developing the GULN Vegetation Structure and Composition monitoring protocol (VSCMP) as a combined-methods approach to address multiple vegetation-related vital signs across most or all parks in the network.

The initial, primary objective of the VSCMP is to provide reliable, consistent quantitative information on the physical structural characteristics of park vegetation resources at the larger-area and park/landscape level, together with limited taxonomic and typological biological description and conditional assessment of those sampled resources. Initial development will focus on sampling terrestrial vegetation; additional resource- and question-specific objectives will be developed as linked and derivative monitoring protocols and SOPs are added in the future. After this primary protocol is completed, we will develop additional modules (essentially, secondary sampling designs and associated analytical components) that will address the other vital signs in this group (see Chapter 5 for proposed modules and development dates).

The primary technological basis for the GULN VSCMP is the use of airborne LiDAR, coupled with high-resolution, color infrared (CIR) digital photographic images to collect information about vegetation structure and composition. The use of LiDAR in vegetation assessment and monitoring is rapidly developing, both in technical refinement and in diversity and scope of potential application, as is evidenced by the growing amount of international technical literature on the subject (see Nayegandhi et al. [2006] on *a posteriori* evaluation of sampling footprint sizes; Thomas et al. [2006] on photosynthetic rate and leaf area assessment in boreal mixed-hardwood forests; Anderson et al. [2005] on canopy structure and biomass estimation in mixed forests; and Hinsley et al. [2006] on assessment of woodland habitat for birds). The GULN

VSCMP will involve three major components: (1) collection of structural and dimensional measurement data using LiDAR; (2) collection of data on qualitative plant health and condition, as well as taxonomic identification, using CIR imaging; and (3) field surveys to ground-truth and augment taxonomic, conditional, and distributional information derived from the LiDAR and CIR data. LiDAR and CIR images are coupled (collected simultaneously in one survey flight), ensuring a high degree of sampling co-location and co-visitation with common revisit and panel designs and sampling intervals between these two methods. LiDAR and CIR data will share a joint, two-level development of sampling design, similar to that used for geomorphic monitoring. Ground-truth sampling will be performed separately, on different scales and intervals, and with different revisit schedules.

Naval Live Oaks, Gulf Islands National Seashore.
The dynamics of change in this and similar systems across GULN parks
is a primary focus in network plans for vegetation monitoring using LiDAR.

4.4.1.1. LiDAR sampling

The LiDAR sampling component will employ the same instrument technology used for geomorphic sampling, and generate the same primary sampling design. Sampling is performed in linear flyway belt-transects, creating a virtual systematic grid sample with sampling intensity and spacing of sampling points controlled by the mechanisms described above. Primary sample frames are flyways and composites of flyways up to the parkwide area. Sample grids and points are georeferenced to fixed-location ground stations.

For the VSCMP, LiDAR sampling will collect additional data that provide measures of object and layer surface elevation relative to mineral surface (landform, bald-earth). These data will include elevations of canopy top and one or more sub-canopy layers. These data are used in the analytical design to derive estimates of canopy and sub-canopy layer height and density, as well as measures of the patterns and heterogeneity that collectively provide three-dimensional quantitative assessment of object (e.g., vegetation, canopy, dead timber) structure and size. These data are collected as a column wave-form signature on each sample point in the LiDAR survey;

thus, all aerial, distributional, and geospatial-location aspects of the LiDAR sampling design apply equally to all layers within these vertical data columns.

LiDAR datasets collected for the VSCMP can be readily used in secondary sampling-design development. Data may be stratified using geospatial and elevation data collected within the sample, and/or with reference to prior information (e.g., park maps, research records); may be regrouped to address questions at different scales; and be sub-sampled and clustered by any randomization or targeted sampling approach (e.g., to examine a selected recognized "patch" or vegetation unit on the landscape).

4.4.1.2. CIR image collection and sampling

High-resolution CIR images are taken simultaneously with LiDAR data collection as survey transects are flown. These images form a mosaic of photographic images that can be joined together to create a seamless digital image of the entire LiDAR primary sample frame being considered. The CIR images are then geo-rectified, or spatially coordinated, with the co-collected LiDAR datasets. CIR images contain pixilated color signatures of what was overflown in the flyway. These color-pixel data, combined in co-analysis with LiDAR sample-point structural data, create a color-with-structure signature of a LiDAR footprint (combination or grouping of adjacent LiDAR data points into a larger averaged unit for analysis), interpretable by machine, that will be used to monitor the physical structure, coarse taxonomic composition, and, potentially, some plant-health aspects of the sampled vegetation.

CIR datasets, like LiDAR datasets, can be employed for diverse *a posteriori* use and analysis. When linked with LiDAR data, all sub-sampling, grouping, and stratification applied to a LiDAR dataset will automatically correlate with the CIR data, and reciprocally so, when such manipulations are applied to the linked CIR data. In addition, CIR data may be independently used in *a posteriori* sampling design with separate analyses to address questions not related to structure, such as the possible spread of a plant pest or pathogen that causes a detectable (and geospatially explicit) color change within CIR datasets.

4.4.1.3. Ground-truth sampling

Both LiDAR and CIR sampling methodologies generate potentially large, consistent, and reliable datasets and analytical outcomes information. These are the primary monitoring outputs that will be interpreted by GULN program staff and reported to park managers. For effective utilization in monitoring, outcomes from both methodologies will need to be calibrated and qualitatively verified by ground-truth sampling.

Ground-truth sampling is currently in early development, with collaborating vegetation experts located at Louisiana State University. We anticipate that this sampling will be designed to provide some amount of data about species composition, aerial spacing of larger individuals within selected sample frames, and, potentially, data reflecting plant health or condition. Possible sampling methods will include conventional plant-ecology practices such as transect and plot sampling, as well as point-quarter, line-intercept, and nearest-neighbor methods. Plot and transect size will be determined by subject-matter experts, who will consider both the questions being asked and the scale of the vegetation being sampled.

Sampling plots will be distributed by referencing a park's LiDAR virtual grid (*a posteriori* plot-location selection) or extant park vegetation maps. Ground-truthing is intended to provide *a posteriori* identification or description of a feature (i.e., a patch with structural and/or color characteristics differing from surrounding areas) observed in the LiDAR–CIR combined dataset.

Thus, ground-truthing efforts will be distributed to target those features within the larger LiDAR primary sample frame. For ground-truth sampling, the sample space of inferential interest will be within the boundary of a feature selected on the LiDAR dataset or park map. Allocation of sample plots within that feature will utilize either grid-based systematic distribution (based on a subset of the LiDAR virtual grid, scaled to fit the intended feature) or a simple random distribution across the set of grid points (Figure 4.2). The number, shape, and size of plots used within the feature's sample space will be scaled to provide a sample size adequate to estimate the properties of interest for that patch.

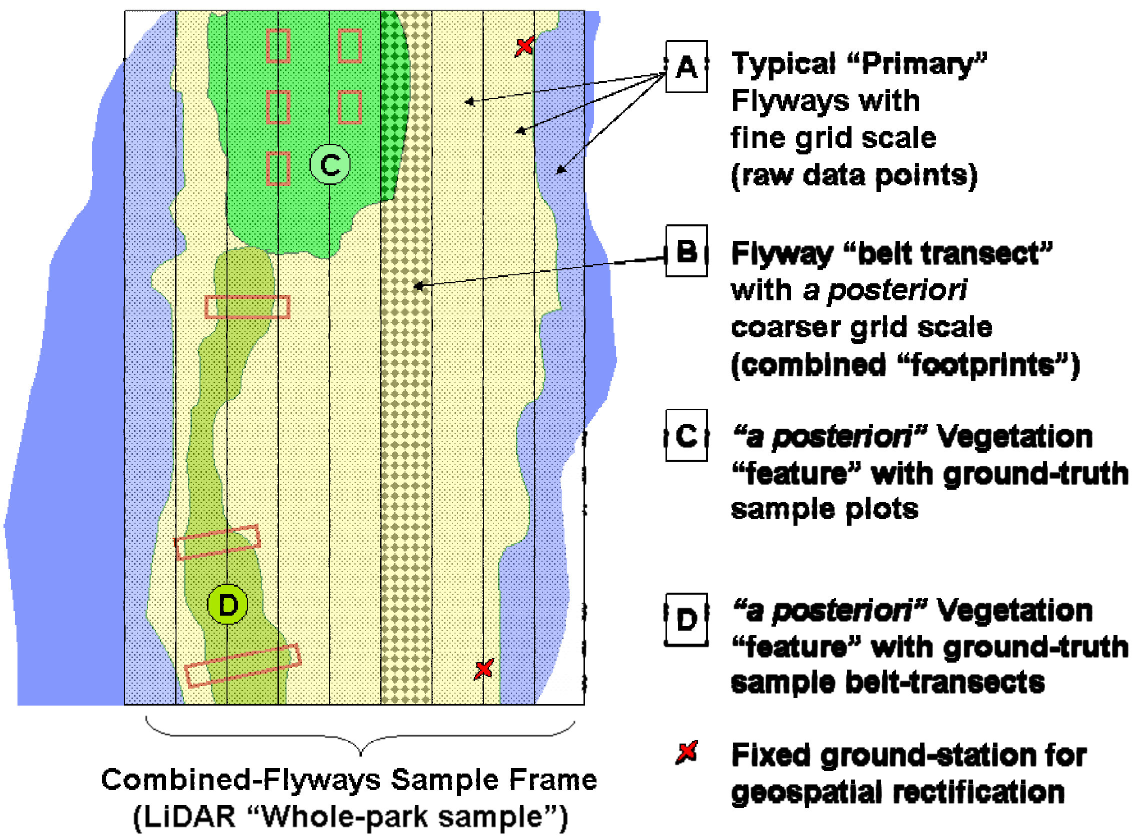

Figure 4.2. LiDAR primary virtual systematic grid parkwide sample (A) with super-imposed secondary sampling designs, including change-of-grid, combined-point footprints, observed vegetation features, and ground-truth sampling within observed vegetation features (B, C, and D.)

4.4.1.4. Sampling intervals, revisit schedules, and panels used in the GULN VSCMP

The GULN program has yet to finalize the sampling interval, frequency, and scheduling of terrestrial vegetation monitoring. One model currently under consideration for LiDAR–CIR vegetation sampling would treat GUIS and PAIS as one panel to be sampled in conjunction with geomorphic monitoring, while other parks would be distributed among two or more panels to be sampled on a "1 on, 3 off" revisit design (type 1-3]. We further anticipate that some parks may receive additional sampling runs following acute storm events or if a park requests assessment of a possible acute event, such as a pest outbreak. Sampling frequency and revisit schedules for ground-truth sampling will be developed on a per-park and as-needed basis in consultation with the parks and with collaborating vegetation experts.

4.4.2. Amphibians

Amphibian populations and communities are a high-priority monitoring focus for most GULN parks. We have initiated development of a network-wide Amphibian Communities monitoring protocol in collaboration with staff at the University of Georgia's Savannah River Ecology Laboratory. The primary objective of this protocol is to provide network parks with quantitative assessment and monitoring of common amphibian species as biological indicators of changing ecosystem conditions. Likely questions focus on local relative abundance, large-site occupancy, and age and sex structure within populations. Both sampling methodologies and sampling designs remain to be selected, but we anticipate that this protocol will utilize established methods and designs derived from current practices used by the Partners for Amphibian and Reptile Conservation and USGS-Amphibian and Reptile Monitoring Initiative.

***Bufo valliceps*, the Gulf Coast Toad, is common to most GULN parks, and may serve as a cross-parks comparative indicator for amphibian monitoring.**

***Hyla squirella*, the squirrel tree frog, on JELA's Barataria Preserve. This common species may serve in conditional monitoring of amphibians on several GULN parks.**

Typical sampling methodologies include intercepting and trapping mobile individuals (pitfall traps, drift fencing, visual surveys), providing acceptable artificial habitat (cover-board sampling), conducting net and trap sampling in aquatic habitats, and using audio census methods ("frog-loggers," listening surveys). Each of these methodologies involves different assumptions and practices concerning both spatial and temporal sampling distribution and intensity.

We expect that amphibian sampling will be environmentally stratified based on landform, elevation gradients, slope and exposure aspects, and substrate composition. Sampling points, plots, and transects may be distributed systematically across an entire park (based on a park map grid), within defined strata, or in semi-randomized and simple random designs within sample spaces. In many cases, sample locations will be specifically keyed to local habitat details. Amphibian experts frequently use habitat-targeted sampling due to the strong habitat specificity of many species. Sampling may involve multiple sampling visits per site over each season, as many species exhibit diel behavior patterns and seasonal activity cycles. We should expect that within-year sampling revisit schedules may be specific to a park, based on which species are common at that location. We anticipate that all parks included in this effort will be sampled every year, in a network-wide, one-panel revisit design [1-0].

All amphibian sampling will be spatially explicit, and sampling sites will be located with GPS coordinates. Use of geospatial locators will support *a posteriori* correlation of amphibian data with vegetation structure and geomorphic landform data (habitat structure and dimensionality) collected during those monitoring efforts.

4.4.3. Migratory and resident birds

Both migratory and resident birds are of monitoring interest to most GULN parks. Several parks host high bird diversity because they are located on important migration flyways and, in some cases, in important overwintering and/or breeding areas. Most network parks have high levels of visitor interest in birds and are host to variably active birding groups. The GULN program has elected not to pursue bird-population monitoring as a network task, but will support individual park monitoring efforts with a common methodology and sampling-design protocol, technical advice, and network-level data management assistance. To this end, we will adopt methodological and analytical components of the Heartland Network (HTLN) Landbirds monitoring protocol and support its implementation in network parks at the discretion of park managers. To a large extent, park staff and park-associated volunteer birders will implement this protocol.

The sampling methodology for all parks and habitats will be based on the fixed-time duration, point-based variable circular plot (VCP) sampling described in the HTLN protocol (Peitz et al 2004). VCP is a distance-sampling methodology generally used to determine relative abundance and trends in bird populations. During sampling, an observer records birds seen or heard within a set time period (usually between 3 and 10 minutes) from a station located along a transect or on a systematic grid. VCP can utilize visual and/or auditory detection of birds. Our use of this methodology will, in practice, approximate the point-count approach used for the Breeding Bird Survey, except that our application will include estimating the distance-from-observer for each bird seen or heard during the sampling event.

4.4.3.1. General sampling design and distribution of sites

Site selection will be discretionary or judgmental for all GULN parks that undertake bird monitoring under this protocol. Because we do not intend for this effort to provide parkwide quantitative estimators, nor statistical inference to bird-population parameters or conditions on a parkwide basis, use of guided discretionary distribution of sampling sites is a justifiable approach. We expect to continue using extant sites that have been subjectively chosen and used in previous years by park monitoring efforts and/or local birding groups active in specific parks, as these sites have become established for the park, visitors, and personnel who are likely to be involved in performing sampling activities. Where parks are interested in adding new sites, these will be selected either by judgment (e.g., placement of added sites in areas considered to be habitats of interest by the park and/or local experts), or, if park area is sufficiently large, by placement on a systematic grid or along transects through the park. In this latter case, the GULN will assist the park in developing a sampling design that fits its needs and available resources for monitoring. The grid can be stratified to focus on questions of interest (e.g., place-sampling emphasis on coastal dunes and beaches on PAIS, or place emphasis on a particular management unit within a larger park, such as BITH). The systematic grid will either be derived from the primary virtual grid for terrestrial vegetation sampling (complete with its geospatial markers) or created and superimposed on a park map. In either case, geospatial location of sampling points will support *a posteriori*, spatially explicit correlation of bird-count and distance data with vegetation-structure data (habitat characteristics) and geomorphology. The number of sites to be sampled in any park will be limited by available sampling effort and park size.

The populations to be monitored (breeding, year-round resident, seasonal resident, and migrant birds) will be identified by specific parks in consultation with their local birding groups and experts. Sampling frequency, replication, and revisit design will be developed for each park in collaboration with park staff and local birding groups. It is anticipated that most parks will use some form of the one-time-per-sampling-occasion revisit design [1-0].

4.5. Gulf Coast Network Approach to Landscape Dynamics

Change in adjacent land use, particularly land conversion and development for urban/residential and commercial development, is a high-priority network concern. Most GULN parks are, to some extent, interested in how and what is changing in terms of development and land use on properties surrounding and adjacent to parks. Our approach to monitoring changes in land use is to consider posted and approved building permits and other formal planning and permitting instruments as being the best available predictors of near-future land development. The GULN, in collaboration with staff at Texas A&M University, is developing a protocol to provide early detection of planned and pending development on lands adjacent to network parks (see Chapters 3 and 5). Fundamentally, this protocol will provide a prediction of what will be developed, and where, in the near future, and will augment other information (such as historic and recorded changes in land use and landscape-level analyses and trends) that may become available through other monitoring efforts.

The general methodology will be to exhaustively sample paper and electronic development and building-permit databases for all public jurisdictions (e.g., counties, municipalities, water districts, utility districts) involved with permitting watershed alteration, development, and construction on lands within a defined buffer adjacent to the boundary of each monitored park. Initially, sampling will focus on permits that have been approved and filed. Later development of this protocol will potentially extend sampling to include filed permit applications and project proposals as additional tools to facilitate predicting near-future development around parks. Data and information to be collected and reported will include identification of project type, scope, and size; proposed start and completion dates; and locations.

The general sampling design is a repetitive exhaustive sample (total census) of all available data in sampled databases on a short-interval or real-time sampling schedule. The sample frame and sample space are the buffer around the park boundary. Buffer size will be selected by the park, and may differ for different types of permits (e.g., a buffer for residential and retail building may be set to include all lands within 3.0 km of the administrative boundary, while a utility and major transportation buffer may extend out 15 or 20 km or more to capture highway and power-plant development). Sampling frequency (revisit design) may be anything up to continuous electronic survey of available databases, as determined by factors such as access to databases and files granted by affected jurisdictions. It is likely that sampling will be adaptive in schedule, as different jurisdictions are likely to permit and support differing levels and rates of access to their data, and there may be some time lag in approval and posting of permits.

4.6. Freshwater Monitoring Design

This section summarizes several aspects of the sampling design and plan for monitoring chemical and physical water quality parameters in the five inland parks of the GULN (BITH, NATR, PAAL, SAAN, and VICK). Complete details of design rationale, sample site selection, and sampling schedule are presented in the Gulf Coast Network Water Quality Monitoring Plan

(WQMP) and its associated monitoring protocols in Appendix M. By intent, this is a long-term monitoring program designed to form a comparative database of selected water quality parameters from within an individual park or stream over time. Its primary design and sampling strategy are selected for long-term trends detection, rather than response to catastrophic or singular events that might affect water quality, such as a break in an oil pipeline.

The GULN WQMP will adapt the basic program of proven national and state standards of the USGS National Water Quality Assessment (NAWQA) and the Texas Commission on Environmental Quality (TCEQ) Clean Rivers Program (CRP). Implementation of the GULN WQMP will rely upon, and fully articulate with, monitoring efforts already in place in Texas, and will, wherever possible, articulate with efforts being performed by other appropriate states and agencies. Explicitly, the GULN will make full use of all available non-NPS monitoring efforts and programs, including USGS gaging stations, to provide effective monitoring for park waters. This strategy will both ensure that data are consistent and comparable among the parks and with those obtained by other entities monitoring like resources in the region, and potentially provide significant savings through cost-sharing and leveraging with these other entities.

The five inland GULN parks being addressed in the current WQMP constitute a diverse array of monitoring needs and objectives. Park waters are not equally important across all parks, and each park has specific concerns about threats, associated biota, and relative resource value of their waters. For purposes of developing the GULN WQMP, park waters were classified into three categories, which were then used to determine the primary distribution of sampling effort across the five inland parks. Those categories are as follows:

Table 4.3. Monitoring categories for Gulf Coast Network freshwater parks.

Category	Characteristics	Park(s)
1	• Water resources are central to park establishment or mission • High amount of recreational use • Contains federally or state-listed threatened, endangered, or rare aquatic or dependent species • Known exceedances of key water quality standards or 303(d)-listed waters • High probability of water resource damage with little or no information of fundamental elements of hydrogeology or water quality	BITH NATR
2	• Water resources, although important with respect to general interpretation or aesthetics, are not central to park establishment or mission • Limited or no contact recreational use • Contains no federally or state-listed threatened, endangered, or rare aquatic or dependent species	SAAN
3	• Water resources are not central or perhaps even mentioned in park establishment or mission • No contact recreational use • Contains no federally or state-listed threatened, endangered, or rare aquatic or dependent species • In general, water resources are ancillary in nature and management	PAAL VICK

These categories, along with differences in specific park needs, affect both allocation of monitoring effort and the specific parameters sampled. Numbers of sampling sites and specific parameters will vary among parks accordingly, as detailed in Appendix M.

4.6.1. Synoptic sampling and general sampling schedule

Our primary approach to monitoring will, like the USGS-NAWQA and TCEQ-CRP programs, rely upon synoptic sampling, in which water samples are taken on fixed calendar dates regardless of flow and weather conditions. This strategy has proven to yield statistically valid data that can be used to track long-term trends in water quality. In synoptic sampling, all sites within a park will be sampled in a rotation order on set calendar dates.

The GULN water quality program is designed to provide an integrated assessment of the spatial distribution of general water quality conditions in relation to hydrologic conditions and major contaminant sources. The general sampling schedule will be either bi-monthly or quarterly, based upon water resources ranking and existing TCEQ-CRP monitoring efforts. This sampling schedule is selected as being most feasible to provide comparative statistics for the selected sites and parameters under variable flow conditions.

Where GULN or other NPS staff will perform sampling field work, sampling dates will be set depending on GULN logistical and staff considerations. Where sampling will be performed by a cooperating state agency (e.g., TCEQ-CRP), sampling dates will articulate with the schedules of that agency's current program. Multiple parks may be scheduled for sampling on the same dates, constituting a panel for sampling schedule purposes. The initial annual sampling schedule (design) is as follows:

- PAAL, with no perennial surface water resources, will not be sampled on a regular schedule, but may occasionally be sampled following large rain events.
- BITH, SAAN, and VICK will be sampled quarterly.
- NATR will be sampled every other month.

Additional details on within-year sampling schedules for each park are provided in the GULN WQMP (Appendix M).

Initial water quality sampling for the GULN will begin in 2007. Data collected during FY2007 will use protocols and SOPs (see Appendix M for details), and will serve as a programmatic test. At the end of the year, the program will be evaluated and any needed modifications will be made under SOP 9, "Revising the Protocol."

4.6.2. Selection of sampling sites

In most cases, selection of sampling sites will follow the general allocation scheme used by USGS-NAWQA: Sampling locations are selected as being either integrator sites (locations commonly at tributary confluences that are representative of water quality issues within individual sub-basins) or indicator sites (locations downstream from either suspected or documented water quality threats or with pristine conditions). It is recognized that in order to best fit with other GULN monitoring activities, some flexibility in site selection is likely.

The following criteria were used in choosing sampling sites in GULN parks:

1. The site's utility as an integrator site (i.e., located at the downstream end of a stream, spring, or tributary and of interest because of presence or absence of significant sources of pollutants within their watersheds).

2. The presence of significant aquatic resources in a stream segment where water quality trend information is needed to corroborate biological trends or to provide park managers with early warning of potential problems.
3. The management interest of a particular site, be it either legislative (i.e., protection status mandated by park legislation or management plans) or regulatory placement on non-attainment (303(d)) list.
4. Integration into existing water quality programs, where sites are selected to fill spatial gaps in these extant programs.
5. The presence of existing water quality data at a given site. While many sites in the GULN have not been sampled prior to this program, some have. An existing water quality record adds to the utility of establishing long term trends if reoccupied in this program.
6. The availability of easy, quick access to the site. Because each park will be sampled synoptically during a single day, sites must be chosen that allow easy and quick access during all flow conditions.
7. The ability to safely access a sampling site. Because many water samplers will be alone, they must be able to access sites safely in all conditions.

Sites were chosen based upon management needs (recreational use, for example), biological reasons (occurrence of listed species), and to co-locate with future sites for aquatic biological monitoring. In nearly every case, sites were chosen by the NAWQA rationale to reflect integrator locations as defined above. Only the highest-priority sites in any given park that can be sampled during one day will be included. Some parks (BITH and SAAN) have active programs administered by local river authorities. In these parks, sites were chosen to fill in spatial gaps in stream reaches to augment existing water quality sampling locations.

The GULN WQMP will initially utilize a set of 34 sites distributed across five parks. A complete description of each site, and the rationale for its inclusion in this monitoring program, are found in the GULN WQMP and associated protocol (Appendix M).

4.7. Water Quality Monitoring in Coastal and Estuarine Waters

Coastal, near-shore marine, and estuarine waters are important monitoring foci in three GULN parks: GUIS, JELA, and PAIS. Key components of network monitoring for this vital sign will include planned adoption of the SECN estuarine monitoring protocol and development of limited fixed-station continuous monitoring at GUIS and PAIS (and possibly JELA). Development of these approaches is expected to occur in FY2007. Collaborators will include USGS staff, the EPA, SECN, and state agencies in Louisiana, Florida, Mississippi, and Texas.

The SECN estuarine monitoring protocol is an adaptation of the protocol used by the EPA for the Coastal Condition Assessment (CCA). The sampling methodologies and general sampling design were developed by the EPA for conditional monitoring of coastal and estuarine waters. The SECN protocol and EPA-CCA utilize a version of GRTS (General Random Tessellation Stratified) sampling for probabilistically allocating sampling effort within the desired sample space. The GULN will directly adopt both the standardized sampling methods and this general design, and apply this model for distributing sampling sites within its parks. The adopted model includes a proposed revisit design for sampling points within the sample frame. The GULN protocol will adopt and follow this schedule.

The GULN anticipates augmenting the adopted protocol with several fixed-station continuous monitoring instruments. Continuous monitoring devices provide detailed, time-related conditional sampling to facilitate real-time assessment of water parameters at presumed critical-system-condition and integrator locations. Protocols for this type of continuous monitoring will be adopted from NOAA's National Estuarine Research Reserves program and the SECN. The sampling locations will be judgmentally selected in consultation with the parks and with experts from the NPS Water Resources Division.

Chapter 5
Sampling Protocols

Monitoring protocols are detailed study plans that explain how data are to be collected, managed, analyzed, and reported, and are a key component of quality assurance for natural resource monitoring programs. Protocols are necessary to ensure that changes detected by monitoring actually are occurring in nature and not simply a result of measurements being taken by different people or in slightly different ways. . . . A good monitoring protocol will include extensive testing and evaluation of the effectiveness of the procedures before they are accepted for long-term monitoring. Peer review of protocols and revisions are essential for their credibility. The documentation should include reviewers' comments and authors' response.

—Oakley et al. 2003, Appendix N

5.1. Introduction

Monitoring protocols are the key, on-the-ground, functional elements of the GULN program. Formal, peer-reviewed protocols ensure consistent, reliable monitoring and facilitate project and program continuity as personnel change. GULN protocols (and the process used to create them) emphasize careful development and testing of methods and designs to provide effective sampling and monitoring; comprehensive review by NPS and outside experts to ensure methodological and design adequacy prior to implementation; and careful documentation to ensure consistent implementation over time. Where possible, the network will take advantage of existing protocols—particularly those that have already undergone I&M and peer review—and adapt them to the particular circumstances of GULN parks. The following sections and tables describe a typical monitoring protocol document; summarize the GULN protocol development process; and identify, with a proposed development schedule, the suite of protocols to be developed by the GULN over the next three-to-five years to address its 19 high-priority vital signs. Protocol Development Summaries for protocols currently under development are provided in Appendix N.

5.2. Protocol Development Process

Once a vital sign has been selected, the next step is to develop a monitoring plan and formal monitoring protocol for that vital sign. Successful development of a monitoring protocol often involves a multi-year research and field-testing effort to determine the appropriate spatial and temporal scale for sampling and to test sampling procedures before they are implemented for long-term monitoring. In many cases, such development requires specialized technical expertise and access to equipment or resources that may not be directly available to a monitoring program. GULN protocol development will be performed through collaborative projects that both (1) take advantage of diverse agency, academic, and other professional expertise and (2) leverage and augment network resources. Most technical development and field work will be performed by non-NPS personnel working in collaboration with network and park staff, along with associated interns and volunteer groups. Current collaborators providing key technical assistance include USGS and academic experts affiliated with NPS Cooperative Ecosystem Studies Units (CESUs). In general, GULN staff will be the primary developers of protocol-associated data management and documentation procedures, and will oversee both field testing and future implementation in network parks.

The general protocol development process is as follows: Staff and collaborators identify the key monitoring objectives and questions, and types of data needed to best answer those questions. Next, the development team selects (or develops) and field-tests appropriate sampling methods and spatial designs. Method and design development takes into account specific properties of the sampled resource, such as taxon-specific habitat use and phenology. For example, amphibian monitoring must account for the details of when and where certain species may be found in a shared habitat. Following field-testing (and possible revision), protocol SOPs are drafted to detail all methods, designs, and related information. Finalized protocol documents are then sent through an informal internal and formal external (peer and expert) review process. Following reviews and revision, the approved protocol will be accepted for full implementation by the program, and implementation will commence according to the design and schedule set for that protocol. Given the lengthy and involved process of protocol development, the network plans to use and modify existing protocols whenever feasible to meet GULN needs.

5.3. Protocol Format and Content

Monitoring protocols will follow the document standards described in Oakley et al. 2003. This guideline specifies protocol document format and content, and emphasizes a modular structure that facilitates information access while supporting a well-documented history of change and revision. The following paragraphs summarize the components of a typical GULN program monitoring-protocol document.

Monitoring protocols consist of discrete sections detailing protocol background, sampling objectives, sampling design (including location and time of sample collection), field methods, data analysis and reporting, staffing requirements, training procedures, and operational requirements (Oakley et al. 2003). The first section is a descriptive narrative. This narrative provides the background and rationale for vital sign selection, including a summary of pertinent research background, local research history, and clear statement of park management information needs concerning the vital sign being monitored. The narrative discusses specific measurable objectives and monitoring questions, and identifies how the data to be collected in the monitoring effort will address these questions. Narratives also summarize the design phase of protocol development and any decisionmaking that is relevant to the protocol. Documenting the history of a protocol during its development phase helps to ensure that future refinement of the protocol does not merely repeat previous trials or comparisons (Oakley et al. 2003). Narratives also provide a listing and brief summary of all SOPs, which are developed in detail as independent sections in the protocol.

The narrative is followed by the SOPs. Protocol SOPs carefully and thoroughly explain, in a step-by-step manner, how each procedure identified in the protocol narrative will be accomplished. At a minimum, separate SOPs address pre-sampling training requirements, data to be collected, equipment operations, data-collection techniques and methods, data management, data analysis, reporting, and any activities required at the end of a field season (i.e., post-sampling equipment maintenance and storage). One 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, by whom, when, and why—emphasizing, in a practical way, the nature of protocols as living documents. The final elements or sections in a typical protocol include Literature Cited and, where appropriate, attachments such as appendices, data tables, handbooks, or any other supporting information.

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

5.4. Protocol Development Schedule

The GULN monitoring program has identified 42 vital signs for possible monitoring in one or more of its parks. Of these, 19 have been identified as being of higher priority (see Chapter 3 and Table 5.1), and will be the focus for development and implementation within the next three-to-five years. The remaining 23 vital signs are not currently slated for protocol development and monitoring, but will be addressed as opportunity and resources permit.

The GULN program currently (FY2007) has development work underway on four protocols:

- Vegetation Structure and Composition,
- Amphibian Communities,
- Adjacent Land-use Change, and
- Freshwater.

Because some of these protocols address more than one vital sign, we expect to develop eight separate protocols for the 19 high-priority vital signs. Later in FY2007, the GULN anticipates adopting or beginning development efforts on four protocols:

- Estuarine and Near-Shore Coastal Waters (patterned after the protocol being developed by the SECN),
- Landbirds (modeled on the HTLN Landbirds protocol), and
- Coastal Geomorphology and Landforms (derived from the same data as the Vegetation Structure and Composition protocol), and
- Submerged Aquatic Vegetation (adopted from the NCBN's SAV protocol).

Over the next few years (FY2008–2010), we will begin additional protocol development as current projects near substantial completion, potential developers are identified, and development resources become available.

Table 5.1. High-priority vital signs to be addressed under monitoring protocols slated for development between 2006 and 2010.

Level 1 Category	Network vital sign	Protocol name	Parks	Justification	Primary monitoring objectives	Start year
Air and Climate	Weather/Climate	Weather and Climate[a]	All	Weather patterns and changes in climate trends are key drivers in all ecosystems. Monitoring weather trends provides critical reference data for interpretation of detected ecological trends.	Understand the natural range and variation in weather patterns and climate trends across the GULN parks. Establish baseline conditions that link all other vital signs.	FY2006
Geology and Soils	Coastal Dynamics	Coastal Geomorphology and Landforms	GUIS JELA PAIS	Changes in barrier-island landforms reflect natural process, storm events, and human actions, and drive diverse change in ecosystems.	Establish a current baseline condition and document changes in coastal barrier-island morphology, including shoreline position, whole-island topography, dune position, sand volume, and whether changes are gradual or storm-induced.	FY2006
Water	Water Chemistry Water Nutrients Water Toxics	Estuarine and Near-Shore Coastal Waters	GUIS JELA PAIS	Chemical and physical water quality parameters are key indicators of coastal marine environment condition and change.	Establish a baseline and document long-term changes in core water quality parameters and selected specific analytes in GULN parks.	FY2007
Water	Water Chemistry Water Nutrients Water Toxics	Freshwater	All	Chemical and physical water quality parameters are key indicators of freshwater aquatic environment condition and change.	Establish a baseline and document long-term changes in core water quality parameters and selected specific analytes for surface fresh waters in GULN parks.	FY2006
Biological Integrity	Non-native Vegetation	Vegetation Structure and Composition–Non-native Vegetation Module, and park-specific monitoring of species of interest	All	All network parks are widely subject to invasion and spread of non-native plants that disrupt or displace desired native vegetation, leading to cascade effects across park ecosystems.	Document impacts on native vegetative communities from invasion and colonization by non-native species. Use monitoring of vegetation communities for early detection of new invasive species or spread or existing species.	Module development to start in FY2007 (later start for park-based projects)

Level 1 Category	Network vital sign	Protocol name	Parks	Justification	Primary monitoring objectives	Start year
Biological Integrity	Non-native Animals	Specific monitoring projects by parks. Network can provide technical advice and data management support.	All	All network parks experience non-native animals, such as feral cats and pigs. Non-natives disrupt park ecosystems by disturbing habitat and exerting unusual predation pressure on native species.	Document in-park occurrence and abundance and impacts on native plant and animal communities in conjunction with other vegetation monitoring.	TBD by park
Biological Integrity	Salt Marsh Plant Communities	Vegetation Structure and Composition	GUIS JELA PAAL PAIS	Salt marsh plant communities are important coastal wetland ecosystem components and provide key habitat for diverse park fauna, including birds and amphibians.	Determine current extent and community composition/structure and monitor changes over time.	FY2006
Biological Integrity	Riparian Communities	Vegetation Structure and Composition–Riparian Module	TBD	Riparian plant communities are important ecosystem components that stabilize river channels and provide key habitat for diverse fauna, including birds and amphibians.	Determine current extent and community composition/structure and monitor changes over time.	Module develop ment to start in FY2007
Biological Integrity	Marine and Estuarine Submerged Aquatic Vegetation (SAV)	Submerged Aquatic Vegetation[b]	GUIS PAIS	SAV is a critical coastal and shallow-marine resource that provides key habitat for diverse invertebrate and fish fauna. SAV is also subject to intense impact from human actions.	Determine current extent and community composition/structure and monitor changes over time.	FY2007
Biological Integrity	Forest Health	Vegetation Structure and Composition–Forest Health Module	BITH GUIS JELA NATR SAAN VICK	Woodlands and forests are important ecosystem components and habitat in several network parks. Monitoring canopy form and growth provides indicators of ecosystem change and impact from pests and disease.	Document trends in components of forest health: pest infestation and disease impact on canopy structure.	Module develop ment to start in FY2007
Biological Integrity	Amphibians	Amphibian Communities	All	Amphibians are a diverse fauna across network parks. Amphibians are considered to be robust and useful indicators of wetland and terrestrial ecosystem condition.	Document trends in species diversity, occupancy, reproductive success, and relative abundance in GULN parks.	FY2006

Level 1 Category	Network vital sign	Protocol name	Parks	Justification	Primary monitoring objectives	Start year
Biological Integrity	Migratory Birds	Landbirds[c]	All (by park request)	Network parks serve as key foraging and rest waystops along migration flyways. Birds are an important attraction for visitors, and monitoring birds in parks can contribute to larger-scale databases and understanding of bird population trends.	Document trends in species diversity and relative abundance in GULN parks (monitored by individual parks with network assistance).	FY2007
Biological Integrity	Resident Birds	Landbirds[c]	All (by park request)	Network parks serve as key reproductive and residence habit for many bird species. Birds are an important attraction for visitors, and monitoring birds in parks can contribute to larger-scale databases and understanding of bird population trends.	Document trends in species diversity and relative abundance in GULN parks (monitored by individual parks with network assistance).	FY2007
Biological Integrity	Terrestrial Vegetation	Vegetation Structure and Composition	All	Vegetation structure and composition provide the key biotic foundation for terrestrial ecosystems and the habitat for most terrestrial animal species. Changes in vegetation reflect both natural process and human actions.	Document trends in distribution, coverage, and community composition/structure, and detect and track succession processes in conjunction with landform changes, storm events, and human activity.	FY2006
Biological Integrity	Threatened & Endangered (T&E)/Rare Small Mammals	Monitored by park. Network can provide technical advice and data management support.	All	Parks are mandated to monitor federally listed T&E animal species. Small mammals are important components of many ecosystems.	Document trends in extent and population estimates (monitoring efforts will be developed by individual parks with network assistance).	TBD by parks
Biological Integrity	T&E/Rare Plants	Monitored by park. Network can provide technical advice and data management support.	All	Parks are mandated to monitor federally listed T&E plant species, and may undertake monitoring of state-listed species. Plants are important components of many ecosystems.	Document trends in extent and population estimates (monitoring efforts will be developed by individual parks with network assistance).	TBD by parks

Level 1 Category	Network vital sign	Protocol name	Parks	Justification	Primary monitoring objectives	Start year
Landscapes	Fire and Fuel Dynamics	Vegetation Structure and Composition–Fuel Load Module	All	Park terrestrial ecosystems across the network include fire processes as both natural and human-impacted components. Fuel-load assessment is critical to effective park fire management and to ecosystem preservation.	Document trends in plant community structure and ground-fuel loading in conjunction with network vegetation monitoring. This effort could be linked with park fire and fuel monitoring projects and activities.	Module development to start in FY2007
Landscapes	Land Cover/Land Use	Adjacent Land-use Change	All	Changes in use of park-adjacent lands, including urbanization and development, lead to diverse threats to park resources. Early detection of change direction, type, and rate support park management responses.	Document in-progress and proposed changes in development, land conversion, and succession, both inside and outside park boundaries. Focus on building and zoning changes leading to change in human density and use patterns adjacent to parks.	FY2006

[a] Data will be largely collected from regional and national databases.

[b] Adopted from the NCBN.

[c] Adopted from the HTLN Land Bird protocol; GULN to provide guidance and data assistance to park efforts.

The vital signs are listed in order of the Ecological Monitoring Framework developed by the National Park Service Vital Signs Monitoring Program (Level 1 Category provided for reference), followed by the anticipated protocol, its justification, monitoring objectives, and proposed development start-up year.

Colored bands indicate where one protocol addresses multiple vital signs.

Development of additional Vegetation Structure and Composition modules to address Forest Health, Fuel Load Assessment, etc., will occur after the core set of terrestrial vegetation metrics are completed.

5.5. Protocol Development Summaries

Protocol Development Summaries (PDSs) are required for all monitoring protocols planned for development and implementation by the GULN. The PDS is a short (one-to-two pages) document that identifies the vital sign of interest and describes why the protocol and monitoring is needed, specific issues and questions being addressed, specific measurable objectives, proposed methodological approach, and other details. The typical PDS includes the following material:

- **Protocol:** Title of the protocol.
- **Parks where protocol will be implemented:** Names or four-character codes for the parks where the protocol is likely to be implemented over the next five years.
- **Justification/issues being addressed:** A paragraph or two justifying why this protocol needs to be developed.
- **Monitoring questions and objectives:** Specific monitoring objectives of the protocol.
- **Basic approach:** Description of any existing protocols or methods that will be incorporated into the protocol, the basic methodological approach, and sampling design.
- **Principal investigators and NPS lead:** The name and contact information for the principal investigators (PIs) and the NPS project manager responsible for working with the PIs to ensure that the protocol meets network and park needs.
- **Development schedule, budget, and expected interim products:** Description of expected costs, timelines, and interim products (annual reports, sampling designs, etc.).

The PDS files for the five GULN protocols currently in development can be found in Appendix N. Additional PDSs will be developed as the program identifies new protocol development projects (see the proposed protocol development schedule in Table 5.4). The complete GULN Freshwater monitoring protocol is located in Appendix M.

Chapter 6
Data Management

Information is the common currency among the many different activities and people involved in the stewardship of NPS natural resources. As part of the agency's effort to improve park management through greater reliance on scientific knowledge, a primary purpose of the I&M program is to develop, organize, and make available natural resource data, and to contribute to NPS institutional knowledge. The I&M program's efforts to identify, catalog, organize, structure, archive, and disseminate relevant natural resource information will largely determine the program's efficacy and image among critics, peers, and advocates.

This chapter summarizes the GULN data management strategy, which is more completely explained in the GULN Data Management Plan (DMP; Appendix O). The DMP presents the overarching strategy for ensuring that program data are documented, secure, accessible, and useful for decades into the future. The plan also refers to other guidance documents, standard operating procedures, and detailed monitoring protocols that convey more specific standards and steps for achieving GULN data management goals for specific vital signs monitoring. The plan is a foundation upon which to build as new protocols are developed, advances in technology are adopted, and new concepts in data management philosophy are accepted.

6.1. Data Management Goals

The goal of the NPS I&M program is to provide scientifically and statistically sound data to support management decisions for the protection of park resources. The goal of data management is to ensure the quality, interpretability, security, longevity, and availability of our natural resource data. The goal of the DMP is to outline the procedures and work practices that support effective data management.

Data Management Plan goals are to ensure that:

- **Data managed by the network are of high quality.** This includes designing standardized data entry, importation, and handling procedures that effectively screen for inappropriate data and minimize transcription and translation errors.
- **Network data can be effectively interpreted.** This requires considering the users' needs to be the primary factor driving the design of summary reports and analyses; establishing rigorous data documentation standards; integrating common data tables and fields in NPS or regional standards; and making summary information available in formats tailored to the variety of audiences interested in I&M program results.
- **Data are secure for the long term.** This includes instituting standard procedures for versioning, data storage, and archiving; natural history archiving; and providing curation and records management to NPS curators.
- **Network data are readily available.** This is achieved by implementing standard procedures for distributing data while protecting sensitive data, and designing a standardized filing system for organizing I&M information.

6.2. Data Management Roles and Responsibilities

Everyone within the GULN I&M program uses or manages data and information, and each has roles and responsibilities in this process. This crucial emphasis on data management, analysis, and the reporting of results will require a large investment of personnel, time, and money. The GULN expects to invest at least 30% of available resources in developing and improving its data management system (see Chapter 10).

For the GULN I&M program to work effectively, everyone within the network will have stewardship responsibilities in the production, analysis, management, and/or end use of data. Table 6.1 lists the roles and primary responsibilities.

The fundamental role of the data manager will be to coordinate these tasks. This requires understanding and determining program and project requirements, creating and maintaining data management infrastructure and standards, and communicating and working with all responsible individuals.

The data manager and project manager are primarily responsible for data management. The network coordinator assists by ensuring that project managers meet timelines for data entry, verification, validation, summarization/analysis, and reporting.

Table 6.1. Data management roles and responsibilities.

Role	Data stewardship responsibilities
Project manager	Directs project operations. Communicates data management requirements and protocols to project staff, network data manager, and resource specialist(s). Responsible for final submission and review of all products and deliverables.
Project crew leader	Supervises crew members to ensure adherence to data collection and data processing protocols, including data verification and documentation.
Project crew member	Records and verifies measurements and observations based on project objectives and protocols. Documents methods and procedures.
Computer programmer	Applies knowledge and abilities related to database software and writing special application code to streamline data input and flow.
Park resource specialist	Understands project objectives, data, and management relevance. Makes decisions about validity, sensitivity, and availability of data.
Curator (park or region)	Manages collection, documentation, and preservation of specimens.
Network data manager	Oversees development, implementation, and maintenance of data infrastructure and standards. Facilitates and integrates data and metadata. Oversees long-term data storage and maintenance. Designs and develops databases and applications. Updates software and hardware and implements secure file server backup scheme.
Network ecologist	Ensures useful data are collected and managed by integrating natural resource science into network activities and products, including specifying objectives, sampling design, data analysis, synthesis, and reporting.
Network coordinator	Ensures programmatic data and information management requirements are met as part of overall network business.
GIS specialist	Provides support for long-term storage of GIS data. Updates and maintains GIS software and tools. Provides technical assistance.

Role	Data stewardship responsibilities
Information technology specialist (USGS or region)	Maintains LAN, establishes and maintains system security and firewall.
I&M data manager (national)	Provides servicewide database design, support, and services. Executes processing to convert, store, and archive data in servicewide databases.
End users (managers, scientists, interpreters, public)	Provides feedback on scientific information, presentation needs, and interpretation. Uses information for management decisions.

6.3. Project Work Flow

From the perspective of managing workflow, there are two main types of projects:

- *Short-term projects*, which may include individual park research projects, inventories, or pilot studies done in preparation for long-term monitoring, and
- *Long-term projects*, which will primarily include the implemented monitoring studies central to the I&M program, but may also include multi-year research projects and monitoring performed by other agencies and cooperators. Long-term projects often require a higher level of documentation, review, and infrastructure development.

From a data management standpoint, a primary difference between short- and long-term projects is an increased need to adhere to standards for long-term projects to ensure internal compatibility over time. While the need to follow standards is still present for short-term projects, sometimes the cost of compliance will outweigh the benefits due to the scope, budget, and level of NPS control over the project. Nevertheless, both short-term and long-term projects share many workflow characteristics, and both generate data products that must be managed and made available.

A project can be divided into five primary stages, each characterized by a particular set of activities carried out by staff involved with the project (Figure 6.1):

1. **Planning and approval.** Many preliminary decisions regarding project scope and objectives are made; funding sources, permits, and compliance are addressed. Although this phase lacks specific data management activities, data managers must be kept informed of projects in this phase, particularly as timelines for products are finalized.
2. **Design and testing.** Details regarding data acquisition, processing, analysis, reporting, and dissemination are worked out. Collaboration between the project leader and the data manager is critical during this phase to assure data quality and integrity. A joint effort is required to develop and document the project methods, data design, data dictionary, and the database itself.
3. **Implementation.** Data are acquired, processed, error-checked, and documented; other products are developed and delivered. All aspects of this phase are overseen by the project manager. Data management staff acts primarily as facilitators to support database applications, GIS, GPS, data validation, summarization, and analysis. Products are delivered to the appropriate staff, and those that do not meet program requirements are returned to the project leader for revision.

4. **Product integration.** Data products and other documents are integrated into national and network databases. Metadata records are posted in clearinghouses, and products are made available to their intended audiences. Data from working databases are merged into master databases.

5. **Evaluation and closure.** Project records in the project tracking database are updated to reflect completion status. The network coordinator, project leader, and data manager should work together to assess how well the project met the stated objectives and what steps might be taken to make improvements.

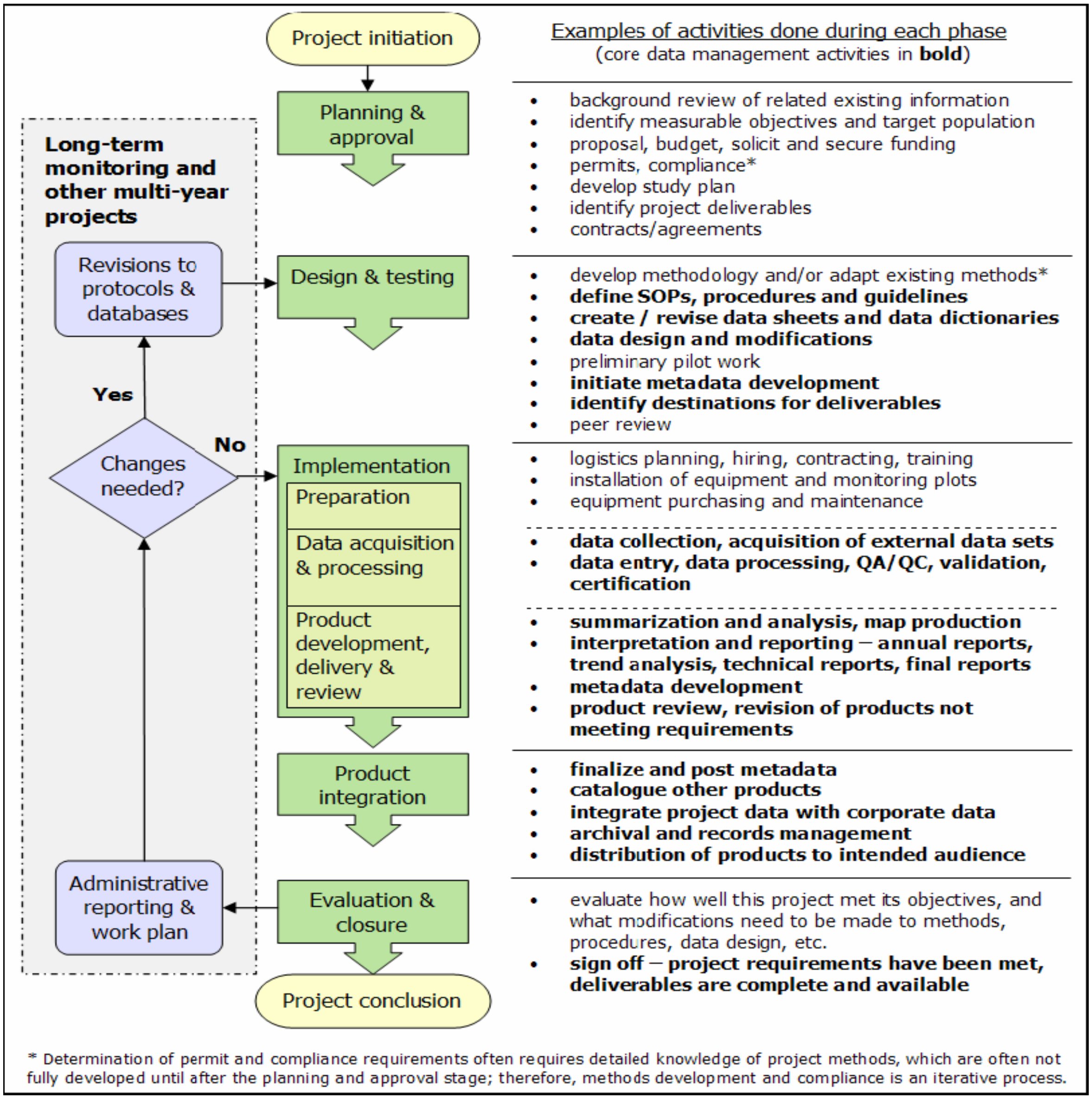

Figure 6.1. Project workflow.

During various phases of a project, data take on different forms and are maintained in different places as they are acquired, processed, documented, and archived. This data life cycle is characterized by a sequence of events, as shown in Figure 6.2.

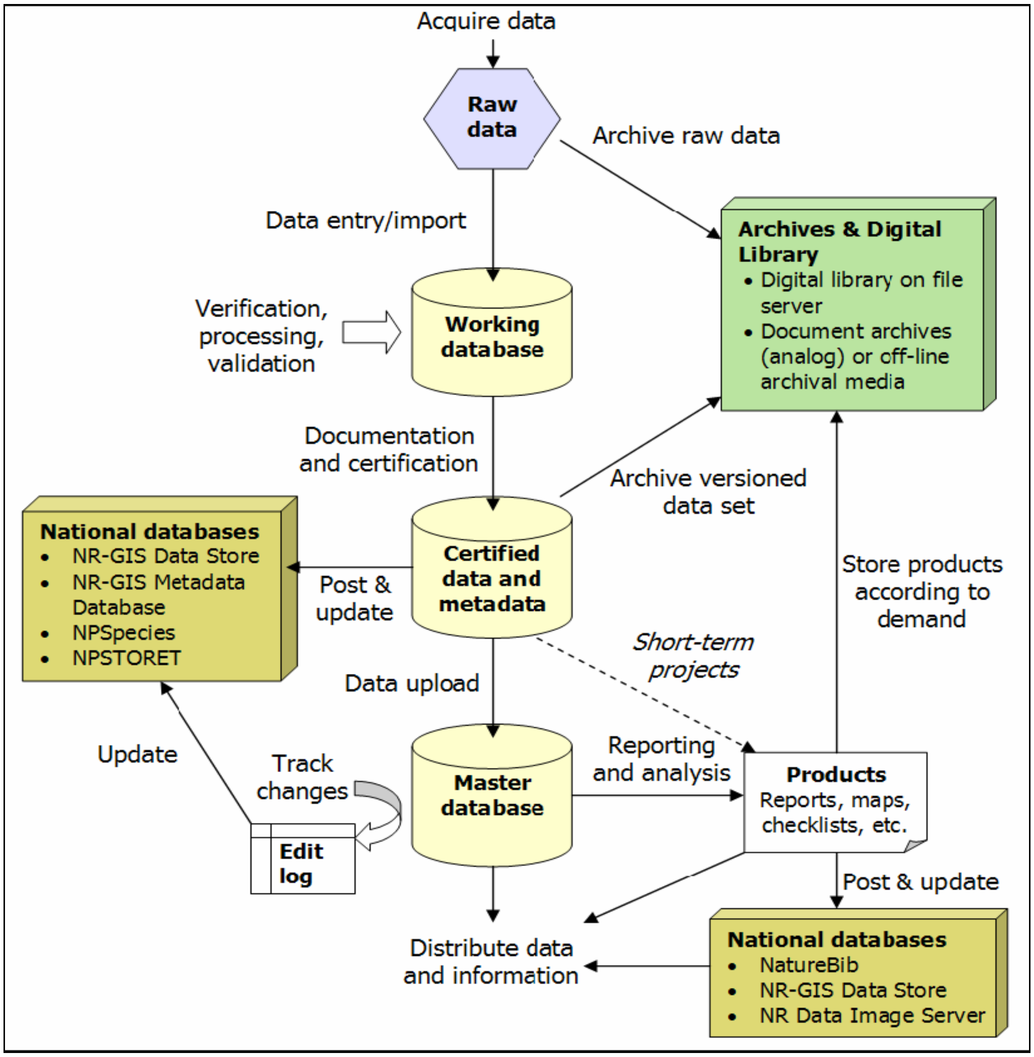

Figure 6.2. Project data life cycle.

Key points of this data life cycle are as follows:

- All raw data are archived intact.
- Working databases are the focal point of all modification, processing, and documentation of data collected for a given data collection period.
- Upon data certification, indicating that the data have passed all documentation and quality-assurance requirements, the data are archived and posted or otherwise integrated with the appropriate national data applications.
- Data for long-term monitoring projects are uploaded into a master database that includes multiple years of data.
- Certified datasets are used to develop reports and other data products, which are also archived and posted to the appropriate national repositories.
- All subsequent revisions to certified datasets are documented in an edit log, which is

distributed with the data.

Specific repositories for most GULN products are indicated in Table 6.2.

Table 6.2. Repositories for Gulf Coast Network products.

Item	Repository
Reports	GULN digital library; posted to NR Data Image Server, linked and accessed through the catalog record in NatureBib; park collection (hard copy)
Digital datasets (non-sensitive)	NR-GIS Data Store, Biodiversity Data Store
Digital data, metadata, and other products; raw and finalized data; protocols; SOPs; completed reports; digital photographs; derived products	GULN data servers and digital library, cooperators for selected monitoring projects
Project materials, voucher specimens, raw-data forms	Park archives and collections, or another park specified repository (e.g., Louisiana State University)
Administrative records	GULN offices and/or park offices, park archives, National Archives

6.4. Data Management Infrastructure and Systems Architecture

Our network information system is built upon a modern information-management infrastructure (e.g., staffing, hardware, software). Systems architecture refers to the applications, database systems, repositories, and software tools that make up the framework of our data management enterprise.

One important element of a data management system is a reliable, secure network of computers and servers maintained by national and local IT specialists, assisted by the network data manager. These individuals attend to hardware replacement, software installation and support, security updates, virus protection, telecommunications networking, and server backups. GULN digital infrastructure consists of network data and GIS servers and servers maintained at the national level (Figure 6.3). Each of these components hosts different parts of our natural resource information system.

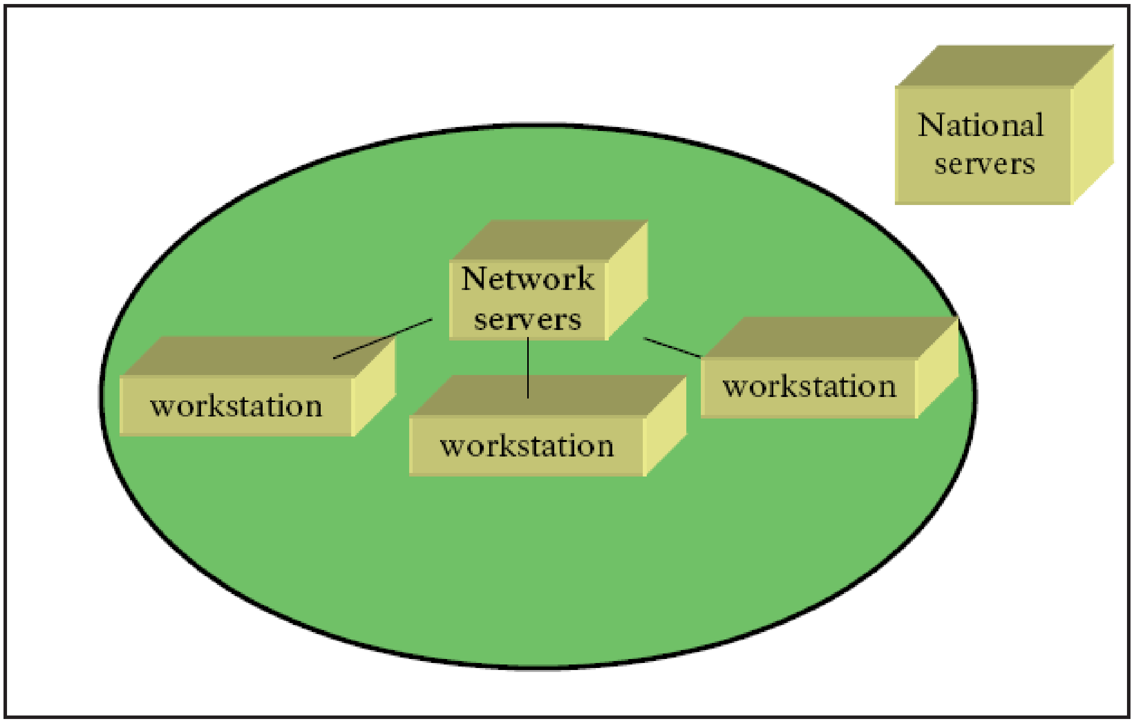

Figure 6.3 Schematic representing the logical layout and connectivity of computer resources.

The national servers host and maintain online applications that provide storage and access to basic natural resource data and information collected by the I&M program (Figure 6.4).

- NatureBib is the master database for natural resource-related bibliographic references.
- NPSpecies is the master database for species that occur in or near each park and the physical or written evidence for their occurrence (e.g., vouchers, observations, and references).
- NR-GIS Metadata Database is the master metadata database for natural resource datasets. This application is currently under development; in the interim, the desktop version of the Dataset Catalog is in use.
- NR-GIS Data Store is a graphical search interface that links dataset metadata to a searchable data server on which natural resource datasets are organized by NPS units, offices, and programs.

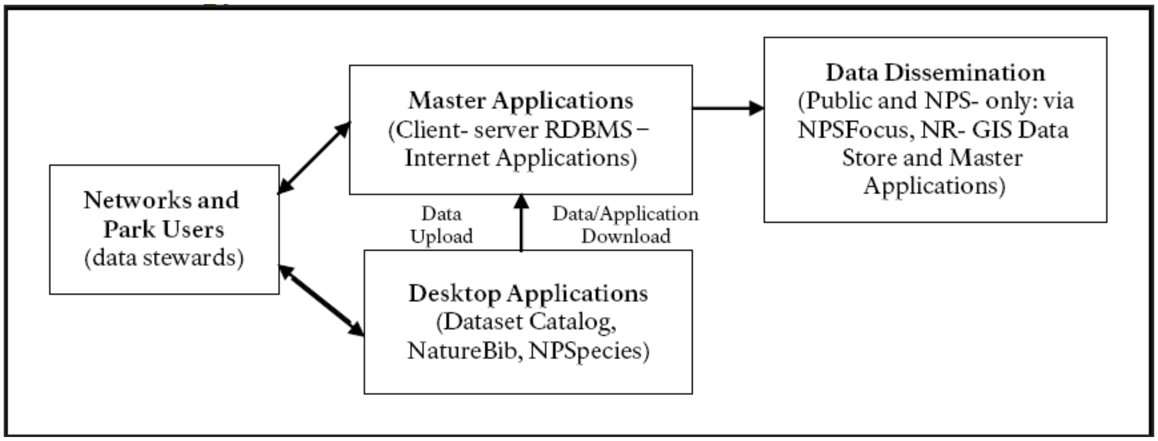

Figure 6.4. National server data flow.

The network data server hosts the following types of data and information:

- **Master project databases.** Compiled datasets for monitoring projects and other multi-year efforts that have been certified for data quality.
- **Common lookup tables.** Park name, employees, species, etc.
- **Project management application.** Used to track project status, contact information, product due dates.
- **Digital library.** Network repository for read-only pdf versions of project deliverables, reference documents pertaining to NPSpecies, and general documents related to the network (e.g., reports, methods documentation, data files).
- **Digital photo library.** Network repository for digital photos not related to a specific vital sign and not considered to be data photos.
- **Local applications.** Desktop versions of national applications such as NPSpecies and Dataset Catalog.
- **Working project materials.** Working databases and draft copies of reports.
- **Archived final datasets for inventory and monitoring projects.**
- **Public file sharing directory.**

The network GIS server hosts GIS files (personal GIS projects, park base spatial data and imagery, project-specific themes, LIDAR data, and remote-sensing analysis working and final data).

6.5. Database Design Strategy

Rather than developing a single integrated database system, the GULN uses modular, stand-alone project databases that share design standards and links to centralized data tables. Individual project databases are developed, maintained, and archived separately. In this way, datasets are modular, allowing greater flexibility in accommodating the needs of each project area. Individual project databases and protocols can be developed at different rates without a significant cost to data integration. In addition, one project database can be modified without affecting the functionality of other project databases. Also, by working up from modular datasets, we avoid a large initial investment in a centralized database and the concomitant difficulties of integrating among project areas with very different—and often unforeseen—structural requirements. Furthermore, the payoff for this initial investment is not always realized down the road by greater efficiency for interdisciplinary use.

Project database standards ensure compatibility among datasets, which is vital given the often unpredictable ways in which datasets will be aggregated and summarized. Well-conceived standards also help to encourage sound database design and facilitate interpretability of datasets. The GULN will follow the standards for database objects used by the Natural Resource Database Template (http://science.nature.nps.gov/im/apps/template/index.cfm) to the extent possible. Databases that are developed for park and network projects will contain the following main components:

- Common lookup tables that contain lists of parks, personnel, and species;
- Core tables and fields based on network and national templates that contain who, where, and when for project data collection; and
- Project-specific fields and tables containing recorded field data.

6.6. Data Acquisition and Processing

The I&M program handles two general data types:

1. Programmatic data: Any data produced from projects that are initiated (funded) by the I&M program or projects that in some way involve the I&M program.
2. Non-programmatic data: Includes data collected from NPS sources and data produced by external non-NPS sources.
    - Non-programmatic NPS data: Any data produced by the NPS that did not involve the I&M program, such as park visitor use information.
    - Non-programmatic external data: Any data produced by agencies or institutions other than the National Park Service, such as USGS, NOAA, and various state agencies.

Most data acquired by the network will be collected as field data (inventories and monitoring studies) or discovered through data-mining initiatives (legacy/existing data). Methods of field-data collection, such as paper field-data forms, field computers, automated data loggers, and GPS units, will be specified in individual monitoring protocols and study plans. Field-crew members will closely follow the established SOPs in the project protocol.

The GULN will conform to NPS standards and mandates, as well as to national I&M program standards and procedures, to facilitate program integration and data/information sharing. General and protocol-specific SOPs will provide detailed instructions for processing specific types of data.

6.7. Quality Assurance/Quality Control

The data collected during GULN inventory and monitoring studies will only be valuable, and useful in the long term, if we have confidence in the quality of that data. Our efforts to detect trends and patterns in ecosystem processes require data of documented quality that minimize error and bias. Data of inconsistent or poor quality can result in loss of sensitivity and lead to incorrect interpretations and conclusions. High-quality data and information are vital to the credibility and success of the I&M program, and everyone plays a part in ensuring that our products conform to these standards.

NPS Director's Order #11B: Ensuring Quality of Information Disseminated by the National Park Service (http://www.nps.gov/policy/DOrders/11B-final.htm) specifies that information produced by the NPS must be of the highest quality and based on reliable data sources that are accurate, timely, and representative of the most current information available. Therefore, we will establish and document procedures for quality assurance (QA) and quality control (QC) to identify and reduce the frequency and significance of errors at all stages in the data life cycle. When these procedures are followed, the progression from raw, to verified, to validated data implies increasing confidence in the quality of those data. The data manager will establish SOPs to ensure compliance with DO #11B. These procedures will document both internal and external review processes for data and information disseminated outside the network, as well as guidance for handling complaints about data quality.

Although many QA/QC procedures will depend upon the individual vital signs being monitored, some general concepts apply to all network projects. Specific procedures to ensure data quality must be included in the protocols for each vital sign. Examples of QA/QC practices include:

- Standardized field-data collection forms.
- Use of field computers and automated data loggers.
- Proper calibration and maintenance of equipment.
- Field-crew and data-technician training.
- Use of database features, such as built-in pick lists and range limits, to reduce data-entry errors.
- Automated error-checking routines.

We appraise data quality by applying verification and validation procedures. Data verification determines whether digitized data match source data. Data validation determines whether the data make sense. The Data Management Plan describes several methods for verifying and validating data, and each monitoring protocol will include specific procedures for assuring data quality.

A final report on data quality will be incorporated into the documentation for each project. This will include a listing of the specific methods used to assess data quality and an assessment of overall data quality prepared by the project leader.

6.8. Data Documentation

Data documentation is a critical step toward ensuring that all datasets retain their integrity and utility well into the future. Complete, thorough, and accurate documentation should be of the highest priority for long-term studies, and because long-term datasets are continually changing, this documentation must remain up-to-date. Data documentation refers to the development of metadata, which at the most basic level can be defined as "data about data" or, more specifically, as information about the content, context, structure, quality, and other characteristics of a dataset. Additionally, standardized metadata provide a means to catalog datasets within intranet and internet systems, thus making these datasets available to a broad range of potential users.

Without metadata, potential users of a dataset have little or no information regarding the quality, completeness, or manipulations performed on a particular copy of a dataset. Such ambiguity results in lost productivity (as the user must invest time in tracking down information) or, in the worst case, renders the dataset useless because answers to these and other critical questions cannot be found. As such, data documentation must include an up-front investment in planning and organization.

At a minimum, we will require the following elements for documentation of all data managed by the network:

- Data dictionaries and Entity Relationship Diagrams for all tabular databases;
- Formal metadata compliant with Federal Geographic Data Committee standards, the National Biological Information Infrastructure (NBII) profile (where appropriate), and the NPS Metadata Profile for all geospatial and biological datasets; and
- Project documentation.

We will create all metadata according to NPS standards and guidelines. Formal metadata will be created using Dataset Catalog, an NPS tool for producing abbreviated metadata, or the ArcCatalog data management application included with ArcGIS software, supplemented by the NPS Metadata Tools Extension developed by the NPS Midwest Region GIS Technical Support Center. We will publish all metadata to the online NR-GIS Metadata Database. All documentation will also be maintained with its accompanying dataset(s) on network servers.

6.9. Data Analysis and Reporting

Creating meaningful information from datasets through summaries and analyses is a critical component of the I&M program and characterizes the network's data management mission to provide useful information for park personnel. Close coordination between the project manager, ecologist, and data manager is important to identify opportunities and methods to streamline data extraction and exports from databases based on project objectives, protocols, and data management and analysis SOPs. Where possible, project databases will include automated summary and report routines.

To make datasets available for subsequent analysis by third parties, the network will establish a timeline and series of data processing steps, including error-checking, summarizing, analyzing, and distributing data. Project managers will be responsible for their project databases, but once a year they will review and certify the dataset, write an annual report, and make the data available in a common repository for others to use in syntheses and further analyses. Data analysis and reporting are discussed in more detail in Chapter 7.

6.10. Data Dissemination

One of the most important goals of the I&M program is to integrate natural resource inventory and monitoring information into NPS planning, management, and decisionmaking. To accomplish this goal, the network will use a variety of distribution methods to make data and information collected and developed as part of the program available to a wide variety of users, including park staff, other researchers and scientists, and the public. We will ensure that:

- Data are easily discoverable and obtainable;
- Distributed data are accompanied by complete metadata that clearly identifies the data as a product of the NPS I&M program;

- Data that have not yet been subjected to full quality control will not be released by the network, unless necessary in response to a FOIA request or unless accompanied by a data quality disclaimer;
- Sensitive data are identified and protected from unauthorized access and inappropriate use; and
- A complete record of data distribution/dissemination is maintained.

Distribution options include the network data and GIS servers, the GULN digital libraries, and several online interfaces. The national I&M program has developed several web-based applications and repositories to store different types of park natural resource information:

- **NPSpecies:** Data on park biodiversity (species information).
- **NatureBib:** Park-related scientific citations.
- **Biodiversity Data Store:** Raw or manipulated data products that document the presence/absence, distribution, and/or abundance of any taxa in NPS units.
- **NR-GIS Metadata and Data Store:** Spatial and non-spatial metadata and accompanying datasets.
- **Gulf Coast Network Web Sit**e: Reports and metadata for all I&M data produced by the network.

6.11. Data Maintenance, Storage, and Archiving

Data, documents, and any other products that result from projects and activities that use network data are all crucial pieces of information. Directions for managing these materials are provided in NPS Director's Order #19: Records Management (2001; http://www.nps.gov/refdesk/DOrders/DOrder19.html) and the accompanying NPS Records Disposition Schedule (NPS-19 Appendix B, revised 5-2003; http://home.nps.gov/applications/wapc/records/nps19app-b.pdf). This guidance states that records of natural and cultural resources are considered "mission-critical" (i.e., permanent records that are to be transferred to the National Archives when 30 years old), and that copies of these materials "should not, in any instance, be destroyed."

To ensure high-quality, long-term management and maintenance of this information, the GULN will implement procedures to protect information over time. These procedures will permit a broad range of users to easily obtain, share, and properly interpret both active and archived information, and they will ensure that digital and analog data and information are kept up-to-date in content and format so they remain easily accessible and usable, and protected from catastrophic events (e.g., fire and flood), user error, hardware failure, software failure or corruption, security breaches, and vandalism.

Technological obsolescence is a significant cause of information loss. Data can quickly become inaccessible to users if they are stored in out-of-date software programs, on outmoded media, or on deteriorating (aging) 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, datasets must be consistently migrated to new platforms or saved in formats that are independent of specific software or platforms (e.g., ASCII delimited text files). Storage media should be refreshed (i.e., copying datasets to new media) on a regular basis, depending upon the life expectancy of the media.

Regular backups of data and off-site storage of backup datasets are the most important safeguards against data loss; therefore, we have established data maintenance and backup schedules for data stored on the network data servers. Backups of data stored on personal workstations are done on external hard drives and are the responsibility of each staff member. In addition, it is recommend that staff members store or regularly copy important files onto the network server. Backup routines represent a significant investment in hardware, media, and staff time; however, they are just a small percentage of the overall investment that is made in program data.

Chapter 7
Data Analysis and Reporting

This chapter summarizes our approach to analysis and reporting of monitoring data, interpretation, and information for our client parks. Our approach is based upon three factors that contribute to monitoring-program success: quality and timeliness of information, rigorous data analysis, and effective communication to address multiple audiences with a diverse range of information needs. The first section provides an overview of general program strategies to address information needs. The following sections provide summaries of data-analysis approaches and staff responsibilities, network information reports, targeted audiences, and proposed reporting schedules.

7.1. Information, Audiences, and Strategies

The success of a monitoring program may best be measured by the quality and timeliness of its primary product: information. Information is the common currency among the many different activities and people involved in the stewardship of a park's natural resources. Activities such as park planning, inventories, monitoring, research studies, restoration, control of invasive species, management of threatened and endangered species, fire management, trail and road maintenance, law enforcement, and interpretation all require natural resource information. As part of the NPS's effort to improve park management through greater reliance on scientific knowledge, a primary role of the I&M program is to develop, organize, and make available natural resource data. The I&M program also contributes to the institutional knowledge of the NPS by facilitating the transformation of scientific data into information through analysis, synthesis, and modeling. These data may come from many sources, including new field data collected through monitoring efforts, other park projects or programs, other agencies, and the broader scientific community (Figure 7.1).

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

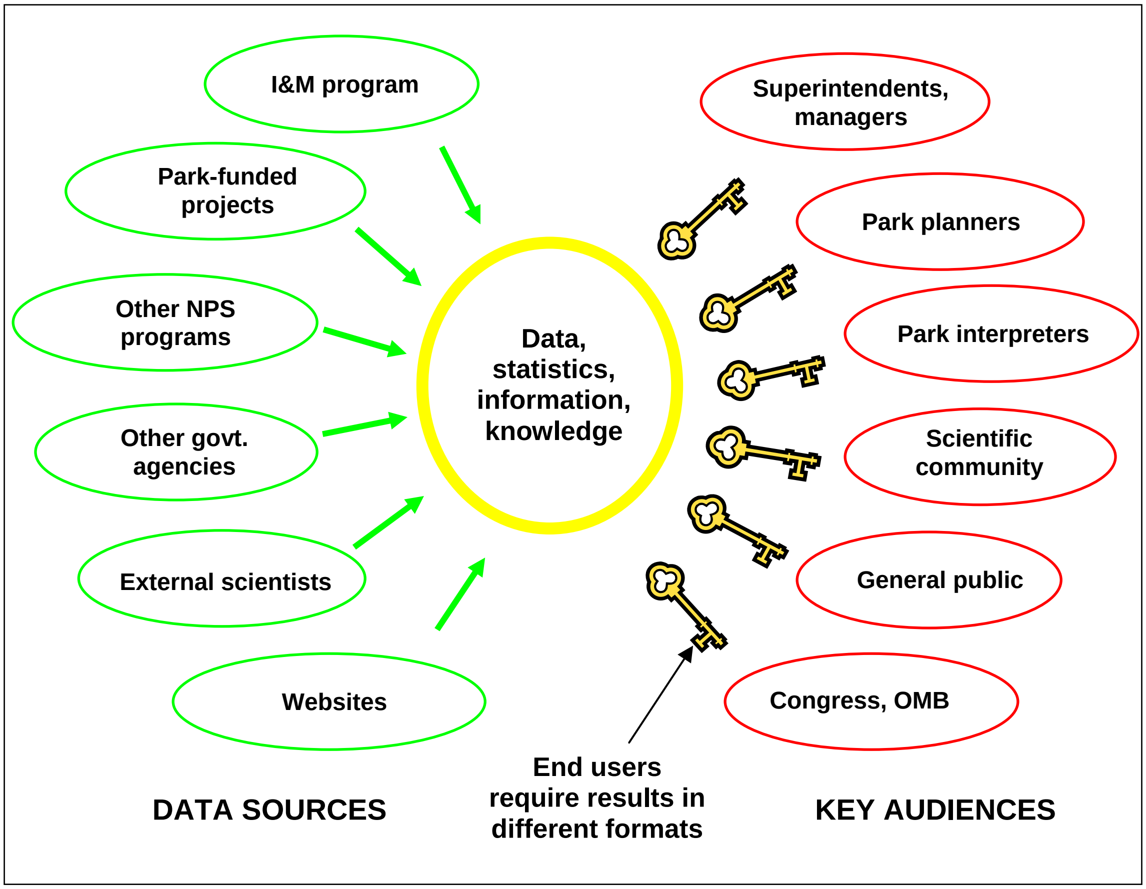

Figure 7.1. Scientific data for determining the status and trend in the condition of selected park natural resources will come from multiple sources, and will be managed, analyzed, and disseminated to multiple audiences in several different formats in order to make the results more available and useful.

We recognize that information reporting is not effectively met by a uniform approach; we have to meet the needs of many audiences. The primary utility for many of our products is at the park level, where the key role of the I&M program is to provide park managers and interpreters with the information they need to make better-informed decisions and to work more effectively with other agencies and individuals for the benefit of park resources. Discussion with staff at all network parks has been extremely informative; park staff at various levels, from superintendents to resource technicians and interpretive staff, are intensely interested in the outcomes and findings of monitoring efforts. Each has different needs and desires relative to what, how, and when information is provided to them. In addition, certain data are needed at the regional or national level and, as stated by the National Park Advisory Board, the findings "must be communicated to the public, for it is the broader public that will decide the fate of these resources." Other key audiences for monitoring results and information include park planners, interpreters, researchers and other scientific collaborators, the general public, Congress, and the President's Office of Management and Budget (OMB; Figure 7.1). Our strategy for adequately addressing this diverse audience is summarized in Section 7.3.

7.2. Data Analysis

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

Four general levels of data analysis are anticipated during implementation of our monitoring protocols and program: (1) descriptive and summary statistical analysis; (2) determination of conditional status for a monitored resource; (3) determination of trends in condition over time for a monitored resource; and (4) synthesis of status and trend information across multiple resources over time to depict larger-scale aspects of ecosystem health and function (Table 7.1). Descriptive analysis may be performed at any time following data collection and entry. Status and trends analysis will be performed on protocol-specific schedules. Larger-scale synthesis across multiple resources and monitoring efforts will occur only after adequate amounts of data have become available for all considered resources and variables. In addition, trend analysis and synthesis can only occur after appropriate time has passed to adequately capture temporal scales of considered phenomena. Long-term trend reports and syntheses will be subject to peer review, as appropriate. Data analysis may be performed by many different people, including the network data manager, coordinator, ecologist, hydrologist, GIS specialist, and/or associated technicians and interns. Generally, analysis will be supervised and coordinated by the key project lead and/or network coordinator and ecologist.

Table 7.1. Four general levels of data analysis for Gulf Coast Network vital signs, and the lead analyst responsible for each.

Level of analysis	Description	Lead analyst*
Data summarization/ characterization	Calculation of basic statistics from monitoring data, including measures of location and dispersion. Summarization encompasses measured and derived variables specified in the monitoring protocol, and forms the basis of more comprehensive analyses and communication of results in both graphical and tabular formats.	The principal investigator (PI) for each monitoring protocol, working with the data management staff, will produce data summaries. Parameters and procedures are specified in the monitoring protocols.
Status determination	Analysis and interpretation of the 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 historical levels? • Do observed values exceed a regulatory standard, known or hypothesized ecological threshold? • What is the spatial distribution (within park, network, or ecoregion) of observed values for a given point in time? • Do these patterns suggest directional relationships with other ecological factors? • Status determination will involve both expert interpretation of the basic statistics and statistical analysis. Assumptions about the target population and the level of confidence in the estimates will be ascertained during the analysis.	The PI for each monitoring protocol is the lead analyst for status determination, but the network coordinator, cooperators, partners, interns or other network staff may conduct analyses and assist with interpreting results. Consultation with regulatory and subject matter experts will support status determination.
Trends evaluation	Evaluations of trends in vital signs will address: • Whether there is directional change in a vital sign over the period of measurement and • What the rate of change is, and how this pattern compares with trends over broader spatial scales and known ecological relationships. 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.	The PI for each monitoring protocol is the lead analyst for trend determination, but the network coordinator, cooperators, partners, interns or other network staff may conduct analyses and assist with interpreting results. Comparison with relevant long-term experimental results will aid interpretation.

Level of analysis	Description	Lead analyst*
Synthesis and modeling	Examination of patterns across vital signs and ecological factors 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); and • Development of predictive models. Synthetic analysis has great potential to explore ecological relationships in the context of vital signs monitoring and will require close interaction with academic and agency researchers.	The network coordinator, ecologist, and hydrologist are the lead analysts for data synthesis and modeling, but the PIs for various protocols and cooperators, partners, interns, or other network staff may conduct analyses and assist with interpreting results. Integration with researchers and experimental results is critical.

*The lead analyst will ensure that data are analyzed and interpreted within the guidelines of the protocol and program, and ensure that trend reports and syntheses are subject to peer review. Actual analysis may be performed by a variety of personnel.

7.3. Information Reporting

The GULN reporting strategy focuses on meeting the needs of parks first, followed by higher NPS levels, other government agencies, and the public. We will implement this strategy by developing a comprehensive array of report formats and schedules that ensure we can deliver the right types of content, including data, technical analyses, conclusions, interpretations, and—where appropriate—recommendations for possible actions, to a wide range of users in a timely fashion (Tables 7.2 and 7.3). The range of users will include network park staff, scientists, cooperators, adjacent land managers, and other potential collaborators. Information from network data-mining and inventory projects is being entered into the NPS master web-based databases, and monitoring data will be added as that part of the program gets underway (i.e., to NPSpecies, NatureBib, and the Natural Resource Database Template). The network has developed a website (http://www.nature.nps.gov/im/units/guln/), as an additional route to disseminate information and updates to parks and the public. Network staff and cooperators will present posters and papers at professional meetings, write papers for publication in technical journals and other publications, and write popular articles for park brochures and newspapers. We are also exploring the possibility of sharing information from network projects with the Central Southwest/Gulf Coast Information Node of the NBII, a collaborative effort that links information, biological databases, and analytical tools with information consumers such as government agencies, academic institutions, non-government organizations, and private industry.

Table 7.2. Summary of the content of reports and other information products of the I&M monitoring effort, intended audience, reporting schedule, and responsible entities for each.

Monitoring protocol	Information content	Target audience and format	Responsible person	Schedule
Weather and Climate[a]	Data will be collected for all parks from regional and national databases where those data are determined to accurately reflect in-park conditions. Data include precipitation amounts and patterns, temperature, relative humidity, wind speeds and direction, storm events with measures, air quality measures (ozone, particulate counts).	Park management staff, other federal and state agencies, scientific community.	Network coordinator, data manager*, GIS specialist provide database management for parks. National Weather Service and NPS-WASO/Air Resources Division lead on data analysis and interpretation.	Annual reports. Additional reports TBD by park needs.
Coastal Geomorphology and Landforms	LiDAR datasets with elevation (z), GPS coordinates (x, y), shoreline position, and time for each sample point. Data for parkwide survey.	Park management and interpretive staff, other federal and state agencies (FL, MS, TX), scientific community, public interest.	Network coordinator, data manager, GIS specialist, ecologist*. USGS, NASA collaboration in sampling, data analysis, and interpretation.	Annual reports, event reports, long-term trend reports as requested by park.
Estuarine and Near-Shore Coastal Waters	Summary of baseline, trends in pH, temperature, dissolved oxygen, specific conductance, major ions, turbidity, selected chemical analytes, primary productivity, sediment characteristics, depth by site, sample date/time. May include aquatic macro-invertebrate species diversity and numbers.	Park management and interpretive staff, other federal and state agencies (FL, MS, TX), scientific community, public interest.	Network hydrologist*, coordinator, data manager, GIS specialist, ecologist. State and contract collaboration in sampling, data analysis, and interpretation.	Annual reports, additional semi-annual reports TBD by park, long-term trend reports as requested by park.
Freshwater	Summary of baseline, trends in pH, temperature, dissolved oxygen, specific conductance, major ions, selected other chemical analytes, flow regime data by site, site locations, date/time of samples (sites may include standing and running waters, ground water). Future development may include aquatic macro-invertebrate species diversity and numbers.	Park management and interpretive staff, other federal and state agencies, scientific community, public interest.	Network hydrologist*, coordinator, data manager, GIS specialist, ecologist. State and contract collaboration in sampling, data analysis, and interpretation.	Annual reports, additional semi-annual reports TBD by park (acute events), long-term trend reports as requested by park.

Monitoring protocol	Information content	Target audience and format	Responsible person	Schedule
Vegetation Structure and Composition	LiDAR data, including ground, canopy, and mid-canopy elevation, density, and frequency data; GPS coordinates and date/time for each sample point in a parkwide dataset. Matrix of color infrared (CIR) images with taxon and condition indicators, GPS location, and time for each image. Ground-truth taxonomic and frequency data on plants in sampled areas.	Park management and interpretive staff, other federal and state agencies, scientific community, public interest.	Network coordinator, data manager, GIS specialist, ecologist*. USGS, NASA collaboration in sampling, data analysis, and interpretation.	Annual reports, additional semi-annual reports TBD by park (follow-up on storms, management-specific issues), long-term trend reports as requested by park (5-year).
Submerged Aquatic Vegetation[b]	Aerial extent and locations of seagrass beds, measures of bed health and condition (e.g., density, plant biomass, epiphyte loads). Links to estuarine water quality monitoring.	Park management and interpretive staff, other federal and state agencies, scientific community, public interest.	Network coordinator*, data manager, GIS specialist, ecologist. Contract collaboration in sampling, data analysis and interpretation	Annual reports, event reports, long-term trend reports as requested by park.
Amphibian Communities	Counts, body lengths and weights, sex, collection locations and times/date by species for adult amphibians (*Anura* and *Caudata* spp.). Egg-mass counts, mass size estimates, species ID, sample location data, time/date. Digital record images for species and locations. Audio records of calls (*Anura*). Weather conditions, air temperature, and relative humidity at sample sites. Water pH, temperature for all aquatic sites.	Park management and interpretive staff, other federal and state agencies, scientific community, public interest.	Network coordinator, data manager, GIS specialist, ecologist*. Contract collaboration in sampling, data analysis, and interpretation.	Annual reports, additional semi-annual reports TBD by park (follow-up on storms, mgmt specific issues), long-term trend reports as requested by park.
Landbirds[c]	Bird-count data by location or site by date/time. Data may include species, sex, distance from sampler, guild sum counts, with sample date/time; weather data (precipitation, temperature, wind speed and direction, cloud-cover) during sampling period.	Park management and interpretive staff, scientific community, public interest.	Network coordinator, data manager, GIS specialist, and ecologist. GULN provides advice and data management support to user parks. Parks* implement and report on monitoring. Contract collaboration in sampling, data analysis and interpretation.	Report types and schedule TBD. User parks determine level of network reporting support.

Monitoring protocol	Information content	Target audience and format	Responsible person	Schedule
Adjacent Land-use Change	Data will include planned construction period, dimensional and construction-type information, and locations of new and planned land development in defined buffer around parks. Data collected from filed building permits on a periodic basis by park.	Park management and interpretive staff.	Network coordinator*, data manager, GIS specialist. Contract NGO collaboration in sampling, data analysis, and interpretation.	Real-time alert reports, monthly or other period of routine report TBD by park and by local activity level. Annual report for all parks.

*indicates lead

[a] Follows NPS national protocols and guidelines.

[b] Adopted from NCBN.

[c] Adopted from HTLN Landbirds protocol; GULN to provide guidance and data assistance to park efforts.

Table 7.3. List and proposed schedule for the various formal reports and publications related to the I&M program.

Report or Venue	Schedule	Who does it?
Annual Administrative Report and Work Plan	Annually: October 30	Network coordinator
Annual monitoring reports or specific project reports to parks, STAC (formal analysis and management recommendations)	Annually: variable, usually December/January. STAC meets in selected park semi-annually.	Network coordinator, network staff
Analysis and synthesis of data, trends; reports to parks, STAC (formal analysis and management recommendations)	Annual analysis: variable, usually December/January. Trends vary by monitoring topic; many will not be discernible over short time periods. STAC meets on selected park semi-annually.	Network coordinator, network staff
Synthesis reports	Every 3–5 years. Integrates findings from all 19 vital signs, identifies linkages among the vital signs, infers cause and effect, and serves to identify research needs.	Network coordinator, network staff
Resource monitoring interpretive highlights of interest to park visitors	Variably as outcomes of interest become available.	Network staff
Technical and scientific papers, presentations, book chapters, journals, workshops, meetings	Variably as material becomes available.	Network staff, collaborators, and cooperators
National report: Condition of Natural Resources in National Parks	Annually: date variable.	NPS WASO, with input from parks, I&M networks, other divisions
Periodic program reviews	Every five years.	WASO I&M staff
Park and resource issue-focused workshops and meetings in parks	Variably as material becomes available.	Network and park staff, collaborators and cooperators, outside experts
Website-based data, newsletters, report summaries	Posted as materials become available.	Network staff

Note: All public news releases will be coordinated through the parks' resource managers and superintendents prior to release.

Chapter 8
Administration and Implementation

This chapter describes the GULN plan for administering the monitoring program. The network has developed a near-term (three- to five-year) plan under which monitoring will begin and the development of additional protocols will be initiated. In this chapter, we describe the makeup of the Board of Directors and Technical Committee; the network decisionmaking process; the staffing plan; how network operations are integrated with other park operations; key partnerships; how field work will be carried out; and the periodic review process for the program.

8.1. Board of Directors

The Gulf Coast Network Board of Directors (BOD) includes the superintendent from each network park, the Southeast Region inventory and monitoring coordinator, and the network coordinator (Table 8.1). One of the superintendents serves as the board chairperson and one serves as vice chairperson. Because the parks are evenly split between the Southeast Region and the Intermountain Region, the vice chair is selected from a park in the opposite region as the chairperson. A new vice chair is selected bi-annually, when the sitting vice chair becomes chairperson. The result is that the chairmanship of the board alternates between the two regions. The superintendents are the voting members of the board, and the other members serve as advisors to the superintendents. A charter for the BOD, approved in November 2004, guides the function and operation of the board. The BOD is committed to operate in and foster an atmosphere of fairness, trust, selflessness, and respect. A key feature of the charter is that all decisions are made by consensus.

Table 8.1. Composition of the Gulf Coast Network Board of Directors, July 2007.

Title	Name	Voting member	Advisor to board
Superintendent, BITH	Todd Brindle, *Vice Chairperson*	X	
Superintendent, GUIS	Jerry Eubanks	X	
Superintendent, JELA	David Luchsinger	X	
Superintendent, NATR	Vacant	X	
Superintendent, PAAL	Vacant	X	
Superintendent, PAIS	Vacant	X	
Superintendent, SAAN	Steve Whitesell	X	
Superintendent, VICK	Monika Mayr, *Chairperson*	X	
Southeast Region I&M Coordinator	Larry West		X
GULN Coordinator	Martha Segura		X

As described in the network charter, the major responsibilities of the BOD are to:

- Promote accountability and effectiveness for the I&M program through timely review of progress, quality control, and GULN expenditures.
- Provide guidance to the GULN coordinator, Scientific/Technical Advisory Committee, and natural resource staffs of GULN parks in the design and implementation of vital signs monitoring and other management activities related to the Natural Resource Challenge.
- Review and approve recommendations from the GULN coordinator and the Scientific/Technical Advisory Committee.
- Determine strategies and procedures for leveraging GULN funds and personnel to best accomplish the network's goals.
- Consult on the hiring of new network personnel.

8.2. Scientific/Technical Advisory Committee

The Board of Directors and the Scientific/Technical Advisory Committee work together to develop and implement the monitoring program. The BOD is the final decisionmaking body and is accountable for the entire network. The STAC provides technical assistance and advice to the board. The permanent members of the STAC consist of at least one representative of the resource management staff of each of the network parks (usually the chief), delegated by the superintendent (Table 8.2). The network coordinator serves as the chairperson for the STAC. Remaining members of the committee include the network data manager, the network ecologist, and the network hydrologist. The STAC also includes key cooperators and members of the academic community and USGS involved in development of the conceptual models, monitoring protocols, and water quality monitoring plan. These ad hoc advisors to the STAC are not considered permanent members, but play an important role in providing technical expertise to the STAC and BOD. Ultimately, the decisions made concerning the monitoring program are made by the BOD, and are based on the management needs of the parks.

Table 8.2. Composition of the Gulf Coast Network Scientific/Technical Advisory Committee, June 2007.

Title	Name	Park
GULN Coordinator	Martha Segura	GULN
GULN Science Information Specialist (Data Manager)	Whitney Granger	GULN
GULN Ecologist	Robert Woodman	GULN
GULN Hydrologist	Joe Meiman	GULN
GULN GIS Specialist	Jeff Bracewell	GULN
Supervisory Biologist	Curtis Hoagland	BITH
Natural Resource Management Specialist	Riley Hoggard	GUIS
Resource Management Specialist	Nancy Walters	JELA
Natural Resource Management Specialist	Kurt Foote	NATR
Chief of Science and Resources Management	Darrell Echols	PAIS
Supervisory Ranger	Greg Smith	SAAN
Biologist	Greg Mitchell	SAAN
Natural Resource Program Manager	Virginia DuBowy	VICK

8.3. Staffing Plan

In accordance with national I&M goals, network activities revolve around five program functions:

- **Conducting baseline inventories** of natural resources in network parks (including those currently underway: vascular plant and vertebrate surveys, vegetation mapping, soils mapping) and fulfilling other critical inventory needs of network parks;
- **Developing an integrated, scientifically credible, long-term ecological monitoring program** to efficiently and effectively monitor status and trends of selected vital signs;
- **Developing data management and decision support systems,** including GIS and other tools, to aid park managers in identifying, implementing, and evaluating management options;
- **Integrating inventory and monitoring programs** with park planning, maintenance, interpretation, and visitor-protection activities to help the parks in their efforts to make natural resource protection even more of an integral part of overall park management; and
- **Cooperating with other agencies and organizations** to share resources, achieve common goals, and avoid unnecessary duplication of effort and expense.

The network staffing plan is designed to support these functions and provide park managers with the professional expertise needed to implement a successful inventory and monitoring program. The staffing plan is designed with the goal of keeping fixed costs, such as permanent staff, vehicles, and office space, at less than 50% of the network budget (see Chapter 10) to allow flexibility in partnerships and data acquisition. We do not expect that most data collected in support of the network will be done by network staff. Shorter-term technical and field-data collection positions will be filled by cooperative agreements with other state and federal agencies and universities, students, interns, and volunteers from the Student Conservation Association. The core permanent network staff consist of a coordinator, a quantitative ecologist, a hydrologist shared 50:50 with the CUPN, a science information specialist (data manager), and a GIS specialist (Table 8.3). Short descriptions of these and other positions follow.

8.3.1. Coordinator

The coordinator provides overall direction for the GULN I&M program. The coordinator works with network parks, the STAC, BOD, and the Southeast Region I&M coordinator to develop inventory and monitoring strategies and recommend implementation schedules for funding and staffing consideration. This position coordinates project-specific data analysis and reporting, and ensures that information is provided to park managers in useful formats. The coordinator supervises the GULN professional-level positions and provides general oversight and accountability for the network program.

Table 8.3. Permanent Gulf Coast Network staff positions and their primary duties.

Position	GS-level	Duty station	Primary duties
Network Coordinator	12	Lafayette, LA	Provides direction and manages overall planning and implementation of the network I&M program; provides program oversight and supervision; serves as advisor to the Board of Directors in making programmatic decisions and maintaining accountability of the program.
Science Information Specialist	11	Lafayette, LA	Primary person responsible for all aspects of data management for the network; conducts data archiving and dissemination, database development, and overall QA/QC for the network; coordinates all IT activities.
GIS Specialist	9/11	Lafayette, LA	Coordinates and maintains all GIS and spatial data for the network; ensures data and metadata standards and quality; assists network parks with GIS needs; conducts analyses of spatial data.
Quantitative Ecologist	12	Lafayette, LA	Serves as the principal advisor in ecology for the network; coordinates the development of monitoring protocols; coordinates with partners and academia on protocol development and implementation; conducts project-specific data analysis, summary and reporting, data validation, and verification.
Hydrologist	12 (share with CUPN)	Mammoth Cave, KY (CUPN)	Coordinates, develops, and implements the network's water quality monitoring program; trains technicians; conducts project-specific data analysis, summary and reporting, data validation and verification; coordinates partnerships for the purpose of water quality monitoring.

8.3.2. Science information specialist

The data manager has a central role in ensuring that project data conform to program standards, designing project databases, disseminating data, and ensuring long-term data integrity, security, and availability. In order to maintain high data-quality standards and promote ready use of project data, the data manager collaborates with the ecologists and/or project managers to develop data-entry forms, QA/QC procedures, and automated reports. The data manager also coordinates all information technology (IT) activities, purchases computers, and collaborates with university and USGS computer support personnel.

8.3.3. GIS specialist

The GULN GIS specialist maintains spatial data themes associated with network parks and inventory and monitoring projects; incorporates spatial data into the network GIS and maintains standards for these data and the associated metadata; develops procedures for sharing and disseminating GIS data to network parks and partners; conducts analyses of spatial data; assists network parks on park-based projects; trains network staff, interns, and technicians on the use of GPS and GIS technology; and serves as the primary contact with Southeast Regional Office (SERO) GIS support staff.

8.3.4. Ecologist

The ecologist coordinates the development of monitoring protocols, including protocol design and pilot testing; data collection (field collection and collection of existing data from other sources); data quality during all phases of a project (including the QA/QC process and the creation of project documentation and metadata); and the preparation and dissemination of project analyses and reports. The ecologist also provides oversight and supervision for biological technicians working on GULN projects. In addition, this position serves as the primary technical contact for potential partners working on monitoring issues.

8.3.5. Hydrologist

The hydrologist serves as the primary subject-matter expert for aquatic resource issues. The hydrologist coordinates all aspects of water quality monitoring projects on the five predominantly freshwater parks, including protocol design and pilot testing; data collection (field collection and collection of existing data from other sources); data quality during all phases of a project (including the QA/QC process and the creation of project documentation and metadata); and the preparation and dissemination of project analyses and reports. The hydrologist also provides oversight and supervision for biological technicians working on GULN and CUPN projects. In addition, this position serves as the primary technical contact for partners working on aquatic resource issues in all eight network parks.

8.3.6. Interns

In addition to the permanent staff listed in Table 8.3, the network currently has two student interns from the University of Louisiana–Lafayette. The GULN maintains an agreement with the University of Louisiana–Lafayette for office space and both undergraduate and graduate student interns. Interns have assisted the network with data management activities, web site template migration, and administrative tasks.

8.4. Program Integration

Integration with park operations will be an important component of this program. Data, summaries, and reports will be made available to all park operations, including resource management, interpretation, law enforcement, and maintenance. Most network parks already integrate cultural and natural resource management activities. We have selected vital signs and monitoring approaches with the express purpose of providing data that can be used by the parks; network data have already been used in planning for cultural landscape management. Where possible, parks have indicated their ability to provide housing for field crews, transportation to monitoring sites, and other assistance to the network. Overall, the network parks are unable to have park personnel conduct monitoring of network vital signs. The network has developed individual conceptual diagrams for each of the parks (Appendix K) that are designed to be modified as needed to graphically show what the network is monitoring and why.

The GULN I&M program office in Lafayette is centrally located in the network, but is not located within a park. In-park visits by network staff and regularly scheduled meetings will be important for developing greater integration into park operations. As field work begins and data are collected, more integration with park staffs will be possible. Opportunities to help all divisions in the parks will be actively sought. Participation by park personnel on the network's Board of Directors and STAC further helps to integrate the network's planning with the parks' concerns and activities.

8.5. Partnerships

Partnerships and cooperative agreements will be important to the implementation of the GULN monitoring program. Some of the key partners for implementation of the monitoring program are listed in Table 8.4. Additional agreements will be put in place for vital signs that will be developed in later years. (Cooperative agreements that were used solely for the purpose of the inventories are not included in this list).

Table 8.4. Key partnerships for the Gulf Coast Network.

Agency/ Organization	Division/ Department	Personnel	Duties
USGS	Florida Integrated Science Center	Dr. John Brock and Amar Nayegandhi (ETI Professional, Inc.)	Collection and interpretation of LiDAR data, development of the coastal geomorphology protocol and the vegetation structure protocol
Louisiana State University	Herbarium	Drs. Kyle Harms and Lowell Urbatsch	Ground truth in support of the vegetation structure protocol
USGS	Louisiana Water Science Center	Drs. Chris Swarzenski and Dennis Demchek	Phase 1 planning and development of the estuarine water quality monitoring plan
Texas A&M University	Landscape Architecture and Urban Planning	Drs. Chris Ellis and Sam Brody	Development of the land use change early detection protocol
University of Georgia	Savannah River Ecology Laboratory	Drs. Kurt Buhlmann and Whit Gibbons	Development of the network-wide Amphibian Communities monitoring protocol
Lower Neches Valley River Authority			Water quality monitoring at Big Thicket National Preserve
San Antonio River Authority			Water quality monitoring at SAAN
San Antonio Audubon Society			Landbird monitoring at SAAN

8.6. Program Review Process

Periodic reviews of the network's monitoring program and protocols are critical to ensure that the program is on the right course and that if course corrections are needed, they are accomplished quickly to save unnecessary expenditures of resources and time. Review of the program will occur at several different levels and timescales.

1. On an annual basis, the Annual Administrative Report and Work Plan (AARWP) provides the STAC and BOD with an opportunity to review what has taken place during the past year and what is planned for the upcoming year, and thus, an annual opportunity to review and evaluate the program. The AARWP is also presented at the annual BOD meeting, allowing the board to discuss progress and ideally resulting in a real evaluation and not a routine approval of the plan.
2. The network is planning an annual STAC meeting that will be an opportunity to present and discuss the technical aspects of the monitoring data, allow park resource managers to convene, present monitoring data and analyses, and discuss resource issues of concern with other managers in the network.
3. The program will be formally reviewed by WASO at least once every five years. A formal report is generated from this periodic review, making specific suggestions for changes and revisions in the monitoring program.

Chapter 9
Schedule

This chapter describes the proposed schedule for implementing the GULN vital signs monitoring program. For the protocols under development in the next three-to-five years, we describe the key tasks or issues that must be addressed for each (Table 9.1). We also show the schedule for development and implementation of monitoring for each vital sign for the next five years, or through 2011 (Table 9.2). Detailed sampling schedules for individual protocols are not included here; those details will be included in the protocols themselves.

9.1. Key Issues for Each Vital Sign

Table 9.1 describes key events and issues that must occur and be addressed in establishing protocols for the 19 higher-priority vital signs (see Chapter 5). For some vital signs, this may simply entail some coordination with an entity already collecting applicable data (e.g., state water quality programs). For others, this will require a more detailed scoping of the vital sign, pilot data collection efforts, and/or determining analysis methods for the data. Several protocols are designed to address more than one vital sign (see Chapters 4 and 5). In assigning a target calendar year for protocol completion, we have attempted to account for such differences to project the most feasible completion date possible.

Table 9.1. Tasks to be accomplished on protocols before monitoring will be implemented.

Protocol (target year for protocol completion)	Vital sign	Key events and issues to be addressed before monitoring will be implemented
Weather and Climate (2007)	Weather/Climate	Network-wide inventory of existing weather stations was started in FY06 under the larger WASO project. This project will result in recommendations for additional weather stations, if needed. The network will adopt all nationally set standards for weather data. Work will focus on data collection, database development, and reporting strategy.
Estuarine and Near-Shore Coastal Waters (2007)	Water Chemistry Water Nutrients Water Toxics	Techniques for monitoring estuarine water quality are well known. The network will implement a combination of probabilistic and continuous stations following established protocols and in collaboration with SECN. Work focuses on database development, establishing partnerships, completing park-specific sampling designs, and writing the protocol to NPS specifications.
Freshwater (2007)	Water Chemistry Water Nutrients Water Toxics	Protocols are currently being completed for the five freshwater parks. Work focuses on writing the protocol to NPS specifications, establishing partnerships, database development, and field-testing protocols.
Vegetation Structure and Composition *(Non-native Vegetation, Salt Marsh Plant Communities, Terrestrial Vegetation, and Fire and Fuel Dynamics modules)* (2007)	Non-native Vegetation Salt Marsh Plant Communities Terrestrial Vegetation Fire and Fuel Dynamics	Work will focus on ground-truthing in selected vegetation units and sites the standard suite of vegetation metrics that have been derived from the LiDAR data, database development, and writing the protocol to NPS specifications.
Amphibian Communities (2007)	Amphibians	Techniques for monitoring amphibians are well established. Work will focus on development of specific sampling designs for each park, database development, and writing the protocol to NPS specifications.
Landbirds (2007)	Migratory Birds Resident Birds	NPS-approved protocol and a database exist for monitoring landbirds. Work focuses on developing park-specific implementation plans (SAAN as pilot), with focus on this effort being coordinated by each interested park.
Adjacent Land-use Change (2007)	Land Cover/Land Use	Determine success of the “proof of concept” GIS-system currently under development through a cooperative agreement for SAAN. Work will focus on writing the protocol to NPS specifications and expanding the applicability to more network parks.
Coastal Geomorphology and Landforms (2008)	Coastal Dynamics	Techniques for monitoring changes in barrier island morphology/topography are well established. Work will focus on determining frequency of sampling, developing a data management strategy, and writing the protocol to NPS specifications.
Vegetation Structure and Composition *(Riparian Communities module)* (2008)	Riparian Communities	Work will focus on deriving system-specific metrics and development of a “Riparian Communities Assessment” module (SOP) in the vegetation structure protocol.

Protocol (target year for protocol completion)	Vital sign	Key events and issues to be addressed before monitoring will be implemented
Vegetation Structure and Composition *(Forest Health module)* (2008)	Forest Health	Work will focus on deriving system-specific metrics and development of a "Forest Health Assessment" module (SOP) in the GULN vegetation structure protocol.
Submerged Aquatic Vegetation (2008)	Marine and Estuarine Submerged Aquatic Vegetation	Techniques for monitoring will be adapted from the protocol developed by NCBN. Work will focus on modifying the existing protocol for GULN parks and identifying cooperators to implement the monitoring.
Specific to parks (2009)	Non-native Animals	Work will focus on database management for existing park-based monitoring and developing a "Non-native Animal Impact Assessment" module (SOP) in the vegetation structure protocol to detect vegetative impacts of invasive animals (hogs, nutria, nilgai, etc.).
Specific to parks (2009)	T&E/Rare Small Mammals	Work will focus on database management for existing park-based monitoring and providing the parks with existing protocols where possible.
Specific to parks (2009)	T&E/Rare Plants	Work will focus on database management for existing park-based monitoring and developing habitat links with plant communities identified in the vegetation structure protocol with T&E species.

9.2. Protocol Development and Implementation Schedule

Table 9.2 shows the anticipated schedule for protocol completion and implementation at each of the network parks. Not every protocol will be implemented at every park on the same schedule. Especially when new protocols are being developed, and when existing protocols need to be modified for implementation in GULN parks, implementation will occur in phases.

Table 9.2. Implementation schedule, by park, for vital signs monitoring in the Gulf Coast Network from calendar years 2007–2011.

Protocol	Vital sign	Park	2007	2008	2009	2010	2011
Weather and Climate	Weather/Climate	BITH	#	X	X	X	X
		GUIS	#	X	X	X	X
		JELA	#	X	X	X	X
		NATR	#	X	X	X	X
		PAAL	#	X	X	X	X
		PAIS	#	X	X	X	X
		SAAN	#	X	X	X	X
		VICK	#	X	X	X	X
Estuarine and Near-Shore Coastal Waters	Water Chemistry Water Nutrients Water Toxics	GUIS	#, X	X	X	X	X
		JELA	#, X	X	X	X	X
		PAIS	#, X	X	X	X	X

Protocol	Vital sign	Park	2007	2008	2009	2010	2011
Freshwater	Water Chemistry Water Nutrients Water Toxics	BITH	X	X	X	X	X
		GUIS	#*	X	X	X	X
		JELA	#*	X	X	X	X
		NATR	X	X	X	X	X
		PAAL	X	X	X	X	X
		PAIS	#*	X	X	X	X
		SAAN	X	X	X	X	X
		VICK	X	X	X	X	X
Vegetation Structure and Composition *(Non-native Vegetation, Salt Marsh Plant Communities, Terrestrial Vegetation, and Fire and Fuel Dynamics modules)*	Non-native Vegetation Salt Marsh Plant Communities Terrestrial Vegetation Fire and Fuel Dynamics	BITH	-	#	X	X	X
		GUIS	#, X	X	X	X	X
		JELA	#, X	X	X	X	X
		NATR	-	#	X	X	X
		PAAL	-	#	X	X	X
		PAIS	#, X	X	X	X	X
		SAAN	-	#	X	X	X
		VICK	-	#	X	X	X
Amphibian Communities	Amphibians	BITH	#	X	X	X	X
		GUIS	#	X	X	X	X
		JELA	#	X	X	X	X
		NATR	#	X	X	X	X
		PAAL	#	X	X	X	X
		PAIS	#	X	X	X	X
		SAAN	#	X	X	X	X
		VICK	#	X	X	X	X
Landbirds	Migratory and Resident Birds	SAAN	#, X	X	X	X	X
		OTHERS	#	X	X	X	X
Adjacent Land-use Change	Land Cover/Land Use	BITH	#	X	X	X	X
		GUIS	-	#	X	X	X
		JELA	#	X	X	X	X
		NATR	-	#	X	X	X
		PAAL	#	X	X	X	X
		PAIS	-	#	X	X	X
		SAAN	#, X	X	X	X	X
		VICK	#	X	X	X	X
Coastal Geomorphology and Landforms	Coastal Dynamics	GUIS	#	X	X	X	X
		PAIS	#	X	X	X	X
Vegetation Structure and Composition *(Riparian Communities module)* (2008)	Riparian Communities	BITH	-	#	X	X	X
		JELA	#	#	X	X	X
		NATR	-	#	X	X	X
		PAAL	-	#	X	X	X
		SAAN	-	#	X	X	X

Protocol	Vital sign	Park	2007	2008	2009	2010	2011
Vegetation Structure and Composition *(Forest Health module)* (2008)	Forest Health	BITH	-	#	X	X	X
		GUIS	#	#	X	X	X
		JELA	#	#	X	X	X
		NATR	-	#	X	X	X
		PAAL	-	#	X	X	X
		PAIS	#	#	X	X	X
		SAAN	-	#	X	X	X
		VICK	-	#	X	X	X
Submerged Aquatic Vegetation	Marine and Estuarine Submerged Aquatic Vegetation	GUIS	#	X	X	X	X
		PAIS	#	X	X	X	X
Specific to parks	Non-native Animals	BITH	-	#	X	X	X
		GUIS	#	#	X	X	X
		JELA	#	#	X	X	X
		NATR	-	#	X	X	X
		PAAL	-	#	X	X	X
		PAIS	#	#	X	X	X
		SAAN	-	#	X	X	X
		VICK	-	#	X	X	X
Specific to parks	T&E/Rare Small Mammals	GUIS	#	#	X	X	X
		PAAL	#	#	X	X	X
Specific to parks	T&E/Rare Plants	BITH	#	#	X	X	X
		GUIS	#	#	X	X	X
		NATR	#	#	X	X	X
		PAIS	#	#	X	X	X
		SAAN	#	#	X	X	X
		VICK	#	#	X	X	X

*Although largely marine, these parks each have freshwater resources (ponds) for which a separate monitoring strategy will be developed, and linked to amphibian monitoring.

= develop protocol

X = conduct monitoring

- = no activity.

Chapter 10
Budget

In this chapter, we present the budget of the GULN monitoring program during the first year of operation after review and approval of our plan (anticipated to be FY2008). We first show the network budget by the same expense categories networks use in preparing the AAWRPs that are submitted to Congress (Table 10.1). In Table 10.2, we show the same budget, but with more detail, including our projections for network resources devoted to information management.

The GULN annually receives $929,800 from the NPS Servicewide Inventory and Monitoring Vital Signs Program, and $89,000 from the NPS Water Resources Division. We expect to spend approximately 45% of the budget on personnel, including permanent staff and seasonal technicians and/or interns. The staffing strategy has been to have a core of professional, permanent staff to oversee and coordinate the program. Technician-level assistance will be accomplished through CESU agreements for student interns and assistance from the Student Conservation Association (SCA) (see Chapter 8). We will enter into cooperative and interagency agreements for the bulk of the data collection support for the program. Because of the distances involved in traveling to the network parks from the network offices, we will avoid creating a centralized technical staff and the associated budgetary and logistical difficulties. Agreements with regional universities and other federal and state agencies will give us access to local technical assistance, while network staff will oversee the implementation across the network.

Table 10.1. Anticipated budget for the Gulf Coast Network Vital Signs Monitoring Program in the first year of implementation after review and approval of the monitoring plan.

Budget		**2008**	
Income			
Vital Signs Monitoring		$929,800	
Water Resources Division		$89,000	
	Total	$1,018,800	
Expenditures			*% by Category*
Personnel (includes interns/techs)		$460,541	45%
Cooperative Agreements		$402,259	40%
Operations/Equipment		$80,000	8%
Travel		$75,000	7%
Other		$1,000	0%
	Total	**$1,018,800**	

Guidelines for developing a monitoring program suggest that approximately 30% of the budget should be allocated to information/data management so that information is not lost, results are communicated, and adequate reporting takes place. In Table 10.2, we provide the percent of time that each network position devotes to information/data management. We also include anticipated costs for hardware and software to manage and make information available. (Note that many protocols are still under development and several will be completed in FY2007. Staff and strategies for implementing those protocols are difficult to finalize prior to completion of the protocol. We provide the best estimates currently possible.)

Table 10.2. Detailed budget for the Gulf 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.

Budget		**2008**		
Income				
Vital Signs Monitoring		$929,800		
Water Resources Division		$89,000		
	Total	$1,018,800		
Expenditures				
Personnel	*GS Level*		*% Info. Mgmt.*	*$ Info. Mgmt.*
Administrative Assistant (SERO)		$8,176	0%	$0
Network Coordinator	12	$94,962	20%	$18,992
Ecologist	12	$109,667	30%	$32,900
Science Information Specialist	11	$81,000	100%	$81,000
GIS Specialist	9/11	$54,284	60%	$40,713
Hydrologist (50%)	12	$52,453	30%	$15,736
Interns/SCAs		$60,000	30%	$18,000
Cooperative Agreements				
Interagency Agreements		$230,000	30%	$69,000
CESU agreements		$172,259	35%	$68,904
Other				
Operations/Equipment		$80,000	10%	$8,000
Network Staff Travel		$50,000		
STAC/BOD Travel to Meetings		$25,000		
Other		$1,000		
	Total	**$1,018,800**	**33%**	**$336,489**

Chapter 11
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