National Park Service
U.S. Department of the Interior

Northeast Region
Boston, Massachusetts

Northeast Temperate Network Vital Signs Monitoring Plan

Technical Report NPS/NER/NRTR--2006/059

ON THE COVER
Acadia National Park: spruce trees
Boston Harbor Islands NPA: Graves Island lighthouse
Saint-Gaudens NHS: view of Mt. Ascutney from the formal gardens of Aspet
Saratoga NHP: wildflowers

Photographs courtesy of Acadia NP, Boston Harbor Islands NPA, Saint-Gaudens NHS, and Saratoga NHP respectively

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U.S. Department of the Interior
National Park Service
Northeast Region
Boston, Massachusetts

The Northeast Region of the National Park Service (NPS) comprises national parks and related areas in 13 New England and Mid-Atlantic states. The diversity of parks and their resources are reflected in their designations as national parks, seashores, historic sites, recreation areas, military parks, memorials, and rivers and trails. Biological, physical, and social science research results, natural resource inventory and monitoring data, scientific literature reviews, bibliographies, and proceedings of technical workshops and conferences related to these park units are disseminated through the NPS/NER Technical Report (NRTR) and Natural Resources Report (NRR) series. The reports are a continuation of series with previous acronyms of NPS/PHSO, NPS/MAR, NPS/BSO-RNR and NPS/NERBOST. Individual parks may also disseminate information through their own report series.

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Northeast Temperate Inventory and Monitoring Network

Vital Signs Monitoring Plan

September 30, 2006

Approval Signatures

September 30, 2006

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September 30, 2006

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September 30, 2006

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September 30, 2006

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Greg Shriver was the Network Coordinator from November 2002 through November 2005, and Brian Mitchell became the Network Coordinator in October 2005. Fred Dieffenbach is the biologist / data manager for the NETN, and Theresa Moore is the network's Science Communication Specialist. They, along with Don Faber-Langendoen, Geraldine Tierney, Pam Lombard, and James Gibbs, formed the core science team for the Phase III report. Ben Rubin and Shawn Carter assisted the team during earlier work on the Phase I report.

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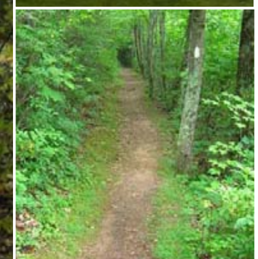
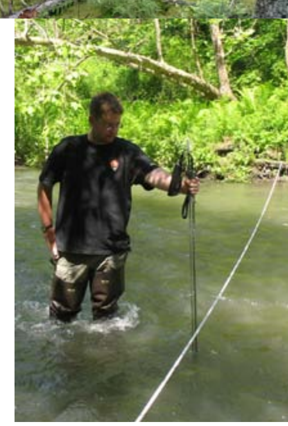
Executive Summary






Knowing the condition of natural resources in national parks is fundamental to the National Park Service's ability to manage park resources and fulfill the goal put forth in the Organic Act: "to conserve the scenery and the natural and historic objects and the wildlife therein unimpaired for the enjoyment of future generations." Funded by the Natural Resource Challenge, the National Park Service has implemented a strategy to develop a program for long-term monitoring of "Vital Signs" of ecological health and condition within the parks. This Inventory & Monitoring (I&M) program program is being implemented within 270 parks, which have been grouped into 32 networks using a consistent framework and process. The Northeast Temperate Network (NETN) consists of 10 parks, and is also coordinating I&M activities for the Appalachian National Scenic Trail.



THE NORTHEAST TEMPERATE NETWORK

The challenge of protecting and managing a park's natural resources requires an ecosystem approach and a broad-based knowledge of the status and trends of park resources. An ecosystem approach is needed because no single spatial or temporal scale is appropriate for all system components and processes. National parks in the Northeast are open systems vulnerable to threats that originate outside of park boundaries, such as air and water pollution and invasive species. Northeast Temperate Network parks are part of larger ecosystems, and they must be managed in that context. The majority of the parks in the NETN were established for cultural and historical reasons and are located in increasingly urbanizing landscapes. The parks protect natural resources located within their boundaries and are comprised of a diverse array of ecological systems including terrestrial, wetland, and intertidal systems, plus a variety of lakes and streams. Land use change surrounding parks, habitat fragmentation, and invasive species are high priority management issues for the parks.

PROGRAM GOALS

Service-wide Goals for Vital Signs Monitoring for the National Park Service are:

- 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
- Provide early warning of abnormal conditions and impairment of selected resources to help develop effective mitigation measures and reduce costs of management
- Provide data to better understand the dynamic nature and condition of park ecosystems and to provide reference points for comparisons with other, altered environments
- Provide data to meet certain legal and Congressional mandates related to natural resource protection and visitor enjoyment
- Provide a means of measuring progress towards performance goals

Parks of the Northeast Temperate Network

- Acadia National Park
- Appalachian National Scenic Trail
- Boston Harbor Islands National Park Area
- Marsh-Billings-Rockefeller National Historical Park
- Minute Man National Historical Park
- Morristown National Historical Park
- Roosevelt-Vanderbilt National Historic Site
- Saint-Gaudens National Historic Site
- Saratoga National Historical Park
- Saugus Iron Works National Historic Site
- Weir Farm National Historic Site

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. The vital signs selected for the Northeast Temperate Network (see table on facing page) represent an integrated list of ecological processes, elements of biotic and abiotic condition, system drivers and stressors, landscape condition, and focal park resources. Moreover, these vital signs are directly relevant to the natural resource management issues of a majority of NETN parks. The vital signs list provides a peer-reviewed, prioritized list of monitoring objectives that should be included over time regardless of how implementation is conducted.

IMPLEMENTATION

Detailed vital sign monitoring protocols will document step-by-step guidance for collecting, analyzing, and reporting information for each vital sign. Centralized staffing, agreements with cooperators, and park supported programs are some of the mechanisms that will be used for implementing monitoring efforts. In some cases other agencies are already monitoring vital signs (for example air and climate) and the NPS monitoring program will focus on acquiring data, interpreting, and reporting results.

INTEGRATION WITH MANAGEMENT

As part of the Service's effort to improve park management through greater reliance on scientific knowledge, a primary purpose of the Inventory and Monitoring Program is to develop, organize, and make available natural resource data. The program contributes to the Service's institutional knowledge by facilitating the transformation of data into information through analysis, synthesis, and modeling. The monitoring networks are designing a system for scientific data collection, analysis, and reporting that is unprecedented in the

history of the National Park Service. Vital signs monitoring will be an integral park of the adaptive management cycle by providing critical information about trends in natural resource conditions. Furthermore, scientifically sound information obtained through inventory and monitoring will be available for management decision-making, research, education, and promoting public understanding of park resources.

Vital Signs Monitored by the Northeast Temperate Network		
Category	**Vital Sign**	**Potential Measures**
Air and Climate	Ozone	Atmospheric ozone concentration (synthesize existing data), foliar injury to indicator species
	Acidic deposition & stress	Wet and dry deposition rates (synthesize existing data), streamwater ANC, streamwater nitrate concentration
	Contaminants	Heavy metal deposition (synthesize existing data)
	Climate	Air temperature, precipitation by type, relative humidity, solar radiation, wind speed and direction, snow water equivalent, snow depth (synthesize existing data)
	Phenology	First flowering of sensitive plant species, first amphibian call dates, length of growing season, ice out/in dates for lakes and ponds
Geology and Soils	Shoreline geomorphology	Relative surface elevation (salt marsh), shoreline position
	Forest soil condition	Ratios of carbon to nitrogen and calcium to aluminum
Water	Water quantity	Water depth, water duration, lake levels, streamflow, groundwater levels/inputs, spring/seep volume, sea level rise
	Water chemistry	Stream water nitrate, stream alkalinity/ANC, water temperature, % dissolved oxygen, specific conductance, pH, color, salinity, chlorophyll a, photosynthetically active radiation (PAR)
	Estuarine nutrient enrichment	Turbidity, number septic systems in and near park, algal biomass, total and dissolved phosphorus, amount fertilizer used within park, residential density near park
	Streams - macroinvertebrates	Diversity of selected communities and sub-communities
Biological Integrity	Exotic plants - early detection	Presence/absence
	Exotic animals - early detection	Presence/absence
	Intertidal – vegetation	Diversity of salt marsh and rocky intertidal community and subcommunities, exotic species extent
	Wetland – vegetation	Diversity of community and subcommunities, exotic species extent, beaver activity
	Forest – vegetation	Community diversity (all layers), tree species, rates of mortality and regeneration, stand structural dynamics, tree basal area by species, canopy condition, snag density, coarse woody debris volume, percent exotic species
	White-tailed deer herbivory	Browse intensity in forests
	Fish – lakes and streams	Diversity of community and subcommunities, percent exotic species.
	Breeding birds	Diversity of forest, high elevation, grassland/scrub, old-field, and coastal communities and subcommunities
	Amphibians and reptiles	Diversity of wetland/vernal pool communities and subcommunities, red-backed salamander abundance in forests
Human use	Visitor usage	Number of visitors by location and activity, trampling impacts, soil erosion
Landscapes	Land cover / ecosystem cover	Change in area and distribution of ecological systems (including intertidal communities) within park and adjacent landscape, patch size distribution, patch connectivity, patch fragmentation, extent of major disturbance, ecological integrity index by ecological system
	Land use	Road network extent, nearby housing development permits, proportion of nearby lands in various categories of human uses, % impervious surface in watershed, nearby human population density, landscape buffers

Chapter 1
Introduction and Background

Introduction

Natural systems in the United States are increasingly being affected by human activities, including urbanization, pollution, habitat fragmentation, and introduced species. The National Park Service (NPS), through congressional enabling legislation, is mandated to protect, preserve, and conserve park resources. Through natural resource monitoring, managers can identify and understand normal limits of natural variation in park resources, as well as detect changes and causes of change that are due to anthropogenic and other stressors. Vital signs monitoring is one of the key components of the NPS Natural Resource Challenge (NRC).

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. This subset of monitored resources and processes is part of the total suite of natural resources that park managers are directed to preserve "unimpaired for future generations" (National Park Service Organic Act of 1916), 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 that were selected because they have important human values (e.g., harvested or charismatic species) or because of some known or hypothesized threat or stressor/response relationship with a particular park resource. Therefore, Vital signs may or may not be indicators of overall ecosystem condition. The broad-based, scientifically sound information obtained through natural resource monitoring will have multiple applications for management decision-making, research, education, and promoting public understanding of park resources.

The NRC, which was launched in late 1999, is a major program to revitalize and expand the natural resource program within the NPS and to improve park management through greater reliance on scientific knowledge. The Vital Signs Monitoring Networks are a key component of the NRC; the networks link parks with shared natural resource and geographic characteristics in order to facilitate collaboration, information sharing, and economies of scale in natural resource monitoring. The networks coordinate the gathering of both baseline resource information and information on long term trends in the condition of National Park System resources. The Northeast Temperate Network (NETN) consists of 10 parks, and is also coordinating I&M activities for the Appalachian Trail (Figure 1.1).

Purpose of the Vital Signs Monitoring Program

The purpose of the Vital Signs Monitoring Program in the National Park Service relates directly to the purpose of the national park system. In this section, we review the justification for integrated natural resource monitoring, as established by enabling legislation for the NPS and specific NETN parks. The NETN seeks to identify and define appropriate vital signs of ecological integrity and to establish protocols for their measurement. The NETN is focused on indicators that represent the diversity of ecological systems and anthropogenic stressors within parks and at different ecological scales. The challenge is to identify a coherent set of indicators that cover the range of ecological resources and stressors and that will provide meaningful information to park resource managers while staying within the program's budgetary

Figure 1.1. Map of the parks included in the Northeast Temperate Network Inventory and Monitoring Program.

constraints. The NETN vital signs program must also provide effective communication tools that allow park managers and other audiences to interpret meaningful changes to park ecological integrity. In order to do so, we have developed an ecological integrity scorecard reporting framework to facilitate effective and timely communication of monitoring information.

Justification for Integrated Natural Resource Monitoring

Knowing the condition of natural resources within national parks is fundamental to NPS's ability to manage park resources "unimpaired for the enjoyment of future generations." National Park managers are confronted with increasingly complex and challenging issues that require a broad-based understanding of the status and trends of park resources. The challenge of protecting and managing a park's natural resources requires a multi-agency, ecosystem approach because most parks are open systems, with many threats, such as air and water pollution and invasive species, originating outside of park boundaries. Moreover, an ecosystem approach is needed because no single spatial or temporal scale is appropriate for all system components and processes. National parks are part of larger ecosystems and must be managed in that context.

Natural resource monitoring provides site-specific information needed to identify and understand changes in complex, variable, and imperfectly understood natural systems and to provide insight into whether observed changes are within natural levels of variability or indicate undesirable human influence. Thus, monitoring provides a basis for identifying and understanding meaningful change in natural systems characterized by complexity, variability, and non-linear responses. Understanding the dynamic nature of park ecosystems and the consequences of human activities is essential for management decision-making designed 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). NPS recognizes the impossibility of tracking everything, and has therefore initiated vital signs monitoring to track a subset of significant park resources and processes.

Field northwest of Burlingham house:
Weir Farm NHS

Legislation, Policy and Guidance

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 of conserving park resources. 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

Horns Pond in Bigelow Preserve, Maine: Appalachian NST

it amended the Organic Act in 1978 to state that "the protection, management, and administration of these areas shall be conducted in light of the high public value and integrity of the National Park System and shall not be exercised in derogation of the values and purposes for which these various areas have been established…"

More recently, the National Parks Omnibus Management Act of 1998 established the framework for fully integrating natural resource monitoring and other science activities into the management processes of the National Park System. The Act charges the Secretary of the Interior to "continually improve the ability of the National Park Service to provide state-of-the-art management, protection, and interpretation of and research on the resources of the National Park System," and to "… assure the full and proper utilization of the results of scientific studies for park management decisions." Section 5934 of the Act requires the Secretary of the Interior to develop a program of "inventory and monitoring of National Park System resources to establish baseline information and to provide information on the long-term trends in the condition of National Park System resources."

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

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

The 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" (NPS 2001).

These are among the many 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 (Table 1.1).

Park Enabling Legislation

Enabling legislation of an individual park, where it exists, provides insight into the natural and cultural resources and resource values for which it was created to preserve. These values may evolve with time, through evolution of park management, legal interpretations, and explicit additions to park enabling legislation. See Appendix: Park Summaries for information on the enabling legislation for each park.

For example, in 1916, when Sieur De Monts National Monument (which later became Acadia National Park) was established, the enabling legislation referred to the "great scientific interest" of the "topographic configuration, the geology, the fauna and the flora of the island" (Presidential Proclamation 1339, 1916). Similarly, the enabling legislation for the National Scenic Trail system highlights the importance of "trails so located as to provide for maximum outdoor recreation potential and for the conservation and enjoyment of the nationally significant scenic, historic, natural, or cultural qualities of the areas through which such trails may pass" (Public Law 90-543, 1968). Most of the other NETN parks are historical sites and parks, where the emphasis is on preserving a historic scene or culturally important locale. The natural landscape is often a critical component of interpreting the significance of these sites, as evidenced by the

Table 1.1. 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.

Taylor Grazing Act 1934
Fish and Wildlife Coordination Acts, 1958 and 1980
Wilderness Act 1964
National Historic Preservation Act 1966
National Environmental Policy Act of 1969
Clean Water Act 1972, amended 1977, 1987
Endangered Species Act 1973, amended 1982
Migratory Bird Treaty Act, 1974
Forest and Rangeland Renewable Resources Planning Acts of 1974 and 1976
Mining in the Parks Act 1976
American Indian Religious Freedom Act 1978
Archaeological Resources Protection Act 1979
Federal Cave Resources Protection Act 1988

Orchard in winter: Morristown NHP

enabling legislation for Weir Farm National Historic Site, which emphasizes the maintenance of "the integrity of a setting that inspired artistic expression" (Public Law 101-485, 1990).

Government Performance and Results Act

The Government Performance and Results Act (GPRA) guides the management of national parks in outlining measurable performance goals and requiring NPS to demonstrate the attainment of those goals to the U.S. Congress. For NPS, four overarching goals provide direction for developing more specific goals:

- Category I goals preserve and protect park resources.
- Category II goals provide for the public enjoyment and visitor experience of parks.
- Category III goals strengthen and preserve natural and cultural resources and enhance recreational opportunities managed by partners.
- Category IV goals ensure organizational effectiveness.

The NETN vital signs monitoring plan clearly assists in meeting numerous Category I goals and augments Category II and III goals. The servicewide goal pertaining to natural resource inventories specifically identifies the objective of inventorying the resources of the parks as an initial step in protecting and preserving park resources (GPRA Goal Ib1). The vital signs monitoring plan identifies the indicators or "vital signs" of the network (GPRA Goal Ib3a) and will be implemented to detect trends in resource condition (GPRA Goal Ib3b). In addition to the national strategic goals, each park has a five-year plan with specific park GPRA goals. GPRA goals relevant to NETN parks natural resource monitoring and management are presented in Appendix: Park Summaries. As NETN parks work to develop new GPRA goals, we will work with them to ensure that progress towards goals can be addressed with data collected by the network.

Monitoring Goals and Strategies

Role of Monitoring

Monitoring is a central component of natural resource stewardship in the National Park Service, and in conjunction with natural resource inventories and research, it provides the information needed for effective, science-based managerial decision-making and resource protection (Figure 1.2). The NPS strategy to institutionalize inventory and monitoring throughout the agency is based on a framework that consists of several key components; (a) completion of 12 basic resource inventories upon which monitoring efforts can be based, (http://science.nature.nps.gov/im/inventory/index.cfm) (b) a network of 11 experimental or "prototype" long-term ecological monitoring programs initiated in 1992 to evaluate alternative monitoring designs and strategies, and (c) implementation of operational monitoring of critical parameters (i.e. "vital signs") in 270 parks with significant natural resources.

Service-wide Vital Signs Monitoring Goals

Servicewide Goals for Vital Signs Monitoring for the National Park Service are as follows:

- Determine status and trends in selected indicators of the condition of park ecosystems to allow managers to make

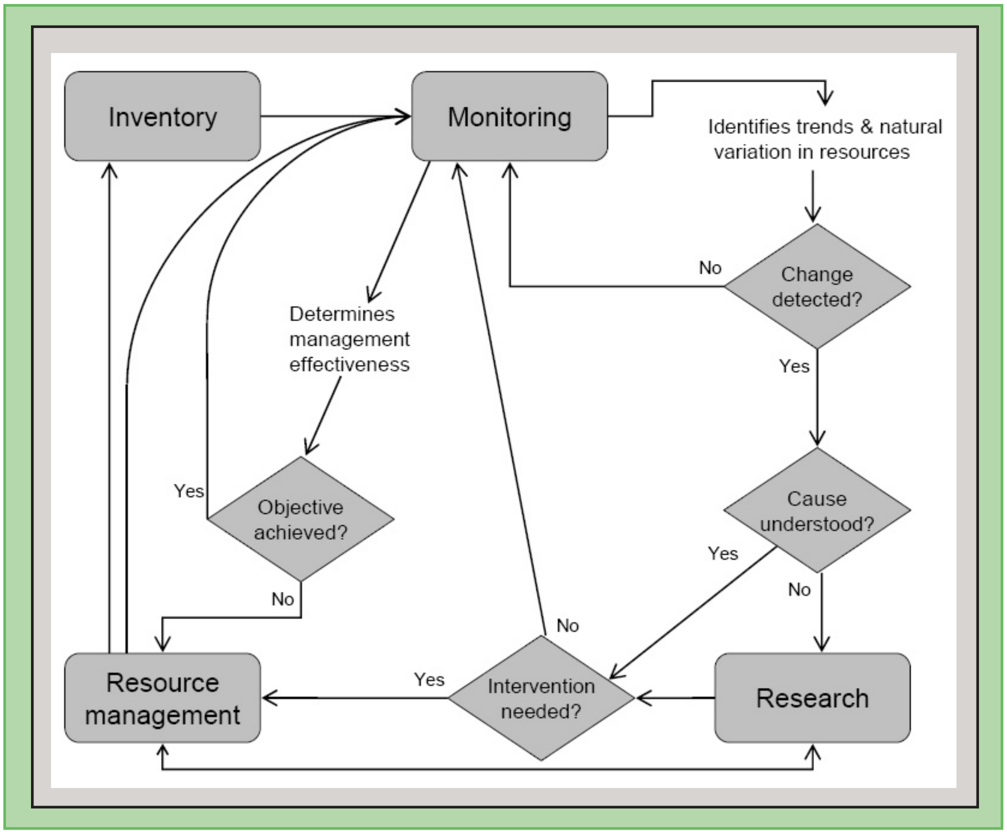


Figure 1.2. Integration of inventories, monitoring, research, and natural resource management activities in National Parks (Jenkins et al. 2002, Elzinga et al. 2001).

better-informed decisions and to work more effectively with other agencies and individuals for the benefit of park resources

- Provide early warning of abnormal conditions and impairment of selected resources to help develop effective mitigation measures and reduce costs of management
- Provide data to better understand the dynamic nature and condition of park ecosystems and to provide reference points for comparisons with other, altered environments
- Provide data to meet certain legal and Congressional mandates related to natural resource protection and visitor enjoyment
- Provide a means of measuring progress towards performance goals

The Three-Phase Process for the I&M Monitoring Program

During the initial planning for park vital signs monitoring, it became clear that a “one size fits all” approach to monitoring would not be effective within NPS due to the tremendous variability among parks in ecological conditions, sizes, and management capabilities. To develop an effective and cost-efficient monitoring program that addresses the information needs of each park and integrates across other park operations like interpretation and maintenance, parks need the flexibility to allow existing programs, funding, and staff to be combined with the new I&M program. Partnerships with federal and state agencies and adjacent landowners are necessary to effectively understand and manage resources and threats that extend beyond park boundaries, and these partnerships will vary across the national park system.

The complicated task of developing a network monitoring program requires an initial investment in planning and design to guarantee that monitoring meets the most critical information needs of each park, and produces scientifically credible results that are clearly understood and accepted by scientists, policy makers, and the public, and that are readily accessible to managers and researchers. These front-end investments also ensure that monitoring builds on existing information and understanding of park ecosystems, and makes maximum use of leveraging and partnerships with other agencies and academia.

The NPS has established a 3-phase planning and design process for the I&M program. *Phase 1* involves defining network goals and objectives, identifying and synthesizing existing data, developing conceptual ecological models of park resources, and completing other background work. *Phase 2* involves prioritizing and selecting vital signs using a process of scientific peer review. *Phase 3* involves the development of specific sampling protocols, a statistical sampling design, a plan for data management and analysis, and a plan for reporting monitoring results. After completion of each phase, each network reports their progress for NPS review within a structured report (such as this one).

We used a standard process to begin Phase 1 of the development of NETN's long-term ecological monitoring program. We began with a series of brainstorming sessions, questionnaires, meetings and scoping workshops (Table 1.2) to identify: (Brody and Pelton) focal resources and ecological processes important within NETN parks, (2) key stressors or agents of change known or suspected to be acting upon NETN ecological resources, and (3) key elements and processes representing ecological integrity within these ecological resources. Conceptual models were then developed to help organize and communicate this information, and identify cause and effect relationships between stressors and response variables. These models became a tool for helping NETN identify, prioritize, and select vital signs (Figure 1.3).

An Integrated Approach to Monitoring

A key initial decision in designing a monitoring program is balancing the need to monitor for current management issues against the need to detect future, perhaps unforeseen threats to park ecosystems. Many writers have enumerated advantages and disadvantages of these two approaches (e.g., Woodley 1993, Noon 2002). Our ability to predict ecosystem response to changes in various system drivers and stressors is limited by our incomplete understanding of ecological systems and processes. A monitoring program that only focuses on well-known threat/response relationships will not provide the long-term information and understanding necessary to address unanticipated, high-priority issues that will arise in the future.

Alternatively, monitoring key ecological properties and processes indicative of ecosystem integrity will allow detection of change in response to unforeseen or uncharacterized stressors and perhaps provide early warning of unacceptable change. Ecological integrity can be defined as "the maintenance of... structure, species composition, and the rate of ecological processes and functions within the bounds of normal disturbance regimes" (Lindenmayer and Franklin 2002). This concept builds on earlier definitions of biological integrity, defined as the capacity to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitats of the region (Karr et al. 1986); ecological integrity is a broader concept which incorporates aspects of abiotic condition such as air or water quality.

Interpreting Ecological Integrity

Ultimately, a vital sign is useful only if it provides information for guiding management decisions or quantifying the success of past decisions. This information must be presented in a way that is clearly understood by managers, scientists, policy makers, and the public. The NETN will accomplish this task by 1) developing standard statistical summaries of vital

Table 1.2. Timeline and milestones for development of the NETN monitoring plan.

Phase	Milestones	Dates
Phase 1	Assess Natural Resources Identify Priorities for Inventory Needs Identify Significant Resources Prioritize Management Issues Identify Monitoring Needs	May 2001 - August 2003
	Develop Program Resources Board Meeting to Review Program and Charter Create Core Science Team Park-based Scoping Meetings	December 2002 - May 2003
	Phase I Plan Phase I Draft Review – Acadia NP (Conceptual Models) Complete Phase I Report	October 2003
Phase II	Phase II Plan Technical Committee Planning Meeting Vital Signs Selection Workshop Technical Committee / Parks Review Workshop Submit Phase II Report	October 2004
Phase III	Phase III Plan Draft NETN Monitoring Plan Draft NETN Data Management Plan Draft NETN Forest, Lakes and Streams, and Breeding Bird Monitoring Protocols	December 2005
	Final NETN Monitoring Plan Final Data Management Plan Final Initial Protocols	September 2006

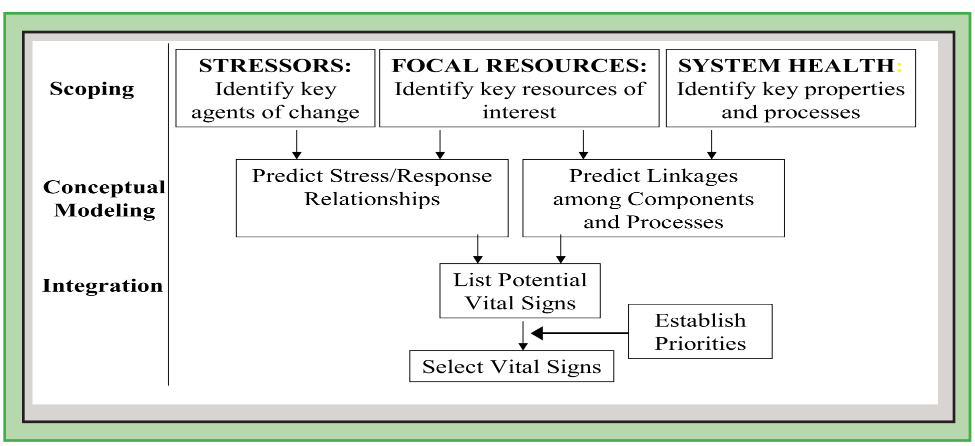


Figure 1.3. Process for identifying and selecting potential vital signs.

Saugus River: Saugus Iron Works NHS

sign measurements, and 2) developing an ecological integrity scorecard that provides basic interpretation of natural resource condition and changes in condition over time. Powerful and effective communication tools are necessary to transform a collection of field data into a clear format that presents an assessment of ecological integrity.

Limitations of Monitoring

Managers and scientists must acknowledge limitations of monitoring that result from the inherent complexity and variability of park ecosystems, as well as those resulting from the limitations of resources available for monitoring. Ecosystems are loosely defined assemblages that exhibit characteristic patterns on a range of scales of time, space, and organizational complexity (De Leo and Levin 1997). Definitions of ecological integrity are problematic, partly because key terms such as "natural" remain vague (Noon 2002). Natural systems as well as human activities change over time, and it is extremely difficult to separate natural variability and desirable changes from undesirable anthropogenic sources of change to park resources. Moreover, limited funding prevents us from directly monitoring all resources that might be at risk. These complexities demand that we recognize our limited understanding of ecological systems and processes, especially as we attempt to use this information to inform management decisions.

In some cases, monitoring data might suggest a cause and effect relationship that can then be investigated by a research study. As monitoring proceeds, as data sets are interpreted, as our understanding of ecological processes is enhanced, and as trends are detected, future issues will emerge (Roman and Barrett 1999). The monitoring plan should therefore be viewed as a working document, subject to periodic review and adjustments over time as our understanding improves and new issues and technological advances arise.

Ecological Resources of the Northeast Temperate Network

Overview of Parks and Natural Resources

The NETN contains 11 parks (Table 1.3), including the Appalachian NST. NETN is coordinating I&M activities for the five networks traversed by the trail, which is being treated as a separate entity for monitoring efforts. The Appalachian NST is on a different schedule and implementation plan from the rest of the NETN, having just recently completed the selection of vital signs (AT Vital Signs Report). Monitoring along the Appalachian Trail will primarily involve analyzing information from existing efforts underway along the trail, plus work to identify and fill information gaps. Because monitoring along the Appalachian Trail will have a different character from monitoring in the rest of the network, this monitoring plan will focus on the 10 other parks in the NETN. These parks contain diverse cultural and natural resources and span two ecological divisions (Laurentian / Acadian and Central Interior & Appalachian). Parks within the network range geographically from Acadia NP in coastal Maine to Morristown NHP in central New Jersey (Table 1.3).

NETN parks range in size from 4 hectares (9 acres) at Saugus Iron Works to more than 19,000 hectares (47,000 acres) at Acadia. These parks include the beginning and end of the Revolutionary War (Minute Man and Saratoga respectively) and a strategic military location for General George Washington (Morristown). Two National Historic Parks commemorate the lives of artists (Saint-Gaudens

Table 1.3. Parks included in the Northeast Temperate Network.

Park Name (state)	Code	Acres*	Hectares
Acadia NP (ME)	ACAD	47,498	19,229
Appalachian NST (GA-ME)	APPA	227,001	91,903
Boston Harbor Islands NPA (MA)	BOHA	1,465	593
Marsh-Billings-Rockefeller NHP (VT)	MABI	555	225
Minute Man NHP (MA)	MIMA	967	391
Morristown NHP (NJ)	MORR	1,707	691
Roosevelt-Vanderbilt NHS (NY)	ROVA	778	315
Saint-Gaudens NHS (NH)	SAGA	150	61
Saratoga NHP (NY)	SARA	3,392	1,373
Saugus Iron Works NHS (MA)	SAIR	9	4
Weir Farm NHS (CT)	WEFA	74	30

* acreage owned by the NPS

and Weir Farm) and Roosevelt-Vanderbilt celebrates the "Gilded Age". Marsh-Billings-Rockefeller and Boston Harbor Islands are both new to the NPS and unique in their establishment and mandates. Marsh-Billings-Rockefeller is the only national park to focus on conservation history and the evolving nature of land stewardship. Boston Harbor Islands, established in 1996, is a culturally and naturally diverse set of 34 drowned drumlins in the Massachusetts Bay managed by a 13-member partnership. Drumlins are elongated whale-shaped hills formed by glacial action. Saugus Iron Works marks the site of the first integrated iron works in North America, which gave rise to the industrial revolution and is known as the forerunner of America's industrial giants. Acadia is the only National Park in the NETN and hosts a diverse array of cultural, natural, and geologic resources. The Appalachian Trail, which crosses some of the most diverse ecological communities in the Northeast, is managed by a unique partnership between the NPS and the Appalachian Trail Conservancy, and provides an exciting opportunity for ecological monitoring across 2,100 miles of habitat representative of the entire east coast of the US. The natural resources, management issues, enabling legislation, and more park specific details are provided in Appendix: Park Summaries.

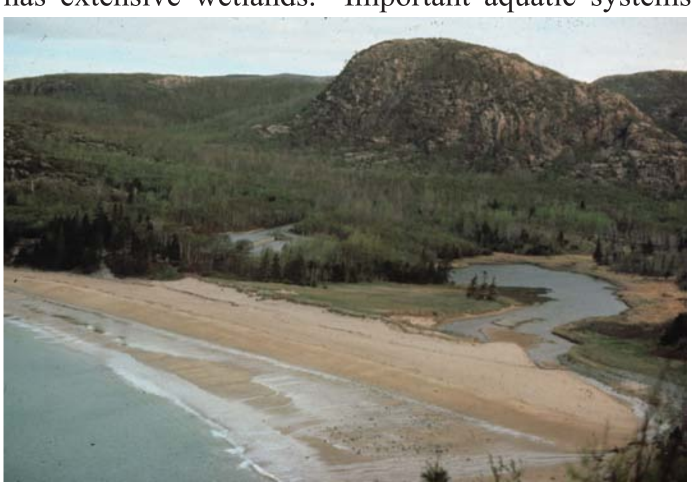
The NETN parks are located within the temperate deciduous forest biome. Temperate deciduous forests are located in mid-latitude areas between the polar regions and the tropics and are exposed to both warm and cold air masses that cause this region to have four distinct seasons. Temperature varies widely from season to season, with long, cold winters and warm summers. Within the NETN, the average annual temperature ranges from about 11˚ C along the southern coast to 4˚ C in the northern highlands. Annual precipitation ranges from 90-120 cm and is relatively evenly distributed throughout the year.

Temperate deciduous forests are dominated by broadleaf trees, including oak, hickory, maple, beech, and birch, often mixed with conifers such as hemlock, spruce, fir, and pine on drier or higher elevation sites. Forests range from the drier central hardwoods oak-pine or oak-hickory stands through mesic northern hardwoods to spruce-hardwoods. Other terrestrial habitats include alpine vegetation, rocky outcrop woodlands, as well as old-field successional habitats and plantations. A variety of wetland and aquatic habitats are present within these forests, including forested and shrub swamps, marshes, wet meadows, fens and bogs, lakes, rivers, ponds and vernal pools. Intertidal habitats are present at Acadia and Boston Harbor Islands, and Acadia also has estuarine habitat.

Worldwide, temperate deciduous forests have been highly altered, with the highest index of human disturbance of any major biome (Hannah et al. 1995), and high indices of fragmentation (Ritters et al. 2000). The northeast is no exception. Temperate deciduous forests in the northeast have been heavily used for timber, cleared for agriculture, or converted into towns and cities. Even so, regrowth of forests on abandoned farms in the last 50-100 years has created a new mix of primary and secondary forests, and increased levels of overall forest cover (Foster and Aber 2004).

Ecological Systems and Communities

NETN is comprised of a diverse array of ecological systems including terrestrial systems, wetland systems, intertidal systems, and a variety of lakes and streams (Tables 1.4 and 1.5). National historic parks and sites also include a variety of human-modified systems that are maintained as part of the parks' cultural mandate. Parks vary widely in the amount of land area represented by each system group. Terrestrial systems dominate all the NETN parks except Boston Harbor and Saugus Iron Works, in which intertidal or wetland systems are dominant. Acadia contains extensive systems in all categories. Minute Man also has extensive wetlands. Important aquatic systems are present at Saint-Gaudens and Saratoga as well as Acadia.



Sand Beach and Beehive: Acadia NP

Park sizes and cultural mandates must be considered in addition to ecological systems when designing the Vital Signs Monitoring Program for these parks. All the parks but Acadia are small, meaning that outside landscape and regional factors have strong influences. The historic parks and sites contain relatively fewer natural ecological systems, but the maintained early-successional habitat within those parks may have other important ecological values, such as providing habitat for grassland birds.

Management Issues for Network Parks – Assessing Threats

Scientific and management issues relevant to natural resource stewardship in the NETN parks were synthesized in scoping workshops and questionnaires (Appendix: Park Summaries). Land use change surrounding parks, habitat fragmentation, and invasive species were identified as "high priority" management issues for nine NETN parks. The human population in the northeastern states was 2.0 times greater in 2000 than it was when the NPS was established in 1916 (Hobbs and Stoops 2002). With the doubling of the human population in New England comes increasing pressure on space and natural resources, and population pressure is the primary cause for natural resource issues in the Northeast. The construction and maintenance of roads is among the most widespread forms of habitat alteration (Trombulak and Frissell 2000) to natural communities and nine NETN parks identified car traffic as a management issue. Roads affect terrestrial and aquatic ecosystems through increased wildlife mortality caused by collisions with vehicles (Groot Bruinderink and Hazebroek 1996), modification of animal behavior (Brody and Pelton 1989), spread of exotic species (Greenberg et al. 1997), and changes in soil and water chemistry (Trombulak and Frissell 2000). Parks and reserves in the northeast exist in a landscape matrix of developed or agricultural lands with some of the highest road densities in the U.S. Most the NETN parks were established for cultural resources but have now become important to the

Table 1.4. Area (hectares) of general system groups within each park.

Park	Terrestrial	Wetland	Intertidal	Aquatic
Acadia	13,215	904	118	980
Boston Harbor Islands	143	20	420	<1
Marsh-Billings-Rockefeller	218	4	0	6
Minute Man	250	105	0	1
Morristown	490	15	0	<1
Roosevelt-Vanderbilt	251	12	0	6
Saint-Gaudens	51	5	0	2
Saugus Iron Works	1	2	0	<1
Saratoga	1082	37	0	2
Weir Farm	27	4	0	2

Table 1.5. Freshwater body area statistics based on existing park geographic information system coverages and previously published information (see Appendix: Water Quality).

Park	Great Ponds (> 10 acres)		Small Ponds (< 10 acres)		Streams		Palustrine wetlands
	number	acres	number	acres	number	miles	acres
Acadia	14	2,370	10	50	41	~80	2,590
Boston Harbor Islands	0	0	1	*	0	0	31
Marsh-Billings-Rockefeller	1	15	0	0	1	0.9	5
Minute Man	0	0	3	*	3	1.2	200
Morristown	0	0	1	*	5	4.4	22
Roosevelt-Vanderbilt	0	0	12	15	3	4.5	72
Saint-Gaudens	0	0	2	5	2	1.6	18
Saugus Iron Works	0	0	0	0	1	.15	5
Saratoga	0	0	2	*	4	12.8	175
Weir Farm	0	0	1	4	1	.06	2.5

* included in wetland estimates

maintenance of biological diversity and ecological integrity in the urbanizing landscapes where they occur and many of them are threatened primarily by external impacts.

Land cover change and the associated threats to natural ecological communities associated with habitat fragmentation are a common theme among the NETN parks. Habitats within landscapes are altered at varying levels of intensity as human demand for space and natural resources increases, leaving many landscapes, especially those where human populations are dense, in a fragmented state (Saunders et al. 1991). Fragmentation is manifested on the landscape via the direct loss of habitat, reduction in size of remaining patches, increased isolation, and loss of habitat diversity (Saunders et al. 1991). Most ecosystems in the northeast have experienced some level of habitat fragmentation, which has been implicated as a principal threat to most species in the temperate zone (Wilcove et al. 1986). NETN parks, many of which were established for cultural resources, are relatively small in size and located in increasingly urbanized landscapes. The role they play to the maintenance of regional biological diversity may, however, be substantial. Falkner and Stohlgren (1997) conducted an analysis of the role of 44 NPS units in the Rocky Mountain region and found small, cultural parks contributed substantially to the conservation of regional biodiversity by acting as biological refugia, migration/dispersal rest stops and corridors, and living outreach programs. They indicated that small units had a disproportionate share of regional biodiversity and an understated role in the conservation of biodiversity in the region. Therefore, establishing and maintaining ecological monitoring programs within all NETN parks is an important component of natural resource management and stewardship.

Mt Ascutney from the Pan Garden: Saint-Gaudens NHS

The ecological effects of invasive plant species were identified by most parks as a primary threat to park ecological communities. We worked with parks to compile a list of the invasive plants known to occur within park boundaries to begin the process of identifying priorities for monitoring and management (Appendix: Invasive Plants). Non-indigenous species spread at the rate of about 700,000 hectares per year in the US, with an impact on human economic systems estimated in the billions of dollars (Pimentel et al. 2001). Invasive species alter ecosystem structure, function, and species composition to such an extent that they threaten native flora and fauna. Non-native species are the second highest threat to the threatened and endangered species in the United States behind habitat loss. Of the 958 species listed, about 400 (42%) are threatened by non-native species (Pimentel et al. 2001).

The NETN parks share some common resource management issues, but also have park specific issues and management priorities (Appendix: Park Summaries). Clearly, coastal issues are a concern for Acadia and Boston Harbor Islands and high elevation forests are a primary concern for the Appalachian Trail. Deer browsing, a significant stressor in many ecological communities, was listed as a management priority for 5 parks. During the initial scoping efforts, climate change was only identified as a natural resource issue for parks with coastal and high elevation habitats; however, climate change is expected to have substantial impacts over the long-term on all NETN parks.

Summary of Existing Park and Adjacent Monitoring Programs

We summarized information from park resource managers regarding current and historical monitoring efforts within NETN parks to identify opportunities to continue, modify, or expand existing programs (Appendix: Park Monitoring). Air quality monitoring within a park is only occurring at Acadia, a designated Class 1 air quality area. Air quality around other network parks is being conducted by other programs (Appendix: Air Quality). Acadia, Morristown, Roosevelt-Vanderbilt, Saint-Gaudens, and Saugus Iron Works currently have water-quality or water-quantity monitoring programs (Appendix: Water Quality). Boston Harbor Islands benefits from a monitoring program conducted by the Massachusetts Water Resources Authority (MWRA). Detailed water quality monitoring programs and existing information are summarized in the water quality Phase I scoping report (Appendix: Water Quality). The period of data collection within parks varies; some monitoring programs were initiated as early as the 1970s and one as recently as 1998.

Data collected as a part of pre-existing monitoring programs will provide historical comparisons and context for the data collected by the NETN vital signs program. In some cases, the NETN monitoring program will build on the program currently in place, especially where measures, sampling locations, and sampling protocols are similar across programs. In other cases, however, compatibility will vary because the monitoring programs at some of the parks are focused on specific resources or have different objectives than the vital signs program. To help us develop partnership opportunities with monitoring efforts being conducted by other federal and state agencies, we also reviewed national, regional, and local monitoring efforts that may be relevant to natural resource monitoring in our network. These 'outside the parks' monitoring efforts are summarized in Appendix: Adjacent Monitoring Programs.

Boston Harbor Islands

Goals and Objectives for the NETN Program

Monitoring objectives have been established by the NETN to help focus the monitoring program and facilitate partnerships for monitoring. Network monitoring objectives, identified below, were used during vital sign development to ensure the identification of a full spectrum of ecological attributes and management issues for possible monitoring. Detailed vital sign monitoring objectives have been identified for individual vital signs as part of protocol development, and may be found in Chapter Five. Table 1.6 presents our monitoring objectives in the national Inventory and Monitoring program's Ecological Monitoring framework.

Table 1.6. NETN monitoring objectives, organized in the Inventory and Monitoring Program's Ecological Monitoring Framework.

Level 1	Level 2	Monitoring Objective
Air and Climate	Air Quality	Quantify trends in ozone and atmospheric deposition, and determine if trends explain patterns in plant growth, health, or mortality
	Weather and Climate	Evaluate long-term trends in weather data and correlate with vital signs monitoring data Determine long-term trends in phenology of focal taxa and habitats, and assess the magnitude of phenological change
Geology and Soils	Geomorphology	Determine trends in sea level change and shoreline position for coastal parks
	Soil Quality	Assess trends in ecologically important forest soil characteristics
Water	Hydrology	Determine baseline freshwater quantity levels and the range of natural variability and assess temporal trends
	Water Quality	Establish the relationship between water quantity and water chemistry, and assess temporal trends Evaluate whether water chemistry and nutrient levels are within the range of natural variability Determine whether marine contaminants could be affecting intertidal species
Biological Integrity	Invasive Species	Detect invasive plants in aquatic and forested habitats Detect invasive earthworms, forest pests, and marine organisms Evaluate impact of forest pests and pathogens on forest health
	Focal Species or Communities	Determine the status and trends of forest, coastal, and grassland breeding bird communities Evaluate impact of ungulates on preferred browse species and tree regeneration Assess the health and integrity of forest, wetland, and intertidal communities
Human Use	Visitor and Recreation Pressure	Determine visitation levels, visitor distribution, and visitor activities, and estimate the degree of wildlife disturbance by humans Evaluate visitor impacts on rocky intertidal, forest, and open upland communities
Landscapes	Landscape Dynamics	Determine current land use and ecological cover types, and document changes over time Quantify trends in land use and land cover, and correlate these trends with trends in monitoring data

Chapter 2
Conceptual Ecological Models

Introduction

The development of conceptual ecological models to identify key system components, linkages and processes is a critical step in the design of a long-term monitoring program. The need for conceptual ecological models has been well established (National Research Council 2000, Elzinga et al. 2001, Noon 2002), and is also recognized by the NPS prototype park monitoring program. Conceptual models improve the planning process for monitoring by explicitly stating key elements of our understanding of system dynamics, which facilitates discussion, evaluation and refinement of the monitoring program (Maddox et al. 1999). Given the complexity of natural systems and the variety of factors that influence ecological processes, there is an obvious need for conceptual modeling as a tool to help organize information and synthesize understanding of system components and interactions. Failures in the development of major ecosystem monitoring programs have been attributed to the absence of sound conceptual models (National Research Council 1995).

The NPS Vital Signs Monitoring Program seeks to facilitate adaptive management by monitoring status and trends in 1) the ecological condition of park resources, 2) key anthropogenic stressors acting upon park systems, and 3) focal park resources. To accomplish this objective, the NETN has chosen to develop conceptual models which are both "effects-oriented" and "predictive or stressor-oriented" (Trexler and Busch 2002). The NETN conceptual models incorporate elements of ecological integrity, which integrate the effects of multiple drivers and stressors acting upon a system over time, as well as specific anthropogenic stressors and focal park resources. These conceptual models provide the foundation for describing potential vital signs and ranking their importance.

Conceptual Model Development

Model Framework

In developing conceptual models for the NETN Vital Signs Monitoring Program, we chose to employ both diagrammatic conceptual models, which help visualize system components and interactions, as well as narratives, which provide additional detail describing our current understanding of system components and interactions. We have chosen a hierarchical approach to model development, beginning with a general model for the each of four key NETN ecological system groups (terrestrial, wetland, aquatic, and intertidal). These general models identify key system drivers (large-scale influences, such as climate and disturbance regime), stressors (foreign or excessive perturbations, such as pollution and land-use change), ecological processes, elements of system condition (abiotic and biotic), and focal park resources acting upon or present within each of these four major ecological system groups (Figure 2.1). We present these general models as diagrams accompanied by detailed narratives in Appendix: Park Conceptual Models. These narratives (summarized below) lay out our current understanding of each of these components and their interactions.

A pair of diagrammatic models was also developed for each NETN park, specifically illustrating the stressors acting upon the terrestrial systems and aquatic resources present within each park (Appendix: Park Conceptual Models). The terrestrial park models identify the dominant and rare terrestrial communities by showing the proportion of each habitat type within each park. The aquatic park models include a hydrologic model of the freshwater inflows and outflows present in the park, as well as information describing freshwater resources. The aquatic models assume that system-wide processes such as precipitation and evaporation occur throughout the park, and that ground-water/

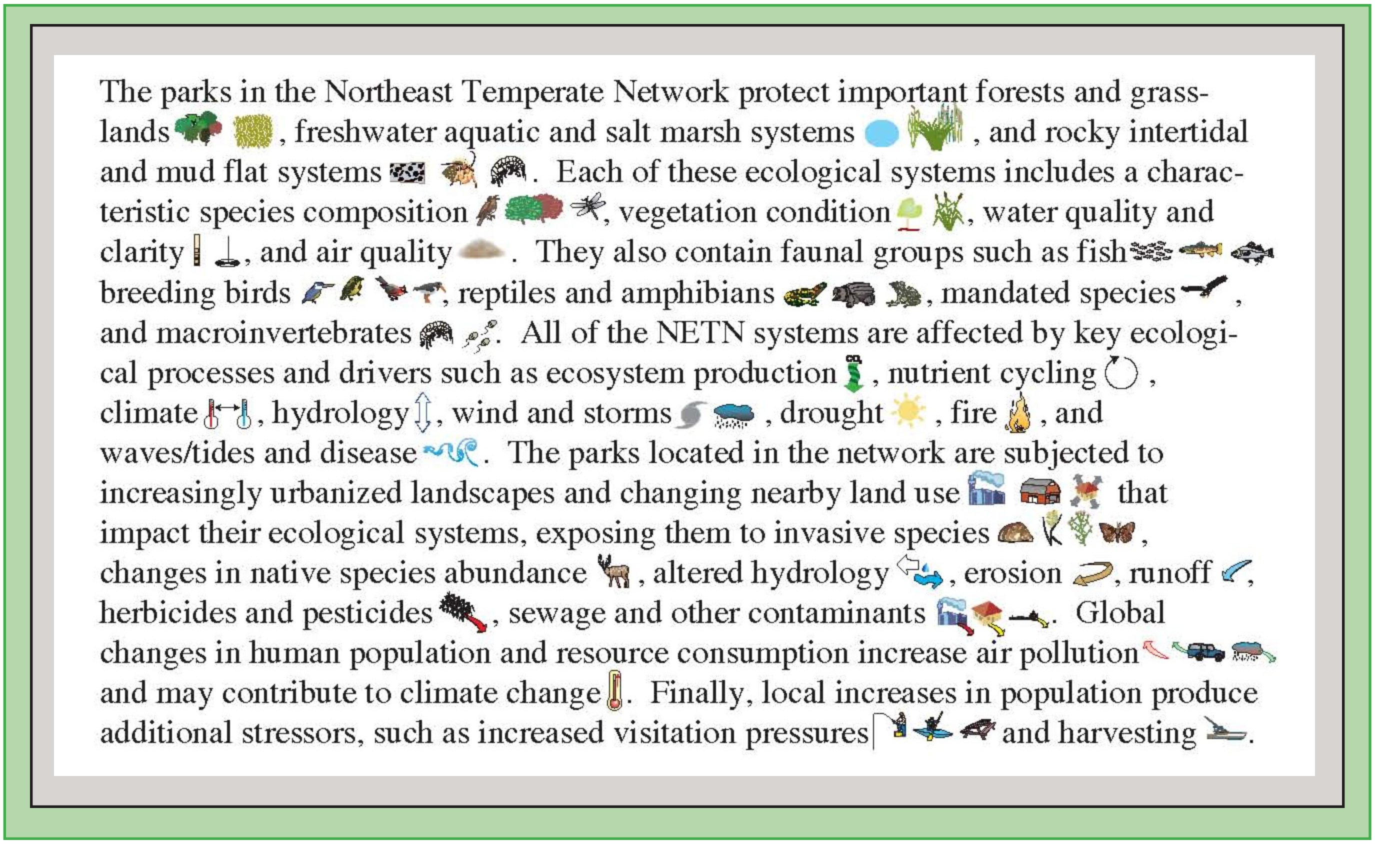


Figure 2.1. Model description.

surface-water interactions occur in both directions and also throughout the park.

Ecological Systems

Terrestrial ecological systems present within NETN parks encompass a variety of forested systems and several types of open uplands and human-modified systems (Table 2.1). The topography and ecology of this region reflects its glacial history, which left a varied landscape of lakes, depressions, moraines, drumlins and other glacial features. Latitudinal and altitudinal variation in temperature, soil quality and disturbance regimes from the coast up into the mountainous regions of New Hampshire, Vermont, and western Massachusetts create the broad ecological system groups present in the NETN parks.

Forested ecological systems within NETN parks can be divided into three general groups (Westveld 1956, Foster 2004): 1) the Central Hardwood forests of southern New England and parts of New Jersey and New York, dominated primarily by oaks with other hardwood species; 2) the Northern Hardwood forests of northern New England, dominated by American beech, yellow birch and sugar maple, with a variety of other hardwood species and hemlock and white pine; and 3) the Spruce-Fir forest found at higher elevations

Marsh-Billings-Rockefeller NHP

Table 2.1. Approximate extent (hectares) of NatureServe terrestrial ecological systems present within the NETN parks. This information will be updated and improved after completion of the I&M vegetation mapping inventory of these parks. Areas listed in larger boxes spanning more than one ecological type indicate that current information does not distinguish between related types. Most Boston Harbor Islands terrestrial communities have yet to be classified and are listed here as "other". Descriptions of these ecological system types can be found in Appendix: Ecological Systems. Park codes are defined in Table 1.3.

Ecosystem Category	NatureServe Ecological System Type	ACAD	BOHA	MABI	MIMA	MORR	ROVA	SAGA	SAIR	SARA	WEFA
Spruce-fir forest	Acadian Lowland Spruce-Fir-Hardwood Forest	6588									
Northern hardwoods/ mixed forest	Boreal Aspen-Birch Forest	1160									
	Laurentian-Acadian Northern Hardwoods Forest	314		33	20		83	13		273	1
	Laurentian-Acadian White Pine-Red Pine Forest	737									
	Laurentian-Acadian Pine-Hemlock-Hardwood Forest	881		97			77	19		432	
	Appalachian Hemlock-Hardwood Forest										
Central hardwoods forest	Central Appalachian Oak and Pine Forest			1		229					20
	Northeastern Interior Dry Oak Forest				112		3				
	Central and Southern Appalachian Northern Hardwood Forest					44					
Open uplands	Laurentian-Acadian Acidic Rocky Outcrop	3295									
	Laurentian-Acadian Calcareous Rocky Outcrop						0.04				
Cliff and talus	Laurentian-Acadian Calcareous Cliff and Talus			0.2							
	Laurentian-Acadian Acidic Cliff and Talus	11									
Rocky shore	Acadian-North Atlantic Rocky Coast	116									
Modified	Native Plantation			45			2	11		4	
	Exotic Plantation		4	18			12				
	Old-field successional		36	3	62	193	15			162	
	Open fields			17		24		6			6
	Agricultural fields				42		8			206	
	Landscaped grounds	112		4	14		50	2	1	5	
Other			104								

in northern New England and along the Maine coast, dominated by red spruce and balsam fir, with white and black spruce (Figure 2.2).

In addition to forested ecosystems, the NETN parks contain substantial areas of open field and successional old-field habitat, which is maintained within many NETN historic parks to satisfy cultural mandates (Figure 2.2). These systems, present in many national historical parks, provide important habitat for grassland and shrubland species, such as the upland sandpiper, Henslow's sparrow, grasshopper sparrow, savannah sparrow, bobolink and eastern meadowlark (Bernardos et al. 2004).

Roosevelt-Vanderbilt NHS

Wetlands represent a diverse set of ecological communities that occur at the transition between terrestrial and aquatic systems. Defined based on hydrology, physiochemical environment, and biota, wetlands are some of the most productive and diverse ecological systems on earth (Keddy 2000). The physiochemical environment of a wetland is defined as the soils, chemical properties, and processes that interact with the hydrology to influence the biota. These three components form the basis for the development and functioning of wetland ecosystems.

Depressional wetlands and seeps are a priority in the northeast United States because of the major function they provide to amphibian breeding (Brinson and Malvarez 2002). These wetlands are most commonly altered or destroyed by urban and suburban development (Brinson and Malvarez 2002), a primary threat to the NETN park natural resources. Wetland loss in NETN states has been substantial, with an average loss of 38% of the original extent. Connecticut has suffered the most dramatic loss, with 74% of the state's wetlands filled or degraded since the 1780s (Mitsch and Gosselink 2000). Wetlands are important landscape features that maintain and enhance biodiversity but are also susceptible to many perturbations (Figure 2.3). Wetlands in the NETN parks are comprised of nine different types of wetland ecological systems (NatureServe 2003) and vernal pools (Appendix: Ecological Systems).

Freshwater aquatic resources within the NETN parks consist of lakes, ponds, streams, groundwater, and springs/seeps (Figure 2.4). These resources are strongly influenced by the activity of glacial ice sheets during the past 2.5 million years. Ice sheets deepened valleys, and transported and deposited vast quantities of sediment onto the scoured bedrock as glacial drift (Randall 2001). Currently, the topographic landscape varies from rolling to mountainous upon mostly acidic bedrock and glacial till.

Lakes and Ponds: Nine NETN parks contain ponds smaller than 15 acres, many of which are human-made impoundments that pre-date the establishment of the parks. Acadia is the only park in which numerous lakes greater than 15 acres are a dominant part of the landscape. Lakes and ponds within NETN parks vary in type, size and trophic status (Appendix: Park Conceptual Models).

The Pogue: Marsh-Billings-Rockefeller NHP

Streams and Rivers: Streams and rivers within the NETN parks vary from first order headwater streams to tidal rivers. Drainage patterns of northeastern streams were altered by the last glaciation. As drift was deposited in varying thicknesses, dams were created and channels blocked. Streams followed a new course based on the slope of the drift surface. Once streams cut through the drift, they often crossed ridges or ledges of hard rock and developed falls and rapids, eventually carving gorges disproportionate to the changes in relief (Fenneman 1938). Several of the parks border large rivers such as the Hudson River and the Connecticut River, and they are occasionally impacted by these larger river systems during times of high water.

Intertidal systems are present in two NETN parks: Acadia and Boston Harbor Islands (Appendix: Ecological Systems). Unlike intertidal systems further south, the systems in these northeastern parks are primarily rocky intertidal systems, with limited areas of mud and sand flats or coastal marsh systems due to the geologic history of New England (Figure 2.5). Pleistocene glaciation scoured sediments from New

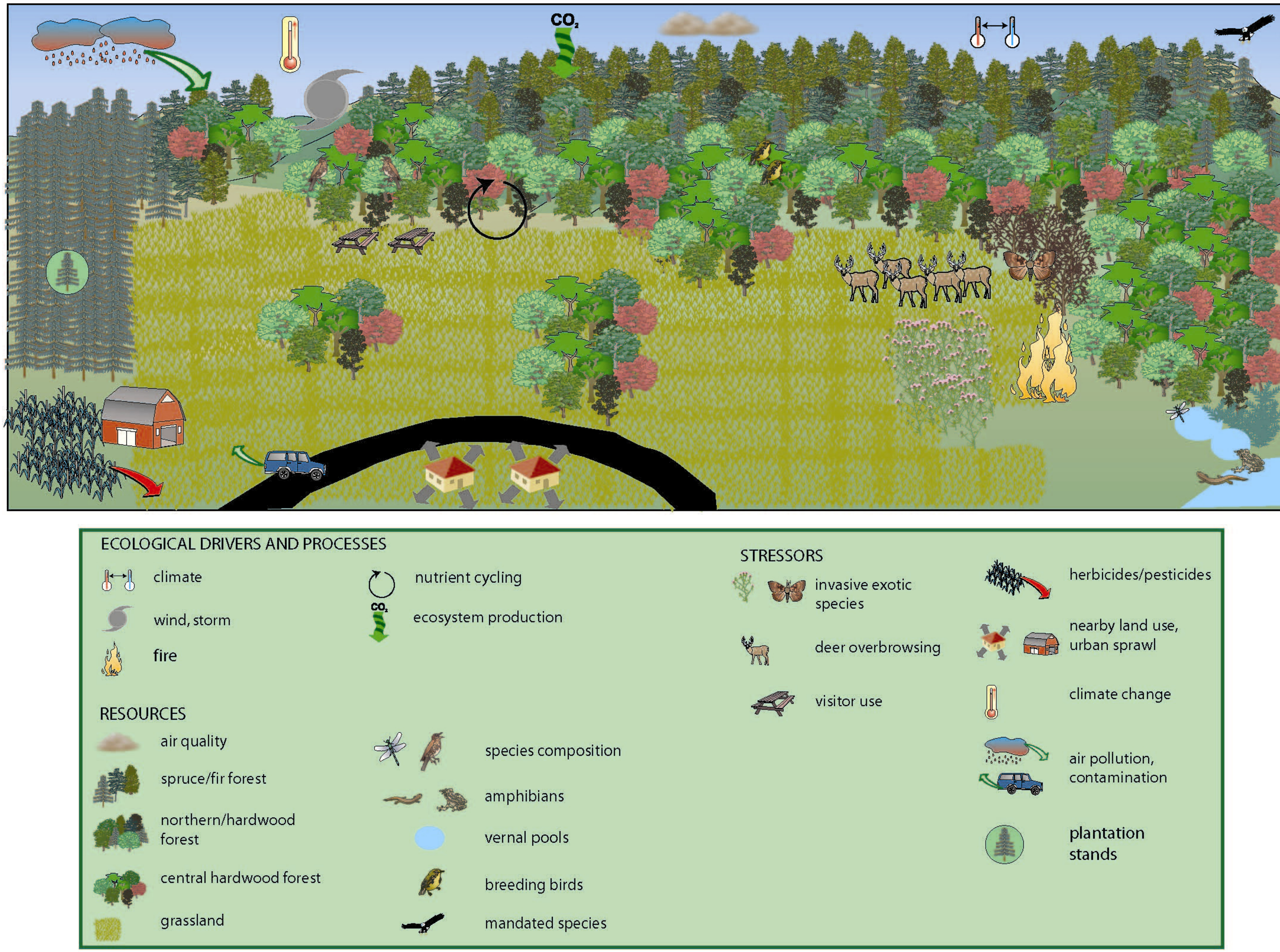
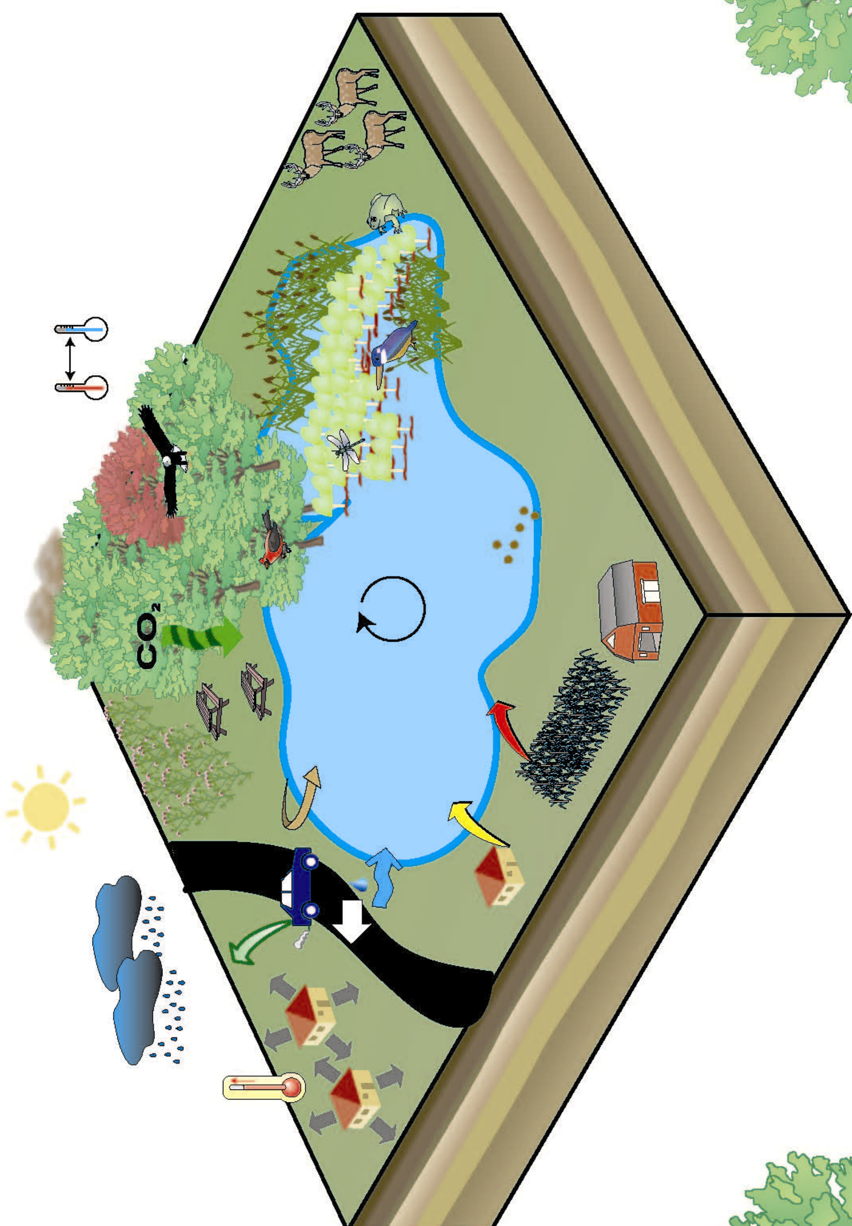


Figure 2.2. Terrestrial conceptual diagram for the NETN parks.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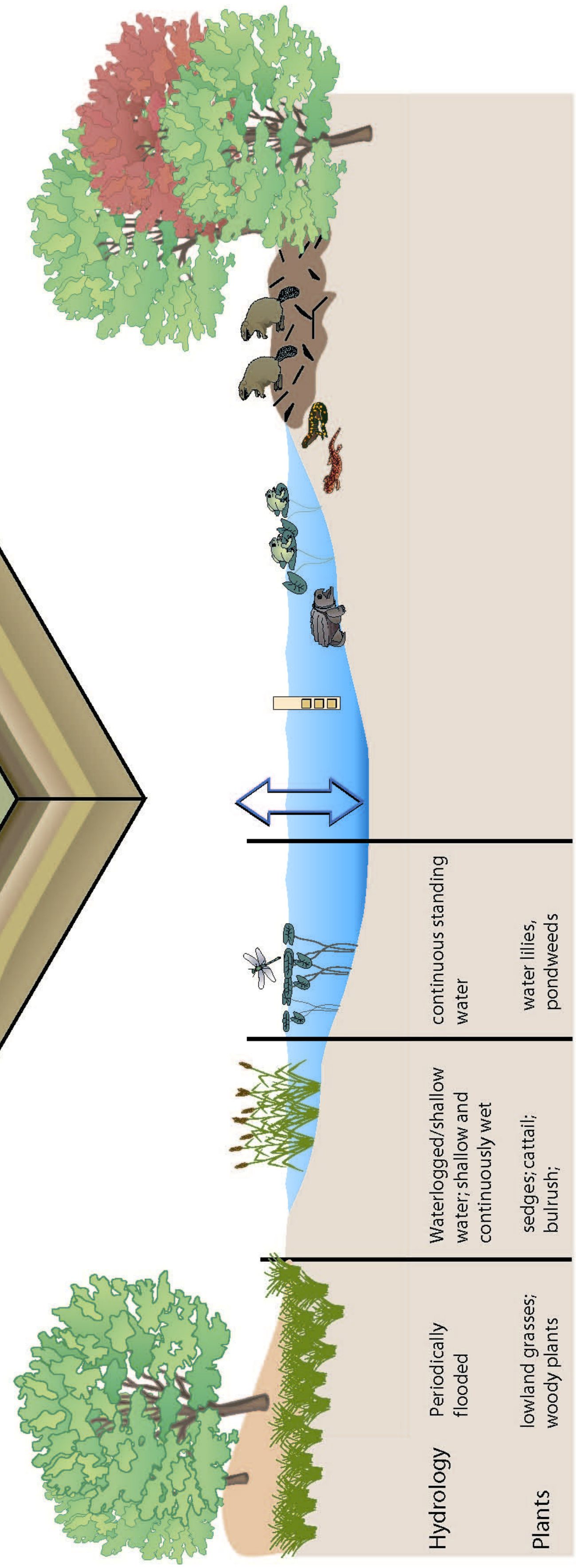

Hydrology
Plants
Periodically flooded
lowland grasses; woody plants
Waterlogged/shallow water; shallow and continuously wet
sedges; cattail; bulrush;
continuous standing water
water lilies, pondweeds

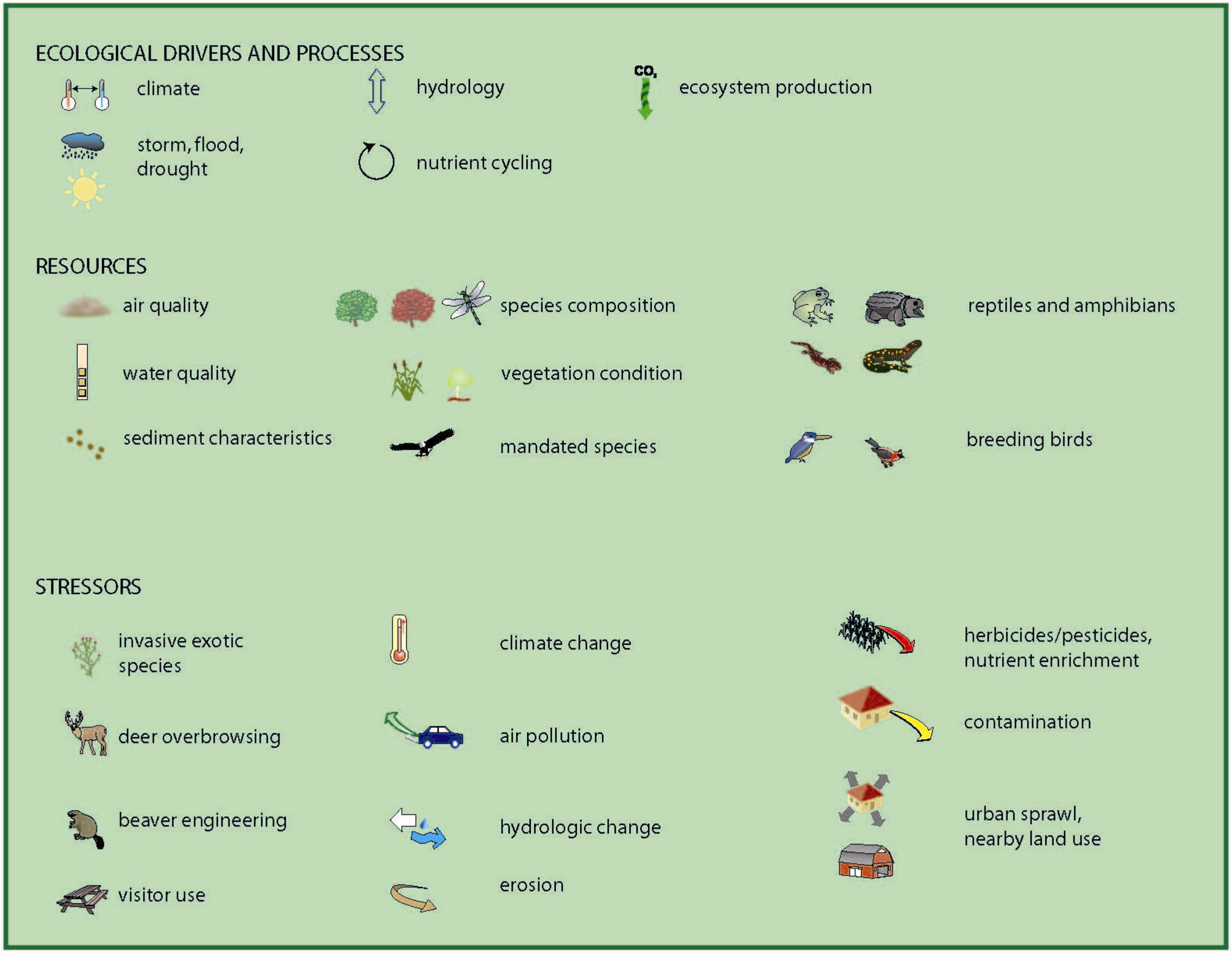


Figure 2.3. Wetland conceptual diagram for the NETN parks.

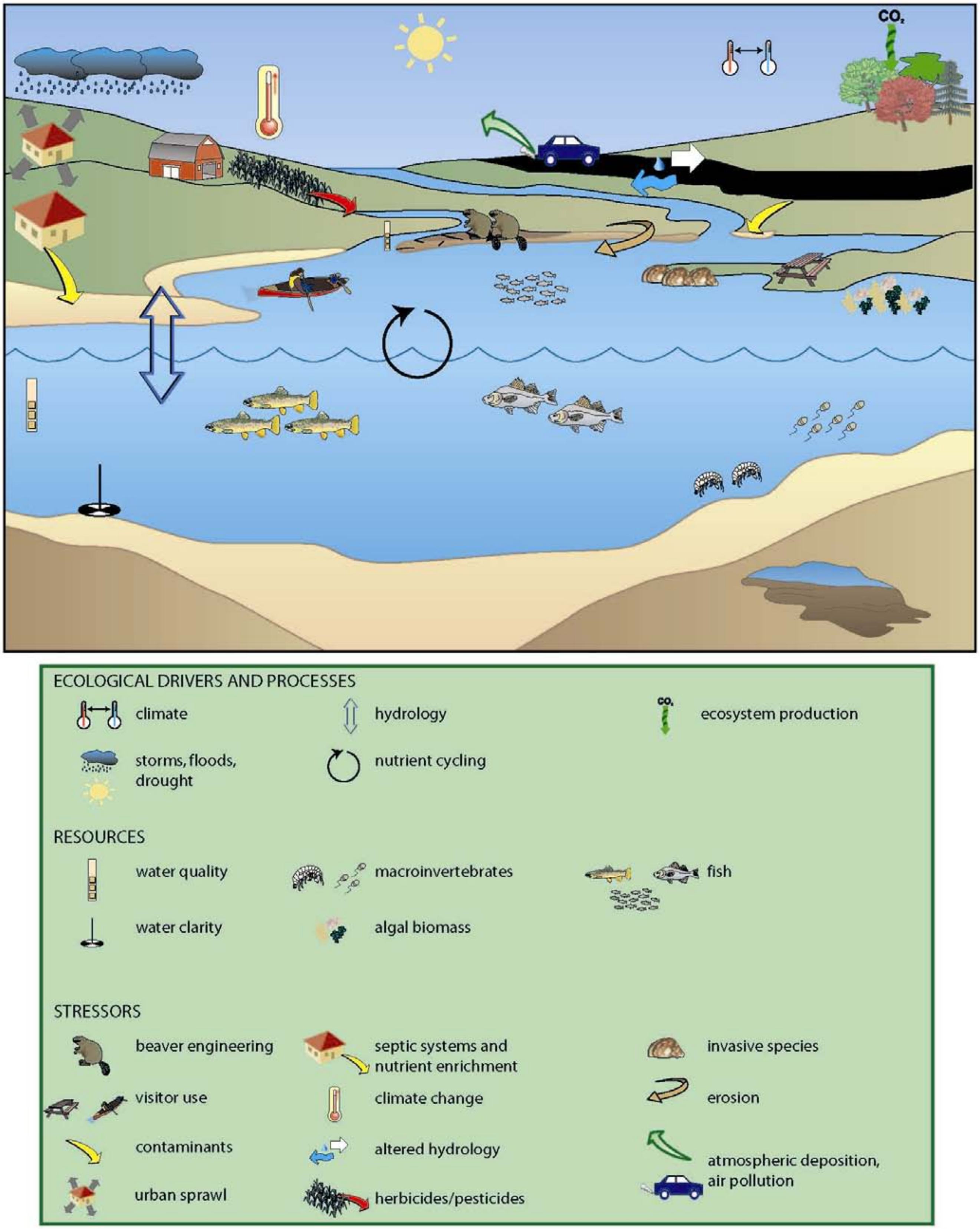


Figure 2.4. Freshwater aquatic conceptual diagram for the NETN parks.

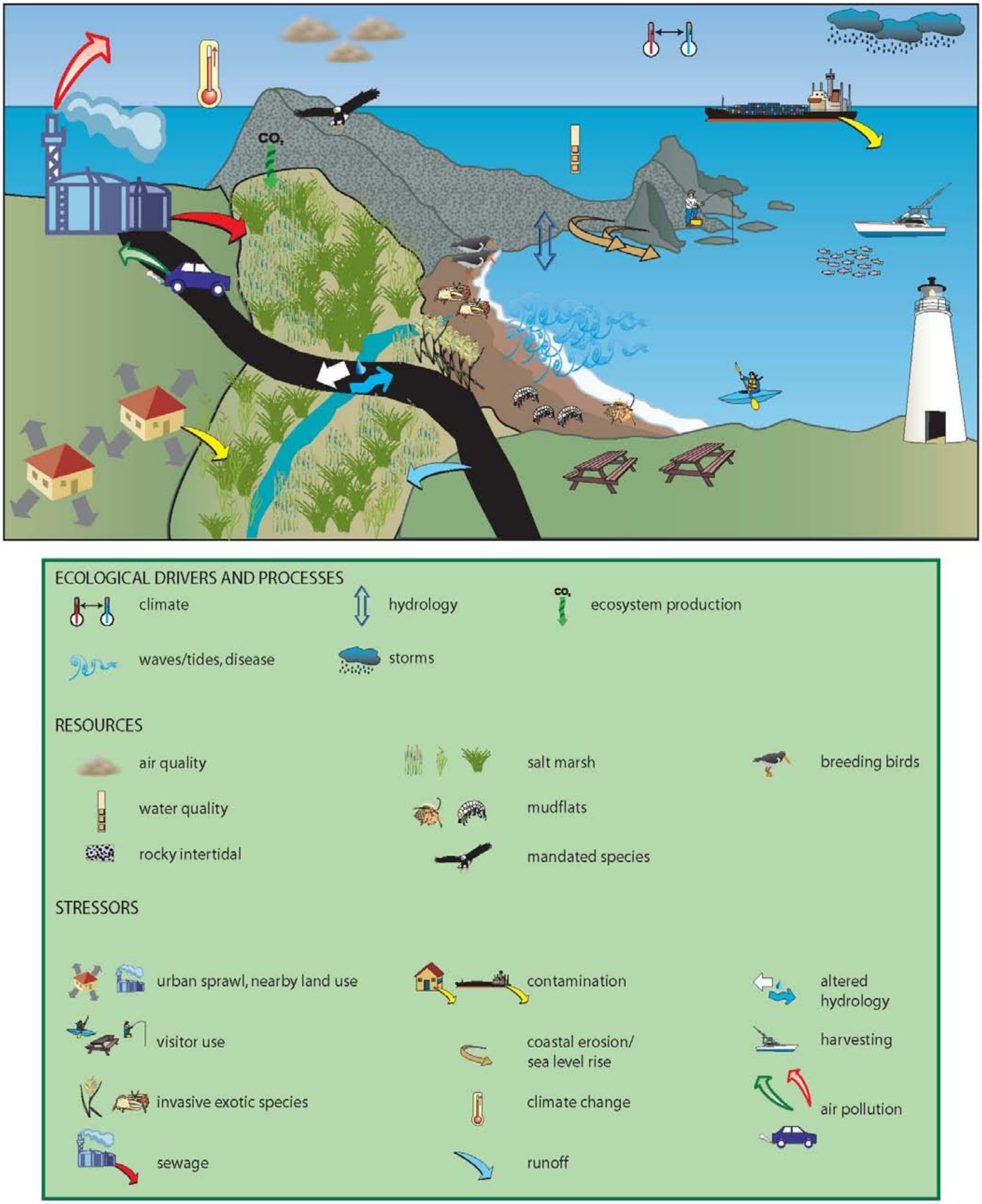


Figure 2.5. Rocky Intertidal conceptual diagram for the NETN parks.

Otter Cliffs: Acadia NP

England shores, so the New England coast lacks the extensive barrier beach and salt marsh habitats which develop from sediment accumulation and are common south of Boston Harbor.

Rocky Intertidal: The rocky intertidal systems which dominate the New England coast are characterized by strongly fluctuating physical conditions, caused by tides, which create stark patterns of vertical zonation. The rocky substrate offers less respite from extreme temperatures, desiccation, and buffeting waves than soft-sediment shores, and thus favors algae and invertebrates that can withstand these physical challenges. The rocky intertidal food chain is supported by high plankton productivity, harvested by filter-feeding barnacles and mussels, and also by benthic algae, consumed by herbivorous snails and urchins. Dominant predators include shell-drilling snails and starfishes in open-coast habitats, and crabs in bays and estuaries. The intertidal zone also provides food for many species of birds, and haul-out habitat for harbor seals.

Mud and Sand Flats: Intertidal mud and sand flats form in protected areas along the coast where diminished water movement allows the accumulation of fine sediments. In contrast to rocky intertidal habitats, organisms inhabiting mud flat systems interact more dynamically with the substrate, burrowing or growing into the mud and respectively increasing or decreasing habitat stability by doing so. Sediments in mud flats possess strong vertical biogeochemical gradients due to subsurface anoxic conditions caused by submersion. Often, a sharp boundary demarcates the anoxic zone, below which anaerobic decomposition processes and chemotrophic bacteria prevail (Howarth and Teal 1980). Intertidal mud flats often support large predator populations - birds, fishes and crabs which feed on worms, clams, and small crustaceans. Food supply in mud flats is strongly linked to water movement processes, which supplies both plankton for filter-feeding bivalves, and detritus for deposit-feeding organisms.

Coastal Marsh: Like mud flats, coastal marshes also develop in protected coastal habitats, often the mouths of estuaries, where fine sediment accumulation enables colonization by halophytic vegetation. Salt marsh systems are successional, beginning with colonization by smooth cordgrass, *Spartina alterniflora*, which binds additional sediment to create higher marsh habitat above tidal influences that can be colonized by additional species (Redfield 1972). Disturbance from winter ice-scour is common in northern salt marshes, and resets this successional development. Like rocky intertidal systems, salt marshes exhibit strong elevational zonation due to gradients of physical stress and competition, though in salt marshes physical stressors (from anoxia and salt) drive ecological patterns at lower elevations while competition dominates at higher elevations more suitable for plant growth. Salt marsh food chains are typically detritus-based, with consumers primarily feeding on plant detritus. Salt marshes provide numerous benefits, serving as protected nursery grounds for many species of fish, shrimp and crabs, providing feeding and nesting area for birds and mammals, buffering shorelines from flood and storm damage, limiting erosion, and reducing coastal nutrient loading by providing sinks for excess nitrogen and sulfur.

Ecosystem Drivers and Processes

Climate: Climate is a key ecosystem driver that affects the structure, composition and function of all ecological systems (Figures 2.2 to 2.5). The northeastern U.S. has a temperate humid continental climate (Trewartha and Horn 1980); this climate displays large daily and seasonal temperature variation and abundant rainfall evenly distributed throughout the year (Bryson and Hare 1974). Temperature and rainfall vary across the region along latitudinal and altitudinal gradients. Mean annual temperatures range from about 11˚ C along the southern coast to 4˚ C in the northern highlands and annual precipitation ranges from 90-120 cm, of which from 10 to 30% falls as snow (Bryson and Hare 1974). The northern part of this region experiences cool summers, and long, cold winters which typically include a persistent snow pack from mid-December until April. In the southern part of this region, summers are warmer, winter temperatures are milder and snow pack development is more variable. The number of freeze-free days annually varies from only about 90 in the White Mountains of New Hampshire and Maine to as many as 180 in a narrow strip along the southern coast (Bryson and Hare 1974).

Disturbance Regimes: Disturbance regimes are another key driver affecting NETN ecological systems. In forested ecosystems throughout the region, frequent windstorms create small- to medium-sized gaps that rapidly regenerate (Lorimer and White 2003, Figure 2.2). Less frequent hurricanes create much larger openings and temporarily create habitat for earlier successional species within the forest mosaic. Periodic ice storms can cause substantial damage over large regions, but tend to result in regeneration rather than stand replacement (Lorimer and White 2003). Historically, fire has been infrequent within the northern hardwood forest, but was more common within the central hardwood forest and probably also within the transitional mixed forest between northern hardwood and spruce-fir (Cogbill et al. 2002). Insect pests and disease are also important agents of natural disturbance, particularly in the low diversity coniferous forest (Lorimer and White 2003, Figure 2.2).

Natural disturbances to wetlands influence hydrology and therefore change the abiotic and biotic attributes of wetland systems. Changes to hydrology can occur naturally to wetlands through succession, beaver engineering, sediment transport, severe weather events, and ice scouring (Figure 2.3). Severe weather

Floodplain: Saratoga NHP

events are the most common source of natural disturbance for wetlands in the NETN and determine the extent and duration of floods and droughts. The direct consumption of plants by geese, muskrats, and other herbivores can be common in some wetlands and greatly alters the vegetation composition and structure (Mitsch and Gosselink 2000).

Floods and droughts are the primary disturbances that affect aquatic ecosystems in NETN parks (Figure 2.4). Floods can occur during any season in the northeast, but are most widespread in the spring when large frontal systems bring steady rain which falls on frozen or saturated ground. In the summer and fall, thunderstorms and hurricanes can cause local flooding (Maloney and Bartlett 1991). Floods are natural recurring events that can cause major morphological shifts in river systems, and cause widespread erosion and sedimentation, especially when coupled with urbanization. Droughts are more difficult to define and quantify than floods, but are also natural recurring events in the northeast.

Hydrology and Geomorphology: Hydroperiod (the frequency and duration of soil inundation) defines the hydrology of a specific wetland and largely determines the type of wetland that will develop in a particular setting. Wetland hydroperiod is influenced by basin morphometry, wetland size, connection of the wetland to groundwater resources, and long-term climatic conditions (Larson 1995, Lent et al.1997, Kirkman et al. 1999, Brooks and Hayashi 2002, Figure 2.3). Hydroperiod is the most important physical factor driving the composition and diversity of the wetland floral and faunal communities and wetland productivity (Semlitsch et al. 1996, Schneider 1999, Mitsch and Gosselink 2000, Brooks 2004). Therefore, monitoring wetland hydroperiod not only provides detailed information about wetland condition, structure, and function but also can be used to better understand the ecological effects of changing weather patterns.

Within the intertidal zone, substrate composition is the primary determinant of community type, and thus is also an important indicator of biotic change. While bedrock and boulder substrates exhibit little change over time, cobble, gravel, sand and mud substrates change both seasonally and over the long-term, in response to storms and sometimes human use.

Nutrient Cycling: Nutrient cycling is a fundamental ecological process that is intrinsically linked to the composition, productivity and function of ecosystems (Figure 2.2). The utility of using some measures of nutrient cycling as indicators of ecosystem status, function or integrity has been widely recognized (Harwell et al. 1999). A major feature that separates wetland from terrestrial systems is the anaerobic nature of wetland soils (Morris 1991). The absence of oxygen in wetland soils slows the decomposition of organic material compared to terrestrial systems. Wetlands, because of the gradients in available oxygen, maintain the widest range of oxidation-reduction reactions of any ecosystem type (Keddy 2000). This effectively allows wetlands to function as transformers of nutrients and metals where elements are converted among an array of chemical states (Mitsch and Gosselink 2000). Wetland nutrient cycling is dominated by the detritus food web where bacteria and invertebrates are a key component in nutrient cycling (Figure 2.3). Most nitrogen is stored in these organic sediments. Nitrogen cycling within a wetland is controlled by the temperature, pH, and the amount of available oxygen (Keddy 2000).

Nutrient cycling of freshwater ecosystems is linked to the productivity and function of these ecosystems. The trophic status of a water body is also a measure of its productivity, or the rate at which organic matter is produced. The invertebrates, algae, bryophytes, vascular plants, and bacteria of freshwater systems, which are responsible for much of the work of nutrient cycling, are adapted to the specific sediment and organic matter conditions of their environment and are thus sensitive to changes in the type, size, or frequency of sediment inputs. Understanding nutrient cycling and productivity in NETN aquatic systems may provide links between ecosystem condition, ecosystem function, and stressors such as non-point source pollution and land use (Figure 2.4).

Ecosystem Productivity: Ecosystem productivity provides a measure of energy flow through the system; productivity is the amount of energy stored as organic matter. Within an ecological system, annual productivity varies with climate and patterns of disturbance as well as with stressors such as insect or herbivore browsing and atmospheric deposition and ozone (Ollinger et al. 2002, Laurence and Andersen 2003). Thus productivity provides an integrated measure of the status of an ecological system or of specific taxa and is an important measure in all ecological systems (Figures 2.2 to 2.5).

Phenology: Northeastern temperate systems are characterized by distinct seasonality that drives patterns of floral and faunal phenology, or the timing

Trout Lily and Red Trillium: Saratoga NHP of natural phenomena. Recent research indicates that anthropogenic climate change may already be driving phenological change in a variety of species (Parmesan and Yohe 2003, Root et al. 2003). Monitoring key phenological occurrences such as bud break and flowering in key species will help determine the magnitude and patterns of such change within NETN systems. The combined effects of climate change and other stressors have the potential to substantially alter hydrological and biogeochemical processes, and thus the floral and faunal communities of NETN park ecosystems.

Resources

The NETN has identified focal taxa as condition indicators of functional or taxonomic groups. While the use of focal taxa as indicators of ecological condition is controversial (Prendergast et al. 1993), this approach can be useful if a range of species representing diverse taxa and various life histories can be included (Terborgh 1974, Griffith 1997, Carignan and Villard 2002). By monitoring diverse taxa, we reduce the chance of failing to detect significant change in the ecological integrity of these systems. Monitoring of taxa that can be readily grouped by their functional relevance, such as assemblages of breeding birds, red-backed salamanders, and certain insect groups will provide an integrated monitoring program for the NETN parks.

Selection of focal taxa as indicators for long-term monitoring should, to the extent possible, detect response to a wide range of stressors at several spatial scales (Noss 1990, O'Connell et al. 1998), and include the range of functional and taxonomic groups important in a particular ecosystem (Terborgh 1974, Keddy and Drummond 1996, Griffith 1997, Carignan and Villard 2002). Monitoring of taxa with specific functional relevance, such as pollination and decomposition, would incorporate indicators of these important ecological processes into NETN ecological integrity ratings.

Selected arthropod taxa provide useful indicators of environmental condition at the scale of the park. In general, arthropods inhabit smaller home-ranges than many larger and more charismatic fauna, and so may be useful as indicators of environmental condition within these relatively small parks. "Flagship" taxa sensitive to anthropogenic stressors also make excellent focal taxa for monitoring. Avian communities may be particularly well-suited due to their sensitivity to habitat fragmentation and the ease of identification (Carignan and Villard 2002). The red-backed salamander comprises a significant component of faunal biomass within temperate forested systems, in which it is widely distributed. This species has been monitored as an indicator of acid stress and climate change (Welsh and Droege 2001).

Wetland vascular plants, or macrophytes, are increasingly being used as indicators of wetland condition (Adamus et al. 2001). Macrophytes are commonly used to delineate wetland boundaries and to classify wetland types. Common plant species in northeast wetlands include: red maple (*Acer rubrum*), silver maple (*Acer saccharum*), green ash (*Fraxinus pennsylvanica*), buttonbush (*Cephalanthus occidentalis*), meadow-sweet (*Spiraea alba*), speckled alder (*Alnus incana*), willow (*Salix* spp.), common cattail (*Typha latifolia*), pickerelweed (*Pontederia cordata*), broad-leaved arrowhead (*Sagittaria latifolia*), and sphagnum mosses (*Sphagnum* spp.).

Wetland invertebrates are important trophic links between plants and their detritus, and animals (Mitsch and Gosselink 2000). Many groups of insects serve important roles in wetland nutrient cycling by shredding plant material to increase availability to bacteria (Adamus et al. 2001). Invertebrate fauna are increasingly being used as indicators of wetland condition (Adamus et al. 2001). Some invertebrate species, such as fairy shrimp (Eubranchipus spp.), are also entirely dependent upon vernal pool habitat and many species act as important predators and prey in wetland ecosystems (King et al. 1996).

Amphibians and reptiles are the dominant vertebrate groups in many freshwater systems of NETN parks (Figure 2.3). Common species include the American toad (*Bufo americanus*), green frog (*Rana clamitans*), American bullfrog (*Rana catesbeiana*), gray treefrog (*Hyla versicolor*), pickerel frog (*Rana palustris*), spring peeper (*Pseudacris crucifer*), eastern newt (*Notophthalmus viridescens*), painted turtle (*Chrysemys picta*), Blanding's turtle (*Emydoidea blandingii*), and snapping turtle (*Chelydra serpentina*). Some species, like wood frog (*Rana sylvatica*), the eastern spadefoot toad (*Scaphiopus h. holbrooki*), and the four species of mole salamander (*Ambystoma* spp.) have evolved breeding strategies intolerant of fish predation and are considered vernal pool obligate breeders. The lack of fish populations is essential to the breeding success of these species. Vernal pools are a high conservation priority in the northeast due to the loss of vernal pools and general lack of regulatory protection for these ephemeral habitats (Figure 2.1).

Other dominant wetland faunal groups include mammals and birds (Figure 2.3). Beaver (*Castor canadensis*) and muskrat (*Ondatra zibethicus*) are common in NETN wetlands; both of these species can cause major changes in marsh vegetation structure and composition. Common wetland avifauna include least bittern (*Ixobrychus exilis*), American bittern (*Botaurus lentiginosus*), great blue heron (*Ardea herodias*), black-crowned night heron (*Nycticorax nycticorax*), wood duck (*Aix sponsa*), black duck (*Anas rubripes*), Virginia rail (*Rallus limicola*), sora (*Porzana carolina*), marsh wren (*Cistothorus palustris*), northern waterthrush (*Seiurus noveboracensis*), and red-winged blackbird (*Agelaius phoeniceus*).

Determining and monitoring species richness, abundance and distribution of intertidal macro-algal vegetation is critical to understanding status and trends of the intertidal zone. Monitoring should focus on attached flora, which forms the base of the community within the rocky intertidal zone. Much of this vegetation is perennial; some, like *Ascophyllum*, can live for decades and exhibit low recruitment and slow growth (Bertness 1999). Ephemeral green algae such as *Ulva* flourish in high nitrogen waters and thus indicate eutrophication. Invasive species like *Codium* are moving into the northeast, and may be indicative of climate change and other disturbance.

Stressors

The ecosystems of New England currently are subjected to a suite of anthropogenic stressors unlike anything encountered during their long history prior to European settlement. These stressors act as agents of change in a myriad of related and often interacting ways. While the effects of some stressors, like acidic deposition, have been extensively studied and are well understood (Driscoll et al. 2001a), the effects of other important stressors, like climate change, are complex and unpredictable enough to elude our understanding despite concerted and ongoing study (McNulty and Aber 2001). The impacts of many stressors will vary depending upon land use history (Foster et al. 2003), and the combined impact of a suite of interacting stressors is certain to yield unexpected results (Aber et al. 2001). In this section, we summarize knowledge about the effects of key stressors upon NETN systems.

Invasive Species: The effects of invasive exotic species on the structure, composition and function of natural systems have become a chief concern of ecologists and land managers over the last 20 years (Drake et al. 1989). Invasion of native habitats by non-indigenous species or by native species whose densities are becoming unnaturally inflated (e.g., white-tailed deer) is presently recognized as second

Spotted Knapweed: Saratoga NHP

only to direct habitat loss and fragmentation as a threat to biodiversity. Currently, northeastern terrestrial systems are being seriously impacted by several species of invasive exotic insect pests and pathogens. The hemlock wooly adelgid has caused widespread mortality of hemlock across the eastern U.S. since introduction here in the 1950s, and threatens to rapidly and substantially reduce or eliminate eastern hemlock throughout much of its range (Orwig et al. 2002). This could have substantial impacts on associated taxa such as forest birds. Invasive exotic earthworms are another important taxa currently spreading through northeastern forests causing "keystone" changes to soil structure and nutrient cycling (Hendrix 1995). Several species of invasive exotic terrestrial plants are also currently impacting northeastern terrestrial ecosystems, by competing with native flora, altering habitat, and altering ecosystem dynamics such as nutrient cycling and hydrology (Mack et al. 2000).

Invasive plants contribute to the channeling (narrowing and deepening) of streams and the eutrophication and depletion of dissolved oxygen of lakes and ponds. Invasive exotic species can also profoundly affect visitor experience, by changing the quality of water used for swimming, boating, fishing, and drinking. The most prolific invasive exotic flora within NETN freshwater aquatic habitats are common reed (*Phragmites australis*), purple loosestrife (*Lythrum salicaria*), and curly pondweed (*Potamogeton crispus*). Bass and bluegill are the primary invasive exotic fauna present in NETN aquatic systems (Mather et al. 2002); these species have the potential to displace native fish communities through habitat disruption, competition for resources, and/or predation. Other exotic invasive exotic species such as zebra mussels have the potential to become management issues if introduced into NETN parks.

Invasive exotic species are also widespread within New England intertidal systems. The native species composition of these systems was depleted by extinctions caused by Pleistocene glaciation (Stanley 1986), leaving these systems particularly vulnerable to invasion by exotic species. Historic and modern shipping practices have supplied a steady influx of invaders, including some of the most common species now encountered (Carlton 1985). These species have drastically altered New England intertidal community composition over the last few hundred years and probably caused many local extinctions, but we lack knowledge of intertidal community composition prior to European exploration and settlement. Within New England salt marshes, the exotic reed *Phragmites australis* has been particularly destructive, out-competing native marsh plants and altering habitat. New invasive exotic species continue to arrive and spread. The Asian shore crab (*Hemigrapsus sanguineus*), native to the coasts of southern Russia, Japan, Korea and China south to Hong Kong, has recently invaded the Atlantic coast. First detected in 1988 by a biology student on Cape May, New Jersey, the crustaceans have been moving north and south along the eastern seaboard. *Botrylloides violaceus*, a colonial tunicate native to the northwest Pacific, was probably introduced by fouling in the 1970s and is now abundant from Long Island Sound to Maine.

White-tailed deer: Morristown NHP

Deer Herbivory: In many parts of the northeastern United States, deer populations have reached historic high levels due to a combination of habitat modification and the extirpation of natural predators (Augustine and deCalesta 2003). White-tailed deer reduce forest regeneration rates and can aid in the introduction and expansion of invasive plants.

Land Management,Agriculture, and Silviculture: The national historic sites and parks within NETN are managed primarily to achieve cultural goals, such as maintaining historical landscapes or practices. In order to achieve this, these parks apply substantial land management to maintain open or early successional habitat, perpetuate agriculture within parks, or practice silviculture within parks. These activities can have significant ecological impacts due to direct habitat alteration, habitat fragmentation, and the application of herbicides, pesticides and fertilizers. In addition, silviculture alters forest structure and composition, as well as ecological processes acting within affected forests.

Hydrologic Alterations and Beaver Engineering: Hydrologic alterations have many causes, including land use history, increases in impervious surface area associated with development, installation of culverts, water withdrawals and discharges, the installation of water storage and release from impoundments, and straightening or confining a channel within an urban area. These alterations can directly affect the aquatic flow regime, sediment transport and water quality. Alterations can also affect geomorphology over the long term by dampening peak flows, changing patterns of aggradation and degradation, constricting a meandering channel, and causing local scour. Hydrologic alterations such as impoundments can restrict the movement of aquatic organisms.

Beaver engineering is one of the most pervasive hydrologic alterations to NETN parks. Water diversions of any kind can be viewed as potential agents of both positive and negative change to wetlands. Beaver can affect almost any wetland type but are especially common along streams and ponds where they build dams. Dam construction typically kills all woody vegetation, reduces the water velocity, and drastically changes plant species composition and structure (Thompson and Sorenson 2000). Beaver alteration of wetlands occurs in decadal cycles with an initial period of flooding after dam creation and impoundment followed by abandonment after the beavers deplete the local food source. Thus, beavers destroy habitat by flooding the unusual vegetation of bogs and fens, for example, but they conversely create many highly productive wetlands along streams formerly dominated by upland vegetation. Despite the many positive effects of beaver engineering, beavers create challenges for park managers when they occur at an excessive level. Beavers topple trees; flood roads, crops, and woodlands; create impoundments; flood riparian areas; and alter riparian vegetation.

Beaver: Acadia National Park

Nearby Landuse and Roads: The landscape of New England has been profoundly altered by human activities over the last four hundred years (Foster et al. 2004). Widespread clearing for agriculture and logging for timber have left very few terrestrial systems in the northeastern United States untouched. In particular, the southern New England coast and adjacent areas of New York and New Jersey are among the most densely settled areas within the United States, resulting in the elimination or drastic alteration of all of the central hardwood forests within this region. Remaining areas are small, fragmented and heavily impacted by human activities, and exist in a matrix of managed rural and suburban habitat. A large and growing body of scientific literature documents the negative impacts of habitat fragmentation on biodiversity in a wide variety of ecological systems (Fahrig 2003). The impacts of fragmentation have been especially well documented upon avian communities, and population declines of a variety of forest interior avian species are linked to habitat fragmentation (Rich et al. 1994, Austen et al. 2001).

A network of roads cuts through the northeast, reinforcing edges and introducing disturbance, pollutants, de-icing chemicals and facilitating invasion by exotic species (Brothers and Spingam 1992, Spellerberg 1998). Roads are among the most widespread forms of habitat modification and can have profound effects on wetland communities (Trombulak and Frissell 2000, DiMauro and Hunter 2002, Gibbs and Shriver 2002, Forman et al. 2003). Road construction has been implicated in the significant loss of wetland biodiversity at both local and regional scales for birds, herptiles, and vascular plants (Findley and Houlahan 1997).

Land uses such as farming, forestry, development, and water management can all affect the magnitude and frequency of stream flow and thus a river's ability to erode the land. When streams are constrained from meandering by urban alterations, hydraulic instability can cause increased deposition, erosion, slumping, over-widening or the abandonment of existing channels for new ones (Dunne and Leopold 1978). As water body buffers expand or contract, sources and amounts of non-point source pollution and runoff to the water body can also change. Barriers between water bodies, such as impoundments, can inhibit the movement of species and thus affect the floral and faunal composition of a water body.

Visitor Use: Visitor use may be one of the most important stressors acting within boundaries of NETN parks. As part of its mission, the NPS aims to preserve unimpaired the natural and cultural resources and values of the national park system for the enjoyment, education, and inspiration of this and future generations. It is a complex task to balance the NPS mission of preserving resources unimpaired while also having the public enjoy, and be educated and inspired by those resources. Hikers can increase erosion on and around trails, trample nearby vegetation and cause soil compaction. Car traffic within parks can cause wildlife fatality and reinforce the fragmentation effects associated with roads. Horse-riding can contribute to trampling, erosion, and aid in the spread of invasive exotic species. Snowmobiling can cause winter-time disturbance to wildlife.

Stressors to freshwater aquatic resources related to visitor use include the extraction of natural resources (such as fish), erosion stemming from multiple uses, road runoff and contamination stemming from the many roads that allow visitor access within the parks, and the introduction of invasive species carried in by visitors.

Roosevelt-Vanderbilt NHS

Rocky and sandy intertidal areas are frequently visited habitats and often the focus of park-led interpretive tours at both Acadia and Boston Harbor Islands. Visitor use at both of these parks can cause substantial trampling and removal of resources. In order to truly understand biotic change within the intertidal zone, it will be important to monitor visitor use, and more specifically, visitor intensity, location, and activity, such as walking, boating, or recreational shell-fishing (Engle and Davis 1996a, 1996b). Trampling and other visitor use impacts are likely to be localized within areas accessible to parking or ferry.

Ozone: Tropospheric (ground-level) ozone is a damaging phytotoxin of significant concern within the northeastern United States (U.S. Environmental Protection Agency 1996). Ozone is formed by sunlight acting upon nitric oxides and simple hydrocarbons from industrial emissions and motor vehicles. Thus, tropospheric ozone levels vary rapidly in space and time, and are highest on sunny, still days in areas within and downwind of urban centers, industrial facilities and transportation corridors. Elevated background levels of tropospheric ozone occur throughout the northeastern United States. In addition to harming human health, ozone damages sensitive plant species by causing a visible spotting or "stipple" on the upper surface of plant leaves. Ozone can cause reduced photosynthesis, reduced growth, premature aging, and leaf loss with or without the occurrence of foliar injury.

Atmospheric Deposition: Acidic deposition, derived from nitrogen and sulfur emissions from electric utilities, manufacturing, agriculture and other sources, is deposited in precipitation (wet deposition), directly onto vegetation immersed in clouds and fog (occult deposition), and also by direct transfer of particles and gases (dry deposition). Deposition of sulfur and nitrogen in rain and snow can acidify soils and surface waters, negatively affecting fish, plants, and other biota.

Anthropogenic atmospheric deposition can dramatically affect water quality in wetland systems. Acidic deposition, in the form of nitrogen and sulfur oxides, can alter wetland structure and function (Morris 1992). Another significant component of anthropogenic air pollution is mercury. Although mercury is a naturally occurring element, studies show that human activities have more than tripled its concentration in the environment, which can cause negative impacts in wetland systems, such as direct toxicity and reduced fecundity of secondary consumers.

Impacted visibility on the Appalachian National Scenic Trail: Great Smoky Mountains NP

Atmospheric deposition is one of the largest sources of nitrogen to streams in the northeast. Measures of atmospheric deposition are critical for understanding water chemistry and stress (Likens and Bormann 1974). Fifty percent of total nitrogen entering New England rivers and streams in 1992-1993 was estimated to come from atmospheric deposition originating both inside and outside the region (Moore et al. 2004). Atmospheric deposition is particularly problematic in NETN parks where surface water bodies may have low acid neutralizing capacity (ANC). This parameter is a key indicator of recovery, determining the capacity of lakes and streams to buffer acidic inputs and prevent further acidification (U.S. Environmental Protection Agency 2004).

Contamination: Anthropogenic sources of contaminants include industrial effluent, municipal wastewater, runoff from agricultural, urban and forested areas, and atmospheric deposition. Human activity speeds the rate at which naturally occurring metals leach into the environment. Concentrations of lead, mercury and zinc within sediments were positively correlated with urban land use in the Hudson Connecticut, Housatonic and Thames River Basins from 1992-1994 (Breault and Harris 1997, Wall et al. 1998). Specific conductance and dissolved chloride concentrations have increased in rivers in New England over the 20th century (Bell 1993, Kulp and Bohr 1993, Strause 1993, Toppin 1993, Trench 1996). This is likely due to the increased use of de-icing salts on roads. Contamination of aquatic systems by road runoff and de-icing chemicals, such as rock salt and magnesium chloride, can substantially impair water quality and affect a variety of organisms.

Wetland contamination is typically associated with runoff from agricultural areas, residential and urban areas, waste water treatment facilities, and atmospheric deposition. Heavy metals such as mercury, lead, zinc, and cadmium can be directly toxic to wetland fauna (Adamus et al. 2001). Contaminants, including trace metals such as copper, lead, mercury, zinc, cadmium, and nickel; organic chemicals such as PCBs; polynuclear aromatic hydrocarbons (PAHs); and pesticides all have been found to adversely affect the quality of surface water and sediments in the northeastern United States (Maine Department of Environmental Protection, written communication, 1992). Contaminants accumulate in sediments, are consumed by bottom-feeding organisms, and then work their way up the food chain. Contaminants inhibit the growth, reproduction, and immune systems of aquatic organisms.

Pollution from many sources significantly impacts intertidal systems. Oil pollution, from urban and suburban runoff and from tanker spills, is a chronic problem (Suchanek 1993). Some seaweeds and many crabs, gastropods and amphipods are very sensitive to oil pollution. Sewage runoff is likewise a pervasive near shore stressor, which can cause coastal eutrophication and toxic algal blooms that negatively affect native species (Valiela et al. 1992). Toxic, anti-fouling paints routinely applied to the undersides of boats are another widespread, chronic stressor; these paints leach into near shore waters and affect many intertidal organisms.

Herbicides and pesticides: Pesticides and herbicides can enter surface water bodies through overland runoff or enter groundwater through infiltration. Concentrations and types of pesticides detected in New England streams depend on land use (Garabedian et al. 1998). Diazinon was most often detected at urban sites while atrazine, metolachlor, and simazine were most frequently detected at sites draining agricultural land. Atrazine was detected at 88 percent of the agricultural sites, was frequently detected in combination with other pesticides, and was the most commonly detected pesticide overall. The high percentage of insecticides detected in urban basins reflects the use of these products on lawns. While wide spectrum pesticides such as DDT have been banned in the United States, contemporary insecticides are soluble in water and can be toxic to fish. Herbicides, while less toxic to fish, can kill aquatic plants (Welsch 1992). Pesticides degrade slowly, accumulate over time, and can be detected in fish tissue even when the concentrations are too low to be detected in stream bottom sediments.

Nutrient Enrichment: Nutrients are necessary for productive aquatic ecosystems, but in high concentrations they can adversely affect aquatic life through excessive plant growth in streams, lakes, and coastal waters. This leads to depleted dissolved oxygen and fish kills. Nutrient concentrations in water generally are related to land use in the upstream watershed or the area overlying a ground-water aquifer (Mueller and Helsel 1996).

Nutrients, especially nitrogen and phosphorous, enter wetlands via surface water, groundwater, and the atmosphere (Brinson and Malvarez 2002) and can dramatically change the composition of both the floral and faunal communities (Bedford et al. 1999). Nutrient enrichment also increases the risk of invasive species establishment in many wetlands, a primary threat to NETN wetland and terrestrial resources. Increases in nitrogen and phosphorous in wetlands causes eutrophication, often at concentrations that exceed natural levels. A dominant source of nutrient inputs into wetland systems comes from agricultural and residential runoff.

Total nitrogen loadings from rivers to coastal estuaries increased from 1900-1994 as a result of increasing use of nitrogen-based fertilizers, the increase in wastewater from municipal and industrial sewage, increased use of de-icing salts on roads, and increased atmospheric deposition of nitrogen. Nitrogen is released into the atmosphere from numerous sources, including fossil fuel combustion, agricultural fertilizers, and animal manure. Aquatic concentrations of chloride and nitrate increased during the 20th century due to municipal and industrial wastewater discharges (Jaworski and Hetling 1996). Specific conductance and dissolved chloride concentrations increased in rivers in New England over this same period (Bell 1993, Kulp and Bohr 1993, Strause 1993, Toppin 1993, Trench 1996) likely due to the increased use of de-icing salts on roads. The passage of the Federal Water Pollution Control Act in 1972 resulted in significant improvements in wastewater treatment throughout New England. Although wastewater practices are much improved, wastewater discharges and septic system effluent can still affect water temperature and increase nutrient concentrations (including nitrogen) in aquatic ecosystems.

Total phosphorus in northeast waters increased until the 1960s for many of the reasons listed above for total nitrogen, but has decreased since then because of a ban on phosphate-containing detergents (Roman et al. 2000). Water quality of three northeast rivers over the last century showed decreasing concentrations of sulfate and total phosphorus, but increasing concentrations of nitrate and chloride (Robinson et al. 2003).

Soil Erosion and Sedimentation: Sedimentation and erosion are naturally occurring processes in aquatic systems, but accelerated rates of either can have negative effects on ecosystem condition. Increased rates of sedimentation can affect wetlands by adding sediment-borne pollutants, burying vegetation and seed banks (Neely and Baker 1989), and changing the water depth and hydroperiod. Burial can smother aquatic invertebrates and fish eggs, and reduce oxygen availability by stimulating plant growth through nutrient addition (Keddy 2000). Excessive suspended sediments can block sunlight and impair photosynthesis, reduce visibility and the ability of fish and other organisms to feed, raise water temperatures and reduce dissolved oxygen, and clog and damage filter feeders and fish gills. Human activities which accelerate erosion include the creation of impervious areas which increase the volume and speed of storm water runoff and erode stream banks. Construction and forestry projects that leave the soil exposed can also accelerate erosion.

Bank erosion: Saratoga NHP

Harvesting: Throughout the history of human settlement in New England, humans have harvested a wide variety of intertidal organisms. While some species are now protected from over-harvesting, collection of many species continues. Shellfish and bait worms are harvested from soft-bottom flats within both Acadia and Boston Harbor Islands. Rockweed and knotted wrack (*Fucus* and *Ascophyllum*) are harvested for lobster-packing. In addition, many species are commercially harvested from the subtidal zone, immediately below the intertidal zone; these species include sea cucumbers, lobsters, and sea urchins. Some data describing the intensity of harvesting activity could be compiled from exiting data collected by local regulatory agencies, such as state agencies and town shellfish wardens.

Sea Level Rise/Shoreline Erosion: Sea level controls the distribution and spatial pattern of intertidal habitats. As sea level rises, the boundary of intertidal habitat types will shift. Currently, sea level is rising at about 2-4 mm/yr along the New England coastline due to global warming, and this rate of change is predicted to accelerate. Sea level data can be compiled from data collected by existing tide gauges in Boston and Bar Harbor operated by NOAA. In addition to sea level rise, shoreline erosion can cause change in the distribution of intertidal communities by loss of physical habitat via movement of intertidal sediment. Shoreline erosion is caused by a variety of natural and anthropogenic forces, including storm wave energy and boat wakes. Shoreline change could be monitored in part as changes in the mapped distribution of intertidal community types.

Climate Change: Anthropogenic climate change is both directly and indirectly altering many key environmental parameters that control the structure, composition and function of ecosystems. While accurate prediction of the effects of the suite of global change stressors upon ecosystems is currently beyond our abilities, a large body of research has been assembled which yields some insight into what may occur. A growing body of evidence also indicates that human activities have accelerated the concentration of greenhouse gases in the atmosphere (IPCC 2002). The climate of the northeastern United Sates is projected to become warmer and perhaps wetter over the next 100 yrs (New England Regional Assessment Group 2001). These changes will likely affect the structure and function of all ecosystems. Easiest to predict are the direct effects of elevated atmospheric CO_2 concentrations on vegetation. Elevated CO_2 has been shown to increase photosynthetic rates and tree growth, though this may be a short-term effect (Long et al. 1996, Rey and Jarvis 1998) that is likely to be limited under field conditions by nutrient availability (Curtis and Wang 1998, Johnson et al. 1998).

Several geophysical and biological studies indicate that spring is coming earlier in New England. The annual date of the last hard spring freeze became significantly earlier between 1961 and 1990 (Cooter and Leduc 1995) and lilac bloom dates at 4 stations became significantly earlier between 1959 and 1993 (Schwartz and Reiter 2000). The impacts of climate change on hydrology in the northeast are just beginning to be understood. Much of the significant change towards earlier lake ice-out dates in New England since the 1800s occurred from 1968 to 2000 (Hodgkins et al. 2003). All of 11 studied rivers in New England had significantly earlier winter/spring high flows from earlier snowmelt, with most of the change occurring in the last 30 years (Hodgkins et al. 2003). Furthermore, snow density on or near March 1 has significantly increased in coastal Maine over the last 60 years, indicating earlier spring melting (Dudley and Hodgkins 2002).

Projected increases in temperature will increase the rate of evapotranspiration, which in turn will alter wetland hydrology. Hydrologic alterations that reduce the flooding period will have the most negative impacts on ephemeral wetland or vernal pools (Brooks 2004). Changes in wetland water temperature due to rapidly changing climate are also predicted to alter the sex ratios of turtle populations because of their temperature-dependent sex determination (Root and Schneider 2002). Wetland herpetofauna may be especially sensitive to climate changes because of the synergistic effects of habitat fragmentation and the increased need for dispersal caused by a reduction in habitat quality. Increases in the rate of temperature change for wetland habitats may force many species to disperse more frequently. As increasingly urbanized landscapes become more hostile to dispersing wetland herptiles, the increased dispersal rates may reduce populations and further bias sex ratios (Gibbs and Shriver 2002, Steen and Gibbs 2004).

Vernal Pool: Marsh-Billings-Rockefeller NHP

Chapter 3
Selecting and Prioritizing Vital Signs

Introduction

The Vital Signs program, by definition, is charged with identifying the key components of park ecosystems that indicate ecological condition and can be tracked over time. To achieve our goal of selecting the subset of vital signs that will be monitored from a comprehensive list of possible monitoring variables, an objective process for selecting and then prioritizing vital signs was established and adhered to (Figure 3.1). This chapter outlines the process for prioritizing and selecting vital signs, how we decided on the process, and the resulting list of NETN Vital Signs.

Strategy for Prioritizing Vital Signs

Early in program development, we established a core science team representing expertise in forest ecology and vegetation science, aquatic ecology, wetland ecology, amphibians, ornithology, biogeochemistry, conservation biology, and ecological data management. The primary responsibilities of this team were to draft, select, and prioritize vital signs. We also solicited the expertise of the Technical Steering Committee and required Board approval for the vital sign selection process and, ultimately, the proposed list of NETN Vital Signs.

We prioritized and selected potential vital signs using a sequential peer review process. The core science team first drafted a list of more than 150 potential vital signs (Appendix: Vital Signs Long List), representing the five major categories identified in NETN conceptual ecological models:

- System drivers and stressors
- Components of biotic and abiotic integrity
- Ecological processes
- Landscape context
- Focal park resources

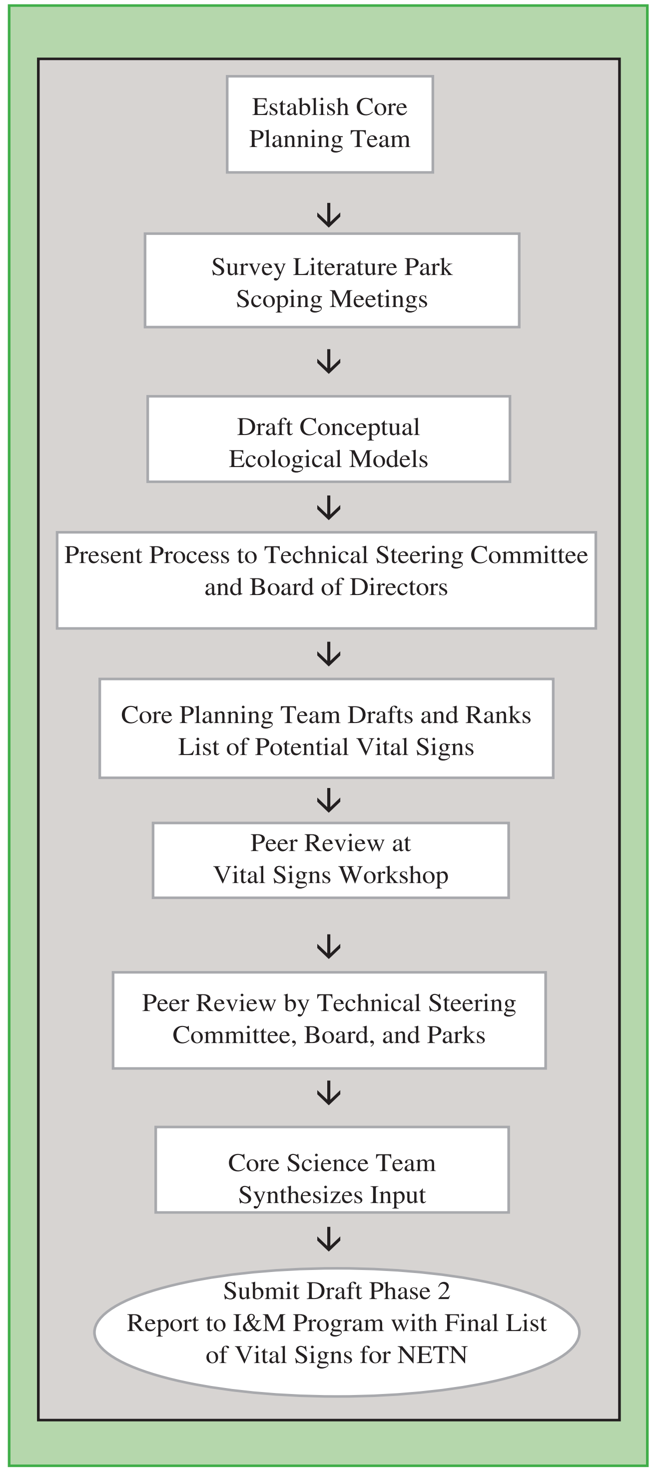


Figure 3.1. Planning process for NETN vital signs selection.

This was a comprehensive list that stemmed directly from the conceptual modeling process. We targeted ecological systems present within the Network that spanned spatial, temporal, and ecological scales of organization.

We reviewed and prioritized this list through a multi-stage process (Table 3.1), comprised of:

- Initial review by the core science team, who created the list of potential vital signs and the criteria for selection
- External peer-review by a group of more than 40 scientists and park managers
- Review by the NETN Technical Steering Committee, composed of both external scientists and NPS staff
- Additional review and revision by the core science team
- National I&M Program review and approval

Technical Steering Committee Guidance

Following I&M program guidance, the Technical Steering Committee agreed that vital signs would be selected from priority park issues based on ecological systems and park conceptual models (See Chapter 2). The Technical Committee and the core science team agreed that integrating the fiscal reality of the NETN's base funds early in the selection process would reduce the need for re-selecting vital signs after prioritization. To that end, we developed three hypothetical staffing

Table 3.1 Rating criteria used by the core planning team and the vital signs workshop participants to rank NETN vital signs.

Rating Category	Rating Criteria
Management Significance & Utility	Relevant to assessment questions Relevant to determining quantitative thresholds Sensitive to or indicative of stress Not redundant unless improves performance Linked to management actions Widely applicable (e.g., useful for multiple purposes)
Ecological Relevance	Clear linkage to ecological function or integrity or specific resource Anticipatory Indicative of status of other resources
Feasibility of Implementation	Availability of standard, well-documented methods Lack of sampling impacts on indicator Rapid, cost-efficient and can be bundled with other indicators for measurement Easily measured with little equipment or specialized knowledge, and large sampling window Baseline data available Long-term data management feasibility
Response Variability	Low or controllable measurement error, high repeatability of measurement Temporal variability predictable or described Spatial variability understood or controllable Sufficient discriminatory ability

and implementation scenarios and projected the cost of each scenario over a ten year period (Appendix: Budget Projections). The results of this exercise were used throughout the vital signs selection process to provide the fiscal "side-boards" for subject matter experts when providing recommendations for what a core monitoring program should contain.

The Technical Committee decided that an effective and focused means for selecting vital signs required establishing workgroups based on the four major ecological system groups present within NETN parks: terrestrial, aquatic, wetland and intertidal ecological systems. These workgroups were responsible for identifying priority issues related to the general ecological systems and providing guidance on selecting vital signs that would track changes in resource condition over time.

NETN Vital Signs Selection Workshop

The core science team organized and hosted a 2-day workshop at Acadia National Park in May, 2004. The core team developed the workshop materials in order to set the stage for identifying and prioritizing the NETN vital signs. Based on our conceptual modeling efforts, we defined general ecosystem categories for the workshop that were representative of park natural resources and identified potential vital signs prior to the workshop. Workshop participants were selected based on knowledge of these general system types, regional issues, and park management concerns and divided into the four workgroups (Appendix: Vital Signs Workshop Summary).

The workgroups were based on the same four ecological system groups as the conceptual models:

- Aquatic resources (lakes, ponds, rivers, streams)
- Freshwater wetlands (forested wetlands, open or shrub wetlands, peatlands, vernal pools)
- Intertidal (cobble beaches, rocky intertidal, soft-sediments)
- Terrestrial (forests, open uplands, rocky coast, plantations, fields and old-field successional habitats)

The intertidal workgroup did not include systems already prioritized by the Northeast Coastal and Barrier Network (i.e. salt marshes and estuaries). The NETN will prioritize these systems in relation to all park ecosystems for both Acadia and Boston Harbor Islands. If salt marshes and estuaries are a high priority for these two parks, the NETN will consider implementation of the Northeast Coastal Barrier Network (NCBN) protocols for these systems in order to expand the standardized regional coastal monitoring program.

After the workshop, the results were summarized (Appendix: Vital Signs Workshop Summary), reviewed, and then presented to a meeting of the parks, the Technical Steering Committee, and the NETN Board of Directors.

Northeast Temperate Network Vital Signs

The Technical Steering Committee, the Board, and the parks reviewed the proposed list of vital signs and approved the "short-list". In Table 3.2 we present a summary of the high priority vital signs with justification for why these are an important component of a long-term monitoring program in the Northeast. The NETN vital signs are comprehensive in scope and include multiple stressors, drivers, ecological processes, biological condition and biotic response indicators.

These vital signs represent an integrated list of ecological processes, elements of biotic and abiotic condition, system drivers and stressors, landscape condition, and focal park resources. Moreover, these vital signs are directly relevant to the natural resource management issues of a majority of NETN parks. The majority of the vital signs apply to most network parks, creating a framework for a standardized, comprehensive monitoring program where protocols can be designed and implemented within the majority of network parks (Table 3.3). The primary exceptions to a comprehensive, network-wide monitoring program occur with the intertidal and lake ecological

Table 3.2 Proposed list of high priority ("short-list") Northeast Temperate Network vital signs presented in the 3-tiered Ecological Monitoring Framework with potential measures.

Level 1	Level 2	Level 3	Vital Sign	Potential Measures
Air and Climate	Air Quality	Ozone	Ozone	Atmospheric ozone concentration (synthesize existing data), foliar injury to indicator species
		Wet and dry deposition	Acidic deposition & stress	Wet and dry deposition rates (synthesize existing data), streamwater ANC, streamwater nitrate concentration
			Contaminants	Heavy metal deposition (synthesize existing data)
	Weather and Climate	Weather and Climate	Climate	Air temperature, precipitation by type, relative humidity, solar radiation, wind speed and direction, snow water equivalent, snow depth (synthesize existing data)
			Phenology	First flowering of sensitive plant species, first amphibian call dates, length of growing season, ice out/in dates for lakes and ponds
Geology and Soils	Geo-morphology	Coastal / oceanographic features	Shoreline geomorphology	Relative surface elevation (salt marsh), shoreline position
	Soil Quality	Soil Function and Dynamics	Forest soil condition	Ratios of carbon to nitrogen and calcium to aluminum
Water	Hydrology	Surface water dynamics	Water quantity	Water depth, water duration, lake levels, streamflow, groundwater levels/inputs, spring/seep volume, sea level rise
	Water Quality	Water chemistry	Water chemistry	Stream water nitrate, stream alkalinity/ANC, water temperature, % dissolved oxygen, specific conductance, pH, color, salinity, chlorophyll a, photosynthetically active radiation (PAR)
		WQ Nutrients	Estuarine nutrient enrichment	Turbidity, number septic systems in and near park, algal biomass, total and dissolved phosphorus, amount fertilizer used within park, residential density near park
		Aquatic macroinvertebrates and algae	Streams - macroinvertebrates	Diversity of selected communities and sub-communities

Table 3.2 Proposed list of high priority ("short-list") Northeast Temperate Network vital signs presented in the 3-tiered Ecological Monitoring Framework with potential measures (continued).

Level 1	Level 2	Level 3	Vital Sign	Potential Measures
Biological Integrity	Invasive Species	Invasive/Exotic plants	Exotic plants - early detection	Presence/absence
		Invasive/Exotic animals	Exotic animals - early detection	Presence/absence
	Focal Species or Communities	Intertidal communities	Intertidal – vegetation	Diversity of salt marsh and rocky intertidal community and subcommunities, exotic species extent
		Wetland communities	Wetland – vegetation	Diversity of community and subcommunities, exotic species extent, beaver activity
		Forest vegetation	Forest – vegetation	Community diversity (all layers), tree species, rates of mortality and regeneration, stand structural dynamics, tree basal area by species, canopy condition, snag density, coarse woody debris volume, percent exotic species
			White-tailed deer herbivory	Browse intensity in forests
		Fishes	Fish – lakes and streams	Diversity of community and subcommunities, percent exotic species.
		Birds	Breeding birds	Diversity of forest, high elevation, grassland/ scrub, old-field, and coastal communities and subcommunities
		Amphibians and Reptiles	Amphibians and reptiles	Diversity of wetland/vernal pool communities and subcommunities, red-backed salamander abundance in forests
Human use	Visitor and Recreation Pressure	Visitor usage	Visitor usage	Number of visitors by location and activity, trampling impacts, soil erosion
Landscapes	Landscape Dynamics	Landscape Dynamics	Land cover / ecosystem cover	Change in area and distribution of ecological systems (including intertidal communities) within park and adjacent landscape, patch size distribution, patch connectivity, patch fragmentation, extent of major disturbance, ecological integrity index by ecological system
			Land use	Road network extent, nearby housing development permits, proportion of nearby lands in various categories of human uses, % impervious surface in watershed, nearby human population density, landscape buffers

Table 3.3 The Northeast Temperate Network vital signs organized in the Ecological Monitoring Framework.

Level 1	Level 2	Level 3	Vital Sign	ACAD	BOHA	MABI	MIMA	MORR	ROVA	SAGA	SAIR	SARA	WEFA
Air and climate	Air quality	Ozone	Ozone	2	2	2	2	2	2	2	2	2	2
		Wet and dry deposition	Atmospheric deposition & stress	2	2	2	2	2	2	2	2	2	2
		Air contaminants	Contaminants	3	3	3	3	3	3	3	3	3	3
	Weather and climate	Weather and climate	Climate	2	2	2	2	2	2	2	2	2	2
			Phenology	3		3		3				3	
Geology and soils	Geomorphology	Coastal / oceanographic	Shoreline geomorphology	3	3								
	Soil Quality	Soil Function and Dynamics	Forest soil condition	1		1	1	1	1	1		1	1
Water	Hydrology	Surface water dynamics	Water quantity	1		1	1	1	1	1		1	1
	Water quality	Water chemistry	Water chemistry	1		1	1	1	1	1		1	1
		WQ nutrients	Estuarine nutrient enrichment	3	3								
		Aquatic macroinvertebrates	Streams - macroinvertebrates	3		3	3	3	3	3		3	3
Biological integrity	Invasive species	Invasive/exotic plants	Invasive/exotic plants-early detection	1	1	1	1	1	1	1	1	1	1
		Invasive/exotic animals	Invasive/exotic animals -early detection	1	1	1	1	1	1	1	1	1	1
	Focal species or communities	Intertidal communities	Salt marsh vegetation	1	1								
			Rocky intertidal vegetation	1	1								
		Wetland communities	Wetland vegetation	1			1	1	1	1	1	1	1
		Forest vegetation	Forest vegetation	1		1	1	1	1	1	1	1	1
			White-tailed deer herbivory	1		1	1	1	1	1	1	1	1
		Fishes	Fishes	3		3	3	3	3	3	3	3	3
		Birds	Breeding birds	1	1	1	1	1	1	1	1	1	1
		Amphibians and reptiles	Amphibians and reptiles	1		1	1	1	1	1	1	1	1
Human use	Visitor and recreation use	Visitor usage	Visitor usage	3	3	3	3	3	3	3	3	3	3
Landscapes	Landscape dynamics	Landscape dynamics	Land cover / ecosystem cover	1	1	1	1	1	1	1	1	1	1
			Land use	1		1	1	1	1	1	1	1	1

Category 1 Vital Signs where Natural Resource Challenge funds are being used to develop and/or implement monitoring.
Category 2 Vital Signs where other funding is used and the monitoring contributes to an overall assessment of park natural resource condition.
Category 3 Vital Signs that need to be monitored in the future but due to funding limitations protocol development or implementation is being deferred.
blank = Vital Sign does not apply to park or there are no plans to conduct monitoring.

systems, because these systems only occur in a few NETN parks. In other cases a park may have spatially limited natural systems, and monitoring was deemed unnecessary. For example, Saugus Iron Works has a small wetland that the NETN does not currently plan to monitor. However, if the park is interested in implementing wetland restoration monitoring, the NETN will at a minimum provide data support and a monitoring protocol to support the park's efforts.

All four workgroups identified climate, species composition (flora and fauna), and invasive exotic species as high priority vital signs. Three workgroups identified water chemistry, landcover/landuse, atmospheric deposition, and contamination as high priority vital signs and two workgroups identified hydrology, visitor impacts, and nutrient enrichment.

Throughout the design of the NETN program, we chose to build a program that could be implemented given the present funding levels for the network. After the vital signs were selected we continued to refine the vital signs by specifying measures and estimating the variation and cost per measure. For example, the "amphibians and reptiles" vital sign could be implemented in many ways with a wide range of costs. Estimating the population of every vernal pool breeding species in each park and tracking those population estimates over time would clearly be much more costly than determining species presence or absence in a subset of vernal pools.

The list of NETN vital signs provides a foundation for the long-term monitoring of natural resource condition in each park. Implementation of the vital signs will require different strategies depending on the existing information, monitoring objectives, and available resources. For example, ozone, air quality, and weather will be implemented using existing data sources interpreted for each park, while forest vegetation and water chemistry will require specific protocols that will be generated and implemented by the NETN. The total suite of vital signs can not be implemented by the NETN, and parks will receive monitoring programs tailored to specific park resources and priorities (Table 3.3). Within the list of identified high priority vital signs, the NETN will implement the most important and comprehensive vital signs and work with other I&M networks and agencies to summarize existing data sources and build partnerships to implement the remaining vital signs over time. The NETN will also work closely with parks to integrate existing park monitoring programs and information into the overall natural resource condition reporting component of the monitoring program.

Description of NETN Vital Signs

Ozone

Ozone pollution is an important stressor of terrestrial vegetation with clear ecological relevance. Atmospheric ozone concentration data is available from the CASTNET network and other sources, and need only be acquired and summarized by the NETN. Ozone stress on specific indicator species should be monitored within some NETN parks to provide the necessary information to better ascertain the ecological effects of ozone. Ozone monitoring is presently ongoing at Acadia and Saratoga. Other parks are within 35 miles of an ozone monitoring station, and therefore it is not necessary to install any new ozone monitoring stations. Acadia is a Class 1 air quality park and therefore has a GPRA goal to maintain or improve park air quality. The NETN will work with Acadia to ensure that necessary levels of ozone monitoring within the park are maintained and to provide park managers with information to meet the air quality GPRA goal (Appendix: Park Summaries). The NETN will also work with the Air Resources Division to summarize existing ozone monitoring data and make these data available to the parks.

Atmospheric Deposition and Stress

Atmospheric deposition is a stressor to terrestrial and aquatic systems throughout the NETN and has been implicated in the decline or degradation of many ecological systems in the region. Estimates of atmospheric deposition are critical for understanding water chemistry and stress (Likens and Bormann 1974). Swain et al. (1992) estimated that 90% of the mercury entering remote lakes in Voyageurs National Park (Minnesota) was derived from atmospheric deposition.

NADP/NTN monitoring equipment
(courtesy NADP/NTN)

Acidic deposition stresses terrestrial vegetation and alters system functioning and biogeochemical cycles. Compiling acidic deposition data is important for any long-term monitoring program because this stressor has demonstrated negative effects on aquatic systems and can alter wetland function and biogeochemical processes. The National Atmospheric Deposition Program/National Trends Network (NADP/NTN) is a nationwide network of precipitation monitoring sites. We will work closely with the NPS Air Resources Division to acquire and summarize these existing data to interpret changes at the park level. All existing air quality monitoring stations associated with network parks have been identified and can be used as data sources (Appendix: Air Quality).

Contaminants

Contaminants, including heavy metal contamination, are of high ecological relevance to both terrestrial and aquatic resources due to the accumulation of trace elements and organic compounds. Bioaccumulation (magnification of contaminants through the food chain) is a serious problem, especially in aquatic organisms. Accumulated contaminants can cause fitness reductions or death in many taxa. Baseline amounts of heavy metals within parks may be at high levels "naturally," and responses may be difficult to interpret without long-term data. The first step in addressing the contaminants issue is to identify and prioritize potential sources for each park. As time and resources permit, we will work to integrate the contaminants vital sign into the monitoring program by first conducting park specific inventories of major contaminants before considering protocol development or monitoring.

Climate

Climate is a key driver of natural systems that affects system structure, composition, and function. Climate data can provide a background explanation for changes or variation in other vital signs. Measures of climate such as precipitation and temperature are critical to understanding the ecological condition of aquatic and terrestrial resources and biota (Hynes 1975, Poff 1997). Monitoring basic climate variables will provide a long-term record of the trends associated with climate change. While management applications related to climate are limited, climate data is useful for ruling out other causes for system responses. The NETN will work with the national I&M program weather monitoring project to integrate existing weather monitoring networks into park specific weather reporting. We will also consider summarizing existing snow cover monitoring programs and obtaining snow cover trends.

Phenology

Biotic responses to climate change will likely be one of the most important conservation issues in the coming decades. By establishing baselines of phenological indictors in the NETN parks, we should be able to document biotic responses to climate change. By monitoring phenological indicators in addition to climate variables, NETN would gain insight into the early impacts of climate change upon functioning ecosystems, including how different species may respond differently to climate change and how these differences may alter ecological relationships and perhaps ecosystem function. Although current funds will limit implementation of a phenology vital sign, we will build on the planned phenology project for the Appalachian Trail, and we hope to implement a rapid assay approach that can incorporate significant contributions from citizen volunteers. Implementing the phenology vital sign would draw upon existing protocols and standards of the European phenology network, the GLOBE program, and the Long-Term Ecological Research (LTER) program.

Shoreline geomorphology

Sea level is an important physical parameter for two network parks (Acadia and Boston Harbor Islands) that controls the distribution and spatial pattern of intertidal habitats. As sea level changes, the boundary and extent of intertidal habitat types will shift. Sea level is presently rising at a rate of about 2-4 mm/yr along the New England coastline and this rise is predicted to accelerate in response to global warming. Sea level is presently measured by NOAA tide gauges in Boston, Massachusetts and Bar Harbor, Maine. We will integrate existing data sources on sea-level changes into the vital signs reporting framework for these two parks and consider integrating measures that will provide specific park-based sea-level rise information into the Rocky Intertidal Monitoring Protocol.

Boulder Beach near Otter Cliffs: Acadia NP

Forest soil condition

Soils are a critical component of forest ecological health, since they provide vegetation with support, water and trace nutrients. We will focus on ratios of carbon to nitrogen and calcium to aluminum, which are reliable indicators of the ecological impacts of acidic deposition. A number of other soil measurements will be made, since their additional costs are extremely low. These will include pH, total organic matter, exchangeable acidity, and extractable potassium, magnesium, phosphorous, sodium, iron, and manganese. This combination of measures will give us long-term data suitable for documenting soil condition and its impact on forest health.

Water quantity

Information about water quantity is necessary because water quantity determines the physical extent and volume of aquatic habitat within the park. Numerous factors affect water quantity, including precipitation, evapotranspiration, water withdrawals, and ground water recharge. Hydrologic conditions are extremely important for wetland structure and function. Hydrology affects most abiotic factors, which in turn affect the biotic condition of the wetland. Without basic hydrologic information, it is not possible to interpret the condition of any wetland resources and this is therefore a high priority for wetland monitoring. Water quantity in lakes, ponds and streams will be measured in NETN parks. Protocol development will be based on existing standards, techniques, and sampling designs developed by the U.S. Geological Survey (Rantz et al. 1982).

Water chemistry

Water chemistry is an essential indicator to any long-term aquatic monitoring program (Gilliom et al. 1995). It is widely applicable, and critical for interpreting the biotic condition and ecological processes of all park aquatic resources. Water chemistry affects the bioavailability of contaminants, and the metabolism of aquatic species. For example, ionic conditions affect osmoregulation (Hoar and Randall 1969) and contaminant uptake (Sinley et al. 1974, Luoma 1989, Spry and Weiner 1991), dissolved oxygen and temperature affect metabolic rate (Hoar and Randall 1969). Water quality parameters are sufficiently well known that abnormal conditions and trends can be recognized or determined statistically. Information from basic water chemistry measures can be directly related to the condition of a wetland and may be correlated with other wetland vital signs. In order for causal relationships between physical and biological processes to be fully understood, it is necessary to

Blow-Me-Down Pond: Saint-Gaudens NHS

obtain basic water chemistry measures in lakes, ponds, streams, and wetlands.

Estuarine nutrient enrichment

The estuarine nutrient enrichment vital sign applies to Acadia and Boston Harbor Islands and was developed by the Northeast Coastal and Barrier Network as a component of the estuarine eutrophication monitoring protocol. The negative effect of nutrient enrichment in estuaries is well documented. Habitat quality can be adversely impacted from increased nutrient inputs, anoxic conditions can arise, and changes to the biotic community can occur. The Massachusetts Water Resources Authority (MWRA) has ongoing water quality monitoring within Boston Harbor and will provide adequate information for the Boston Harbor Islands. The NETN will determine what specific existing monitoring stations are relevant for the Boston Harbor Islands, how frequently these stations are sampled, and how to best establish an information exchange between NPS and MWRA. At Acadia, we will consider implementation of the NCBN estuarine eutrophication monitoring protocol or a subset thereof.

Streams - macroinvertebrates

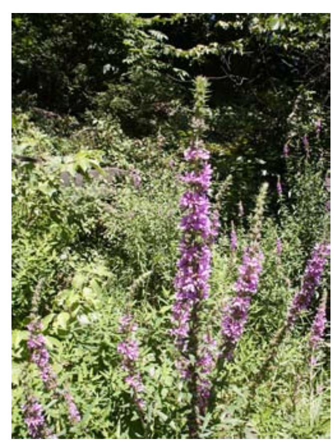
Invertebrate community taxa richness and composition in streams was identified as a high priority that should be considered for implementation, but because the identification of invertebrate taxa requires specialized training or a specialty laboratory (Moulton et al. 2002a, 2002b), we will not be including this vital sign in the initial development of the NETN monitoring plan. Invertebrates may provide a "first response" vital sign because of their rapid response to changes in the physical and chemical structure of the stream environment, but because we will be monitoring these stream variables in the Water Chemistry Vital Sign, the monitoring of the invertebrate community is considered secondary.

Invasive/exotic plants – early detection

Invasive/exotic animals – early detection

The presence and extent of invasive exotic species is a critical management concern at all network parks. Parks would greatly benefit from timely identification and removal of new invasive species. Catastrophic consequences to native species (loss of biodiversity and replacement of native flora and fauna) can result if this vital sign is not addressed. Invasive exotic species are a significant and growing stressor with clear ecological relevance to terrestrial systems within the NETN. This vital sign has relatively strong management implications via exotic species control programs. Numerous groups of invasive exotic species are of concern within NETN, including terrestrial and wetland plants, insect pests and pathogens, earthworms, and intertidal and aquatic fauna. Routine surveys for the presence/absence of particular invasive species should be mandatory at all parks. Lists of non-native species with the potential to invade individual parks already exist in most states and will be integrated into NETN protocols. These lists will identify the types of habitats to examine for invasion.

Knotweed



Purple Loosestrife

Salt Marsh vegetation

Rocky Intertidal vegetation

Wetland vegetation

Forest vegetation

Vegetation structure and composition are highly relevant and applicable to ecosystem condition. Knowing the relative abundance, species composition and condition of the plant community provides an integrated measure of vegetation response to stress, in addition to basic information about habitat quality for a variety of other species. Moreover, this information will allow proper interpretation of many other vital signs. Monitoring the vegetation community is also a good early detection strategy for management of invasive species. Monitoring flora is relatively low cost, sampling is efficient, and changes in plant species composition and abundance can be accurately measured. Knowledge of macro-algal species richness, abundance, and distribution is critical to an intertidal monitoring program and may be an especially important indicator of trampling by park visitors.

Within forests, monitoring vegetation demography in the form of tree seedling and sapling regeneration provides an anticipatory indicator of future forest cover type as well as an integrative measure of the impacts of multiple stressors acting upon vegetation. Monitoring canopy and understory tree mortality provides another key integrative measure of multiple stressor impacts. Stand structure or age class is indicative of both successional stage and habitat quality, and is a particularly useful measure in forest systems subject to silviculture. Legacy features, such as large trees, snags and coarse woody debris provide important habitat for birds, mammals, and herptiles, as well as decomposers, bryophytes and tree seedlings. These legacy features can be useful indicators of wildlife habitat within early- and mid-successional forests and those subject to silviculture. In addition, canopy vegetation condition is an integrative, anticipatory indicator of stress and change within canopy vegetation, which can in turn lead to changes in ecosystem function, habitat quality and stand composition. Canopy vegetation condition can be measured across the landscape using vegetation stress indices from hyperspectral remote sensing (Sampson et al. 2000, Miles et al. 2003). While hyperspectral imagery is currently expensive to obtain, this technology is advancing rapidly and should be considered for inclusion in the NETN monitoring program as affordable imagery becomes available. At the stand scale, canopy condition can be assessed visually onsite as the crown condition of each canopy tree in a plot.

Truants Edge: Weir Farm NHS

White-tailed deer herbivory

White-tailed deer populations have reached historic high levels across much of the eastern US. The associated deer herbivory has ecological relevance for vegetation regeneration and substantial management significance. Many parks in the southern part of the NETN have already experienced degradation in resource condition caused by extensive deer herbivory. We will integrate measures of the ecological effects deer have on forest ecosystems into the Forest Monitoring Protocol (i.e., tree regeneration and presence of indicator species). This will allow us to provide parks with robust information regarding resource condition rather than highly variable estimates of the deer populations themselves. This vital sign is integrated into the forest vegetation vital sign and will provide the necessary information for supporting and improving related management activities.

Fishes – lakes and streams

Fish species richness and composition was identified as a high priority for two parks (Acadia and Saugus Iron Works) and is relevant because fish communities integrate their physical, chemical, and biological environment through time (Tonn et al. 1983, Gurtz 1993). Fish species richness and composition will remain on the high priority list, but development of a monitoring protocol for this vital sign is being deferred until after the implementation of the core NETN protocols.

Breeding birds

This faunal group provides a useful biotic indicator of the effects of habitat fragmentation, and is a highly visible and charismatic group that can garner much public support. The NPS has some management control over fragmentation within the parks, but fragmentation outside park boundaries is a critical stressor for many of the smaller parks. Partnering with existing forest, mountain, and coastal bird monitoring programs provides an opportunity to make inferences related to changes in resource condition beyond park boundaries. This vital sign provides an opportunity for NPS to coordinate with other organizations monitoring bird populations, and to incorporate volunteers into the I&M program. Many reference datasets and standard methods are available, and the response variability is fairly well understood.

Blue-winged warbler © Charley Eiseman

Amphibians and reptiles

Reptiles and amphibians are important park resources associated with both terrestrial and wetland communities, and many species in this group are sensitive to changes in water quality, hydrology, landscape condition, and climate. The herpetofauna

Jefferson salamander

also play important roles in environmental dynamics and assessment. Because many amphibian species have aquatic larvae with terrestrial adult stages, and because many adult amphibians and reptiles use both aquatic and terrestrial habitats, the herpetofauna are a nexus for nutrients and toxicants within and among environments (e.g., Pagano et al. 1999). Also, their multi-habitat life histories may make them especially useful indicators of a broad range of environmental perturbations that affect entire ecosystems (Vitt et al. 1990). Last, concern regarding global declines of both amphibian and reptile populations (e.g., Blaustein and Olson 1991, Lannoo 1998) elevate these groups as a significant monitoring focus. Integrating wetland faunal groups into the NETN monitoring program will provide valuable partnership opportunities with two USGS programs: 1) the North American Amphibian Monitoring Program (NAAMP); and, 2) the Amphibian Research and Monitoring Initiative (ARMI). By integrating NETN monitoring initiatives with ongoing, nationally implemented programs, information can be interpreted at multiple scales and established protocols can be adopted.

Visitor usage

Visitor impacts ranked a high priority designation due to the clear management implications of this fundamental park issue. Many of the NETN parks are heavily visited, and thus allow substantial opportunity for adaptive management of visitor impacts. The

Sand Beach: Acadia NP

intertidal zone, especially the rocky intertidal, is a frequently visited habitat and often the focus of park-led interpretive tours at both Acadia and Boston Harbor Islands. Trampling and removal of resources can be significant. It is important to monitor visitor use, and more specifically, intensity of visitors, location of visitor use, and activities of visitors (e.g., walking, resource removal). Trampling and other visitor use impacts are likely localized to areas with available parking (e.g., at Acadia) or ferry access (at Boston Harbor Islands). We plan to monitor visitor usage as part of the rocky intertidal protocol, which we will begin developing in 2007 with cooperators at the University of Maine. We will pursue visitor usage protocols for other resources once the core NETN protocols are in place; one possibility is partnering with the existing Visitor Experience and Resource Protection (VERP) program at Acadia.

Land cover / ecosystem cover

Land use

Land cover data provides key information on the status and extent of ecological systems; land use data for the larger park region provides important information on habitat alteration and a wide variety of stressors associated with land use change. Land cover change was identified as a high priority issue for all network parks due to concerns arising from the negative effects of habitat conversion within and adjacent to park boundaries. This is particularly true within NETN because many NETN parks are relatively small and potentially affected by outside activities. At a watershed level, land use and land cover affect the quality of aquatic environments (Stauffer et al. 2000, Meador and Goldstein 2003). An initial inventory of land use and land cover will provide context for the observed ecological conditions. If changes occur to this "baseline" condition, they can be interpreted in the context of land use or land cover at the watershed scale. Aquatic ecosystems respond to changes in land use and this response has been documented in urban, agricultural, and forested environmental settings (Meador and Goldstein 2003).

Land use and cover are important vital signs because they integrate across multiple spatial scales; from the buffer around an individual stand, to the larger ecosystem complex within a park's boundary, to the distribution of systems within the region. By implementing a basic land cover change monitoring program, inferences can be drawn between measurable changes in park ecological integrity and anticipated negative effects. Land cover change detection has been identified as a high priority vital sign by most other networks within the Inventory and Monitoring Program, especially those in the eastern United States where human populations have increase dramatically during the last century. The NETN is cooperating with researchers at the University of Rhode Island to analyze land use and land cover change within and surrounding NETN parks (including 10 sections of the Appalachian Trail) between the 1970's and 2002. A draft report of this analysis will be completed in 2006. Once the core NETN protocols are in place, NETN will work to develop a protocol for evaluating landscape change every 5 to 10 years. We will use landscape change information to test whether trends in other monitoring data can be explained by changes in land use and land cover metrics.

Summary

The initial list of NETN vital signs was selected based on our conceptual models (Chapter 2) and prioritized based on conceptual importance, management needs, and feasibility of implementation. These vital signs represent an integrated list of ecological processes, elements of biotic and abiotic condition, system drivers and stressors, landscape condition, and focal park resources. Moreover, these vital signs are directly relevant to the natural resource management issues of a majority of NETN parks. Category 1 vital signs (Table 3.3) will be the primary focus of the NETN during the initial development of the monitoring programs, and other vital signs will be included as the program matures. The vital signs list provides a peer-reviewed, prioritized list of monitoring categories that guides the NETN's monitoring program.

Chapter 4
Sampling Design

Introduction

How we obtain information about the environmental systems we are charged with conserving is critical to proper understanding of resource condition and changes in condition over time. Sampling provides a set of techniques for obtaining information that is scientifically objective and defensible, and basing our sampling on probability theory ensures that monitoring results will be representative of the sampled population (Cochran 1977, Krebs 1998). Sample design is critical to the effectiveness of any monitoring program (Dixon et al. 1998) because the design defines the population and determines the variability of parameter estimates (Thompson et al. 1998), and therefore the ability to detect meaningful change over time. The sampling design ensures that the data collected are representative of the target populations and sufficient to draw defensible conclusions about the resources of interest (Krebs 1998). A complete sample design includes specific information about the spatial locations and temporal frequency of sampling. Goals of a sampling design depend on the objectives and scale of inference for each monitoring question. A sampling design can be used to guide the data collection to determine if two populations differ in some characteristic, to estimate parameters of populations, and to track changes in these population parameters over time. A well-planned sampling design is intended to ensure that the resulting information is representative of the target population, scientifically defensible, efficient in use of time, money, and human resources, and meets the objectives of the monitoring protocol.

Spatial and temporal scales of inference are a primary consideration in developing an overall sample design. The NPS I&M Program was created to provide credible natural resource information that could be interpreted at the park or sub-park levels. We have therefore developed the overall sampling framework such that inferences can be made at the park level and, where necessary, at the level of specific park resources. To increase precision over time, we will generally use repeated measurements of permanently established plots or sampling locations for all NETN protocols. We will strive to co-locate measurements for multiple vital signs in order to reduce sampling costs and improve our ability to make statistical inferences. Where appropriate, we will also include a rotating panel design such that not all parks or plots are sampled during every implementation of a monitoring protocol. This will allow for an increase in the number of sample sites within a park, create a sample design with extensive park coverage, reduce costs, and minimize impacts of monitoring on permanent plots.

Cannons: Saratoga NHP

In this chapter we discuss how our sampling design serves to ensure the scientific merit of our program. We begin by presenting basic sampling concepts and definitions and then describing the underlying framework and philosophy that guided our overall sampling design. Then we describe, in a broad context, how these principles will be employed in sampling terrestrial and aquatic habitats. The specific designs detailed in individual protocols follow from these basic

North Bridge: Minute Man NHP

themes and incorporate variations as necessary. The details can be found in the monitoring protocols for individual vital signs (see the supplemental documents for Chapter 5).

Sampling Concepts

Probability-based Versus Judgment Sampling

There are two main categories of sampling designs: probability-based designs and judgmental designs. Probability-based designs apply sampling theory and involve random selection of sampling units. Because probability-based designs are rooted in sampling theory, each member of the sampled population has a known probability of selection. These designs allow for statistical inferences to be made about the sampled population based on data obtained from the sample units.

An alternative to probability-based sampling is judgment sampling. Judgment sampling involves the selection of sample units based on the expert knowledge of professionals. Judgment sampling designs can be less expensive and easier to implement than probability-based designs, but these design methods are limited in their ability to evaluate the precision of estimates, and inferences can not be made outside of the areas actually sampled. When using probabilistic sampling, quantitative analyses can be used to draw conclusions about the larger, target population. Whenever possible, we have opted to use a probability-based sample design in the development of the NETN monitoring program to ensure that inferences can be made beyond the area actually sampled. The few times when judgment sampling was used include the integration of existing park monitoring locations into the network program. This was limited to ongoing water quality monitoring, and we decided that the benefit of historical information outweighed excluding the sample locations.

Random Versus Systematic Sampling

How a sample is selected from the population greatly influences the precision of the estimates, the cost of implementation, the complexity of the analyses, and the long-term flexibility of the monitoring program. There are many ways to select a sample and the appropriate methodology primarily depends on the objectives of the monitoring program and the spatial and temporal scales of inference.

Generally, there are a few basic types of sample designs and multiple variations on these types. For example, a simple random (or non-stratified random) sample is a method in which sample units are selected from a population using a completely random process, such that all sample units have the same probability of being selected. Selecting a simple random sample is relatively easy but is usually not spatially balanced, and priority resources may not be included in the sample. A systematic sample generally employs a grid-based approach, and ensures spatial balance by requiring sampling at every point on the grid. The main drawback with this approach is that some ecological phenomena are spatially periodic, and a systematic sample will be inappropriate when ecological heterogeneity occurs with similar spacing as the systematic grid.

Generalized Random Tessellation Stratified (GRTS) sampling is a recently developed technique that combines a simple random sample and a systematic grid sample (Stevens 1997, Stevens and Olsen 2004).

Points selected with the GRTS algorithm are ensured of being spatially balanced and randomly located. GRTS produces an ordered list of sampling locations and can select many more locations than are actually needed for a given protocol. If a particular location cannot be sampled, then the next location on the list is used instead, and the spatial balance of the sampling design will be maintained. In addition, the GRTS sampling method allows for sample size adjustments that maintain the overall spatial balance. This aspect of GRTS sampling allows for tremendous flexibility. For example, a power analysis several years into a program may reveal that the monitoring goals can be met with fewer plots, and the GRTS algorithm makes it clear which plots should be removed in order to meet the revised goals and maintain the geographic distribution of plots.

Stratified Versus Non-stratified Sampling

An alternative to a non-stratified sample that would force sample units into specific, pre-defined groups is a stratified sample. In stratified sampling, a sampling frame is divided into mutually exclusive strata and samples are selected from within each stratum (Levy and Lemeshow 1999). Benefits of stratified sampling designs include increased precision, increased efficiency, and greater information about particular subpopulations (Lohr 1999). For increased precision, strata are typically selected such that variation among units from the same strata is less than variation among units from different strata. The major problem with stratification is in defining the strata that will be appropriate over long time periods.

One major reason for using stratification is when there is high interest in stratum-specific analyses and reporting of change. In other words, stratification should be used when each stratum is of interest. Stratified random sampling designs typically allocate equal amounts of sampling effort to each stratum. This ensures that we have adequate sample sizes in each stratum for precise estimates or powerful tests of change. Equal allocation of sampling effort among strata also compensates for the inadequate sampling of rare classes that occurs under simple random or systematic sampling designs. However, equal allocation means that sample units in different strata do not have the same probability of selection (unless the strata happen to have equal areas).

Another important reason for using stratification is when a particular stratum is rare and could be missed by systematic sampling. In this case, equal allocation of effort is not critical, and stratification serves to ensure that the rare stratum is adequately sampled.

We initially considered stratifying our terrestrial sampling protocols by ecological system group to provide precise estimates of change in condition over time within each group. Most NETN parks have less than five ecological system groups, with over 15 groups present at Acadia. This level of stratification comes with substantial financial costs, adds complexity to analyses, and reduces program flexibility to adapt to unanticipated future groupings for analyses. For example, in order to estimate change over combined strata (or over a subset of strata), we would need to weight the analysis to account for the different sampling probabilities in the different strata. Alternatively, if we wanted to conduct a regression analysis with data from multiple strata, we again would need to incorporate weights that account for the different sampling probabilities in the different strata. In addition, stratification can reduce precision. If analyses for groupings other than ecological system are desired, the design stratified by ecological system is likely to be less precise than even simple random sampling. Not imposing stratification on the sampling design would therefore provide more flexibility for data analysis. Finally, stratification by ecological system group would require intensive sampling within each stratum and would therefore be more financially and logistically costly.

In the end, the decision to stratify is a trade-off between precision and flexibility of future analyses and grouping. Because park managers did not specifically indicate that reporting the condition of specific ecological system groups was a priority, and in order to provide for the most flexible yet informative monitoring program, we decided not to stratify for

Weir Farm NHS

our protocols. In situations where a rare ecological system merits a monitoring effort (for example, the pitch pine – broom crowberry woodland community at Acadia), NETN will develop a separate sampling design focused on the rare system.

Detection Probability

Detection probability is the chance of sampling an organism, given that it is present. For many species, this parameter can vary across sampling sites, and it is important to model and adjust for detection probability when monitoring goals include estimates of population size or the proportion of area occupied by a species (Royle 2004, Williams and Berkson 2004, Wintle et al. 2004). When needed, NETN is developing monitoring protocols that are compatible with modeling frameworks that allow us to estimate detection probability. These frameworks include occupancy models, mark-recapture methods, and distance sampling (Buckland et al. 2001, Farnsworth et al. 2002, MacKenzie et al. 2003), and they are particularly applicable to monitoring goals related to wildlife presence and population trends.

Co-location of Vital Signs

We have attempted to co-locate sampling whenever possible to allow for additional associations to be made and to reduce sampling costs. Generally, we will sample in a manner that provides data that allows us to analyze associations between changes in a vital sign (e.g., forest health) with changes in possible "stressors" (e.g., deer herbivory or soil chemistry). One way to assure spatial association of sampling information is to spatially integrate samples across different vital signs. There are at least two ways this can be done. Conceptually, the simplest way to accomplish this is to use common sample points for multiple sampling protocols. This point could be used as a plot center (plots can be different in size and shape depending on the variable to be sampled), or used as a center point for a line transect. The key idea is to attempt to associate the protocol for each specific vital sign or variable with the same set of sample points. Differences in necessary sample sizes and protocol designs makes it difficult to implement this conceptually simple idea, but it may be possible to measure some vital signs at a subset of combined sample points. An alternative method for achieving co-location is by an association rule. For example, if it were feasible to co-locate stream samples with forest samples, the rule might allow us to use the closest stream sampling unit to a forest sample center point (as long as the stream sampling site was within a certain minimum distance). This second approach often leads to complex sampling and analysis issues related to unequal inclusion probabilities.

Summary

NETN plans to use non-stratified GRTS sampling, with co-location of multiple vital signs at permanent plot locations. This approach will give us the ability to maintain the flexibility of statistical analyses, including the ability to associate data from multiple vital signs for more powerful statistical inference. GRTS sampling also allows us to maintain spatial balance if future power analyses or budget changes require us to adjust our sample size up or down.

Terrestrial Sampling

All NETN parks have terrestrial resources, and several vital signs will be sampled based on co-located permanent plots selected with the GRTS algorithm. Within each park, the target population is forest and woodland systems on fee-owned park lands, and vital signs monitored at these plots include forest vegetation, soil chemistry, exotic plant and animal early detection, white-tailed deer herbivory, and trampling (part of the visitor use vital sign). Other terrestrial vital signs (e.g., forest amphibians and breeding birds) will have sampling co-located with the GRTS plots whenever possible, but they will have different target populations and sample designs that will be described in the relevant monitoring protocols. Terrestrial sampling is not planned at Saugus Iron Works, due to the small terrestrial acreage, or at Boston Harbor Islands, due to higher travel costs and the lower overall importance of terrestrial resources. When developing our terrestrial sampling design, NETN tried to create a design that would enable straightforward comparison of NETN data to existing regional programs, such as the USDA Forest Inventory Analysis and Forest Health Monitoring program.

We considered co-location of stream and terrestrial sampling protocols during the early stages of sample design, with the goal of associating changes in forest condition with changes in stream water quality. Because this was not an objective of the monitoring program and because co-location of these two protocols added substantial logistical and analytical complexity, we decided against formal co-location. We do recognize the potential for other methods of analyzing data across protocols. One possibility is defining a spatial unit for analysis of association (e.g., a 1 km by 1 km block or a watershed), and then examine associations using these higher-level spatial units. For example, we might have percent forest cover from one or more sample plots in a 1x1 km block and stream data from within the same spatial unit. We could then examine whether percent forest cover affected stream measurements within that spatial unit.

Spatial Allocation of Samples

There are many ways to control for the spatial allocation and distribution of samples within a park, and the basis for selecting a method for plot selection depends on the monitoring objectives and the scale of inference. As described above, we decided to use the GRTS algorithm to ensure a balanced spatial allocation of plots across each park and for the greatest flexibility for data analysis and interpretation over time. Grid spacing and sample size varied with park acreage in order to ensure a minimum sample for statistical inference in the smallest NETN parks while ensuring that larger NETN parks did not require excessive numbers of plots (Table 4.1). This design allows for statistical inference beyond the scale of the plot while also providing balanced spatial coverage

Table 4.1. NETN terrestrial sampling plot allocation. See Table 1.3 for explanation of park codes. ROVA consists of the Eleanor Roosevelt Home (ELRO), the Home of Franklin Roosevelt (HOFR), and Vanderbilt Mansion (VAMA).

						ROVA				
	ACAD	SARA	MORR	MIMA	MABI	ELRO and HOFR	VAMA	SAGA	WEFA	TOTAL
Proposed total forest plots	132	32	28	20	24	24	20	20	10	300
Proposed sampling intensity (ha. forest/plot)	95	27	17	10	8	5	3	2	2	NA

and flexibility for post-stratification of plots based on ecological system, association, or other criteria as needed over the long-term.

In order to balance competing needs for broad spatial coverage and for intensive quantitative sampling, NETN is prepared to implement a hierarchical, multi-tiered approach for terrestrial sampling by nesting a subset of intensively studied permanent plots within a larger spatial network of more rapidly assessed permanent plots. This approach is a cost-effective strategy for improving our ability to make inferences about ecological integrity of NETN forest systems by providing extensive spatial coverage across all forested parks, coupled with intensive sampling at a sub-set of the permanent plots.

The initial implementation of terrestrial monitoring calls for the full suite of measurements at each plot. These measurements are expected to range in their variability, such that the optimal sample size for detecting trends could differ significantly between measures. As we generate a long-term data set and are able to analyze the variability of each of our measures, we will determine whether some of these measures should only be collected at a subset of intensive plots, while we continue to collect data on the more variable measures at all plots.

Temporal Allocation of Samples

When designing a long-term monitoring program, the temporal allocation of sampling effort is as important to consider as the spatial allocation. Balanced spatial allocation ensures that sampling occurs within parks so that all important natural resources receive sampling adequate to detect changes in condition over time. Balanced temporal allocation ensures that temporal variability is accounted for so that precise estimates of change can be made over time, while simultaneously not wasting effort by over sampling. Evaluating status requires visiting many different sample sites within a park, whereas evaluating change in status over time (trend) involves repeat visits to the same sites. To accommodate the trade offs between extensive sampling to determine current status with the temporal components of trend detection, we will generally employ a rotating panel sampling design to allocate sampling both temporally and spatially.

Roosevelt-Vanderbilt NHS

A panel is a group of sample units that are always sampled during the same period. For example, if sampling were conducted annually, all of the units sampled in a given year would comprise the panel for that year. During any given sampling period, either all of the sample units comprising a panel are sampled or none are sampled. When panels of sample units are constructed, sample effort is rotated from panel to panel through time. This rotating design has the benefit of allowing plots to rest between visits, which reduces the impact of monitoring on the plots.

One drawback of the basic rotating panel design is the lack of connectivity. If one group of plots is sampled in year one, and a different group of sites is sampled in year two, it is not possible to determine what portion of the differences between the groups is due to spatial variability (e.g., microhabitat differences between the groups), and what portion is due to temporal variability (e.g., weather trends). A connected panel design, where a portion of the group from year one is re-measured in year two, allows us to statistically partition the variability into temporal and spatial components.

Our temporal allocation of sampling effort seeks to balance statistical power for trend detection with broad spatial coverage. For terrestrial monitoring at Acadia National Park, NETN plans a visitation schedule incorporating a rotating panel design with connectivity (Table 4.2). Each panel at Acadia contains 11 plots, and this design assures that all 132 plots are sampled four times in every 12-year period.

It was not possible to implement a connected design at the other NETN parks, because of the much lower sample sizes. Therefore, the terrestrial monitoring at these parks will be split into four panels, and each park will have one half of its permanent plots sampled every two years (or three visits to each plot in every 12-year period, Table 4.3). Alternate-year sampling at the historical parks will optimize allocation of sampling effort by reducing travel costs and minimizing monitoring impacts to plots.

The power to detect a trend of specified magnitude, with

Table 4.2. NETN terrestrial panel design for Acadia National Park. Each panel contains 11 plots, and each plot is sampled four times every 12 years.

Panel	Year											
	1	2	3	4	5	6	7	8	9	10	11	12
1A	X	X			X				X			
1B	X				X	X			X			
1C	X				X				X	X		
2A		X	X			X				X		
2B		X				X	X			X		
2C		X				X				X	X	
3A			X	X			X				X	
3B			X				X	X			X	
3C			X				X				X	X
4A				X	X			X				X
4B				X				X	X			X
4C	X			X				X				X

Table 4.3. NETN terrestrial panel design at historical parks. Panel 1 includes half the plots for MABI, MIMA, SAGA, and SARA, while panel 3 includes the remainder of plots for these parks. Panel 2 includes half the plots for MORR, ROVA, and WEFA, while panel 4 includes the remainder of plots for these parks.

Panel	Year											
	1	2	3	4	5	6	7	8	9	10	11	12
1	X				X				X			
2		X				X				X		
3			X				X				X	
4				X				X				X

a given level of significance, is negatively related to variability of the measurements and positively related to sampling effort. Although increasing sampling effort increases the power to detect trends, excessive sampling wastes limited monitoring resources (Bernstein and Zalinski 1983). NETN's challenge is to develop an extensive monitoring program that is also cost-effective. We will meet this challenge by conducting power analyses using available data prior to data collection, and periodically reviewing our monitoring efforts to ensure that the appropriate amount of data is collected as efficiently as possible. As with the spatial allocation of samples, it may turn out that some measures have low enough temporal variability that they do not need to be taken on every visit to a plot. For example, soil characteristics and tree growth rates may change slowly enough that they can be measured on alternate visits. As NETN collects data, we will evaluate temporal variability and determine when the sampling intensity can be reduced without compromising our ability to detect meaningful trends.

Aquatic Systems

Within NETN parks, Acadia has the greatest extent and diversity of aquatic resources (see Chapter 1). Most network parks have limited lake or pond habitats and a few miles of perennial streams. The aquatic sampling design establishes permanent sample locations within all of the parks' aquatic resources and a majority of the resources at Acadia. We employ a judgment design to select sample locations that also integrates, where necessary, historic or ongoing data collection. For ponds and lakes, we are sampling at the deepest point (the deep hole) of every water body that is accessible to field crews. Our sampled population is therefore the deep holes of all accessible park water bodies, and a probabilistic sample is not necessary because we are conducting a complete census of the sample population. For streams, we are sampling at the most downstream point of each park stream (watershed at Acadia) that is feasible for flow and water quality measurements. In some cases, we are also sampling as close as possible to the upstream point where the stream enters the park. Our target population is the water flow and water quality of the best downstream sampling locations. We realize that this judgment design does not allow us to make inferences about all park stream resources. It does, however allow us to meet our primary objectives of characterizing flow and water quality at key index sites within each park. Our measurements will serve as early warning indicators of trends in water flow and quality that will be correlated with conditions at upstream locations. In cases where we have upstream sample locations, we will also be able to determine whether conditions outside of the park are affecting measurements inside the park.

Flat Rock: Morristown NHP

Sampling designs for each park establish the minimum number of sites and samples necessary to characterize and track baseline freshwater resource conditions for NETN parks. Water quality sampling at additional sites (especially the continuation of historic sites or the sampling of sites in cooperation with other agencies) is being encouraged where NETN protocols can be followed. Consistency of protocols across all sites in each park is critical for analyzing and interpreting water quality data within parks and across the NETN. Although attempts have been made within these protocols to continue historic sites and existing methods and SOPs, in a few cases adjustments to historical water quality sampling programs have been made to ensure consistency across the network or to improve methods.

Acadia National Park

Sampling Design in Lakes and Ponds

There are 31 ponds and lakes in or partially within NETN park boundaries. We define lakes as bodies of water that have a surface area greater than 15 acres, and ponds range in size from 1 to 15 acres. Acadia has all 13 water bodies within the network that are defined as lakes. The 18 other open water bodies in the network are ponds. Seven ponds occur in Acadia, two in Roosevelt-Vanderbilt, and one each in Marsh-Billings-Rockefeller, Weir Farm, Saint-Gaudens, Boston Harbor Islands, and Morristown. Very small ponds (< 1 acre) will not be included in the sampling.

Lakes and ponds will be surveyed monthly (May – October) in the field for water level, dissolved oxygen (DO), temperature, pH, conductivity, and water level. Twice each year, samples will be sent to a laboratory for testing of nutrients, color, acid neutralizing capacity (ANC) and chlorophyll a. All lakes and ponds will be sampled at the location of maximum depth (the deep hole), with measurements taken every meter in the water column (every half-meter for ponds outside of Acadia). A mid-lake sample of maximum depth is the conventional sampling strategy used in lake chemistry monitoring programs, and lakes in Acadia have been sampled at the deep hole since 1970. Mid-lake samples have been shown to be representative of surface water chemistry in lakes of up to 1,650 acres in Sweden (Goransson et al. 2004). Results will clearly indicate that only the deep hole was sampled and thus conclusions will only be drawn for these locations. For all lakes and ponds, the point of maximum depth will be located through bathymetric surveys and the use of a GPS unit. In addition, a tape down location for each lake will be established in order for the lake water levels to be monitored. This location will be selected based on access, the presence of an appropriate benchmark, and the ease of getting a tape down measurement.

Generally, we will sample all accessible lakes and ponds every month from May to October. At Acadia, seven of the lakes and ponds will be sampled every year, and the remaining nine lakes and ponds will be monitored as part of a rotating panel design where each water body will be sampled every third year. Acadia has three small ponds that are not accessible by vehicle that will not be a part of the sample design.

Spatial Variability in Lakes and Ponds

The target population being studied is the mid-lake deep hole of NETN lakes and ponds. The spatial variability between different locations within the same water body will not be assessed, but we assume that trends in conditions at the deep hole will be a suitable index for conditions elsewhere in the same lake or pond. Water samples will include depth profiles and depth integrated samples at the deep hole locations, and thus will be representative of the entire water column at these locations.

Sampling Design in Streams

There are approximately 50 miles of perennial rivers and streams flowing through or adjacent to nine of the NETN parks (Boston Harbor Islands does not have freshwater stream resources). Thirty-five miles of stream are in Acadia, eight miles are in Saratoga, and less than two and half miles are in each remaining park. In all parks except Acadia, every perennial stream that allows reasonable access to a location where streamflow can be accurately measured will be monitored for fresh water quality vital signs. At Acadia, every *watershed* that allows reasonable access to a location where streamflow can be accurately measured will be monitored.

In creating a stream sampling design for NETN parks, the challenge was to balance the importance of drawing a random sample so that results could be extrapolated to all locations in each park with several often conflicting additional priorities. These included the need to select sites targeted based on accessibility; the ability to get an accurate discharge measurement; and the benefits of using historical sites with existing data.

Initially, systematic random samples were created using GIS layers of linear stream features by lining up the streams end to end, dividing the total length of streams by the desired number of stations, and then choosing a site every Xth number of miles. Locations that were drawn were often unreasonable for monthly sampling due to accessibility issues. Many other sites were problematic because they were on reaches of stream that were inappropriate for obtaining a discharge measurement due to braided channels or steep slopes, or they were on reaches that would likely have zero flow during a typical August (despite being labeled as perennial on USGS 1:24,000 topographic maps). Furthermore, these randomly drawn sites often were not the historically used sites. This led to a difficult decision between abandoning historic sites in favor of the new randomly drawn ones, and attempting to sample both sites at a much greater expense.

Weir Pond: Weir Farm NHS

Stratifying by watershed or by stream resulted in almost as many strata as sampling points. This meant that all of the stream resources in most parks could be sampled over time. A random design would certainly be preferable by allowing for the extrapolation to all stream points in each park. However, we concluded that a targeted design based on streams and watershed units would allow for higher quality measurements, and would provide information about all of the accessible streams (or watersheds for Acadia) in each park over time.

From this final list of streams, a sampling location within the watershed was selected based on the best location to get a discharge measurement and water quality sample with reasonable access. If multiple locations were possible, the most downstream location was selected. If an historical site existed on the stream that met the objectives of the vital signs program, that site was selected for the stream.

Spatial Variability in Streams

The targeted population is the best downstream sampling locations in the set of all streams (at historical parks) or the set of all watersheds (at Acadia). Depending on the park, all accessible streams or watersheds will be sampled annually (historical parks) or biannually (Acadia) through a rotating panel design. We assume that a downstream point in a stream or in a watershed provides a suitable index of conditions in the stream or the watershed as a whole; we are not assessing the spatial variability of measurements within each stream or watershed. This type of downstream sampling serves to identify streams that may have declining water quality and that may need additional targeted sampling within the watershed. This sampling design does not represent every point within the watershed. Two existing long-term stream gages at Acadia, however, are sampling points high in the watershed, and they will give us some benchmarks for high watershed locations. Samples from these gages will be depth and width integrated at each location, so that the entire cross section at each sampling location will be represented.

Temporal Variability in Lakes and Streams

The NETN aquatic sampling program will document annual and monthly variability in freshwater metrics. We assume that there is little within month or diel variability, and our protocols do not assess these potential sources of variability. Historically in lakes, samples could be taken any day within a month. We are now aiming for a 2-week window to reduce variability. Samples must be taken between 9:00 and 3:00, so some of the diel variability is also eliminated. A pilot study could address some of these temporal variability questions with the use of several extended deployment data recorders in lakes or streams.

Wetland Sampling

We are currently working with the USGS to expand the development of an indicator-based wetland monitoring protocol for Acadia (Neckles and Guntenspergen, work in progress) into a protocol that will be suitable for all wetlands in NETN parks. This Acadia project is evaluating a set of physical, chemical, and vegetation indicators for use in monitoring the integrity of herbaceous and forested wetlands. In addition, spatial and temporal sampling variability will be estimated to determine the monitoring frequency necessary to characterize wetland condition, and the USGS is developing a system that stratifies the sampling effort at selected wetlands. The upcoming (FY06 and FY07) Watershed Condition Assessment at Acadia may provide additional information about wetland condition and important stressors that should be incorporated into the NETN wetland sampling design.

The sampling framework for Acadia National Park incorporates a stratification of wetlands by watershed, wetland type, and "risk factors" (landscape metrics that help identify vulnerable wetlands). We will apply these landscape-scale indicators to classify Acadia's wetlands based on susceptibility to stress. We will also evaluate the relationship between land use and land cover within contributing wetland drainage areas and wetland response indicators. This will help us determine whether broad watershed metrics should be considered as wetland risk factors. We will then use this information as one tier of stratification for sampling Acadia's wetlands, so that wetlands with the greatest risk of degradation are more likely to be sampled intensively. This sampling scheme is scheduled to be finished by the end of 2006. Ultimately, this wetland stratification design will be applicable to the entire suite of NETN parks, although we are likely to sample all of the wetlands within smaller parks.

Acadia National Park

Chapter 5
Monitoring Protocols

Introduction

Monitoring protocols identify specific methods for gathering, analyzing, interpreting, reporting, and storing information related to park natural resource conditions and changes in condition over time. Monitoring protocols provide detailed study plans that ensure consistency in data collection and management; this consistency makes it more likely that changes detected by monitoring are real and not an artifact of differences in methods or observers (Oakley et al. 2003).

Monitoring protocols are stand alone documents that include a narrative and standard operating procedures (SOPs). The narrative consists of an overview and background information, the sampling objectives, the sampling design (including location and time of sample collection), brief descriptions of field methods, data analysis and reporting, plus information about staffing requirements, training procedures, and operational requirements (Oakley et al. 2003). Narratives also summarize the design phase of protocol development and any decision-making that is relevant to the protocol. Documenting the history of a protocol's development helps ensure protocol refinement and avoids repetition of previous trials or comparisons (Oakley et al. 2003).

Protocols include a series of standard operating procedures (SOPs), which carefully and thoroughly explain in a step-by-step manner how field work, data management, quality assurance and quality control, data analysis, and reporting will be accomplished. Finally, monitoring protocols identify supplementary materials needed to document the development and implementation of the protocol (Oakley et al. 2003). Examples of this material includes databases, reports, maps, geospatial information, species lists, species guilds, analysis tools tested, and any decisions resulting from these exploratory analyses. Material not easily formatted for inclusion in the monitoring protocol also can be included in this section.

Marsh-Billings-Rockefeller NHP

The NETN has identified 13 protocols necessary to fully monitor the high priority vital signs (Table 5.1). Six of these protocols (forest breeding birds, forest condition, lakes and streams, coastal breeding birds, rocky intertidal, and wetlands) will comprise the core of the NETN Vital Signs Program, and these protocols will be fully implemented between 2007 and 2009 (Table 5.1). The other seven protocols will be adopted from other agencies or sources, or will be developed as time and resources permit (Table 5.1). A summary of these monitoring protocols is provided below. The protocol summaries include the vital signs wholly or partially addressed by the protocol, the justification for monitoring, the list of objectives, and the parks where implementation will occur (park abbreviations are defined in the glossary and Table 1.3).

Protocols Being Implemented in 2007

The protocols in this section were drafted in 2005, with full-scale test implementation in 2006. They

Table 5.1. NETN protocol development schedule. The schedule includes protocols the network is currently testing that will be ready for full implementation in FY07 (white fill), protocols that will be drafted by the network in FY06 and FY07 (blue shading) and implemented by FY09, protocols being implemented by another program or agency (yellow fill), and protocols being considered for development as funding and resources permit (green shading).

Protocol	Vital Signs Addressed	Target population	Sampling Units
Forest Breeding Birds	Breeding birds	Park forest breeding passerine bird populations (plus grassland birds at Saratoga)	Circular point-distance counts (design also allows removal modeling of abundance and occupancy modeling)
Forest Condition	Forest vegetation, forest soil condition, invasive/exotic plants – early detection, invasive/exotic animals – early detection, ozone, land cover / ecosystem cover, white-tailed deer herbivory, atmospheric deposition and stress, visitor usage	Park forests and woodlands	Permanent forest plots (modified FIA) measured on rotating panel
Lakes and Streams	Water quantity, water chemistry, nutrient enrichment, invasive/exotic plants – early detection	Deep holes of park lakes and ponds; suitable low watershed stream sites	Permanent water quality / quantity sampling locations measured monthly (May – October)
Coastal Breeding Birds	Breeding birds	Park coastal breeding bird species at BOHA (possible extension to ACAD)	Boat transects and colony counts
Rocky Intertidal	Rocky intertidal vegetation, invasive/exotic plants – early detection, invasive/ exotic animals – early detection, visitor usage	Park rocky intertidal habitats (ACAD and BOHA)	Permanent plots or transects
Wetlands	Wetland vegetation, invasive/exotic plants – early detection	Park wetlands	Three permanent plots along a transect within each wetland

Table 5.1. NETN protocol development schedule. The schedule includes protocols the network is currently testing that will be ready for full implementation in FY07 (white fill), protocols that will be drafted by the network in FY06 and FY07 (blue shading) and implemented by FY09, protocols being implemented by another program or agency (yellow fill), and protocols being considered for development as funding and resources permit (green shading) (continued).

Protocol	Vital Signs Addressed	Target population	Sampling Units
Ozone	Ozone	Atmospheric ozone levels in or near parks	Existing ozone monitoring stations
Weather Monitoring	Climate	Weather in or near parks	Existing weather monitoring stations
Wet and Dry Deposition	Acidic deposition	Deposition in or near parks	Existing deposition monitoring stations
Amphibians	Amphibians and reptiles	Forest amphibians, vernal pool and stream amphibians	Coverboard arrays for forest amphibians, TBD for vernal pools and streams
Landscape Dynamics	Land cover / ecosystem cover, land use	NETN parks	Park plus variable buffer, or permanent plot locations plus variable buffers.
Phenology	Phenology	In planning stage for Appalachian Trail; NETN parks may adopt APPA protocol.	To be determined
Visitor and Recreation Use	Visitor usage	To be determined	To be determined

will be finalized after external and internal review of the protocols and the 2006 field season results, and they will be fully implemented across the network in 2007.

Forest Breeding Birds

Vital sign: Breeding birds

Justification: Birds are an important component of park ecosystems, and their high body temperature, rapid metabolism, and high ecological position in most food webs make them a good indicator of local and regional ecosystem change. It has been suggested that management activities aimed at preserving habitat for bird populations, such as for neotropical migrants, can have the added benefit of preserving entire ecosystems and their attendant ecosystem services. Moreover, among the public, birds are a high profile taxa, and many parks provide information on the status and

American redstart
© Charley Eiseman

trends of the park's avian community through their interpretive materials and programs.

Objectives:

- Determine changes in the composition of native and non-native forest passerine species in major habitat types during the breeding season in NETN parks. The focus will be on forest and woodland sampling, except at Saratoga, where grasslands will also be sampled.
- Determine changes in the relative abundance of the 10 most common species at each park, plus the combined suite of Partners in Flight Priority Species.
- Establish correlations between changes in bird communities and site-specific information about park management activities and changes in habitat metrics collected at co-located forest condition plots.

Parks: ACAD, MABI, MIMA, MORR, ROVA, SAGA, SARA, WEFA

Protocol available at http://www1.nature.nps.gov/im/units/netn/reports/reports0.cfm

Forest Condition

Vital signs: Forest vegetation, forest soil condition, invasive/exotic plants – early detection, invasive/exotic animals – early detection, ozone, land cover/ecosystem cover, white-tailed deer herbivory, atmospheric deposition and stress, visitor usage

Justification: The forest condition protocol is NETN's comprehensive terrestrial protocol; it addresses multiple vital signs at co-located permanent plots. Forest resources are subjected to a suite of anthropogenic and natural forces of change, and the NETN forest condition protocol is designed to assess the status and trends in forest and woodland diversity, structure and condition. Vegetation diversity and structure are fundamental properties of terrestrial ecosystems. Monitoring these properties provides basic information describing the site, the type and quality of habitat available for wildlife, and the response of vegetation to anthropogenic and natural stressors and drivers. This basic information provides the foundation to properly interpret many other vital signs (e.g., forest birds). Some NETN vital signs that have been incorporated into this protocol, such as soil condition, deer herbivory, and invasive plants and animals, provide important data that will allow us to assess the cause of changes in forest vegetation diversity and structure.

Objectives:

- Determine changes in the distribution of vegetation structural classes over time
- Compare the distribution of vegetation structural classes to that expected under natural disturbance regimes

Morristown NHP

- Determine changes in canopy closure over time
- Establish correlations between canopy closure and climatic stress, storms, pest and pathogen outbreaks and other disturbances
- Determine changes in snag abundance over time
- Establish correlations between land management practices and snag abundance
- Determine changes in coarse woody debris (CWD) biomass or volume
- Establish correlations between land management and silvicultural practices and CWD
- Determine changes in tree condition over time
- Record the presence of exotic invasive forest pests
- Determine changes in growth and mortality rates by tree species
- Establish correlations between vital rates and air pollution, pest or pathogen outbreaks, climatic stress or other known stressors
- Determine changes in tree regeneration over time
- Determine if deer are likely producing an impact on regeneration
- Determine changes in the spatial extent of high priority invasive exotic plant species
- Determine population trends of species most palatable to deer, most sensitive to ozone and acid deposition, or at the edge of their range
- Determine changes in native understory plant species richness
- Determine changes in exotic plant species abundance
- Determine change in forest floor condition over time
- Determine changes in soil Ca:Al and C:N ratios to assess the extent to which base cation depletion, increased aluminum availability or nitrogen saturation are impacting NETN forest soils
- Determine changes in canopy stress within NETN forested systems based on remotely sensed red reflectance data.
- Establish correlations between canopy stress and covariates including air pollution exposure, pest and pathogen outbreaks, climatic stress and other known stressors
- Determine change in landscape context over time, including forest interior patch size, distance to roads, and fragmentation levels

Parks: ACAD, MABI, MIMA, MORR, ROVA, SAGA, SARA, WEFA

Protocol available at http://www1.nature.nps.gov/im/units/netn/reports/reports0.cfm

Lakes and Streams

Vital signs: Water quantity, water chemistry, nutrient enrichment, invasive/exotic plants – early detection

Justification: Water quantity monitoring is essential for evaluating ecological issues in the NETN parks. Information about water quantity is necessary to interpret other vital signs such as water chemistry, estuarine nutrient enrichment, and contaminants because stream discharge is used to calculate annual loads and annual watershed yields. Furthermore, water quantity determines the physical extent and volume of aquatic habitat at the parks. Numerous factors affect water quantity, including precipitation, evaporation, water withdrawals, and ground-water recharge.

Water chemistry measures are an essential indicator for any long-term aquatic monitoring program. Water chemistry is widely applicable and is critical for interpreting the biotic condition and ecological processes of a system. Measures of water chemistry including pH, dissolved oxygen, water temperature and specific conductivity are fundamental to any long-term water quality monitoring program, and are mandatory as directed by the national Inventory and Monitoring program. Furthermore, color, nutrient levels, and percent dissolved oxygen saturation will be determined at all parks. A long term record of these basic water chemistry parameters in the lakes and streams of the NETN parks will enable resource management professionals to detect trends related to

Concord River from North Bridge: Minute Man NHP

global and regional climate change, as well as site-specific human-induced change. Coupled with this protocol will be a program for early detection of invasive plants in lakes, ponds, and streams.

Objectives:

- Determine changes in water quantity and variability (monthly, seasonal, and annual) for lakes, ponds, and streams
- Determine changes in water chemistry values and variability (for temperature, pH, dissolved oxygen, specific conductance, acid neutralizing capacity, and color)
- Establish relationships between water chemistry and water quantity
- Detect when water chemistry measures exceed thresholds of natural variability, determine the spatial and temporal extent of deviations, and establish whether deviations are due to human activities
- Determine changes in nutrient enrichment by measuring phosphorus and nitrogen levels
- Establish correlations between human activities and trends in nutrient enrichment by comparing monitoring data with data from unimpacted water bodies.
- Determine whether water bodies in NETN parks are in compliance with applicable federal and state water quality standards
- Detect aquatic invasive plants in the freshwater resources of NETN parks

Parks: ACAD, MABI, MIMA, MORR, ROVA, SAIR, SAGA, SARA, WEFA

Protocol available at http://www1.nature.nps.gov/im/units/netn/reports/reports0.cfm

Protocols Being Developed in 2006 and 2007

The protocols in this section are being developed in FY 2006 (Wetlands) or 2007 (Coastal Breeding Birds and Rocky Intertidal). They will be reviewed and evaluated in the field during the year after their development, and fully implemented in the following year. Protocol development summaries are available for each of these vital signs, and protocols will be posted on the NETN web site when they are available.

Coastal Breeding Birds

Vital sign: Breeding birds

Justification: Birds are an important component of park ecosystems, and their high body temperature, rapid metabolism, and high ecological position in most food webs make them a good indicator of local and regional ecosystem change. Moreover, among the public, birds are a high profile taxa, and many parks provide information on the status and trends of the park's avian community through their interpretive materials and programs. Boston Harbor Islands has been identified as an Important Bird Area (IBA) by Massachusetts Audubon. An IBA is a site that provides essential habitat to one or more species of breeding, wintering, or migrating birds. Coastal breeding birds need to be monitored at the Boston Harbor Islands because of the sensitivity of these species to disturbance and because of their important trophic position in marine ecosystems. If resources permit, this protocol will be expanded to include Acadia.

Objectives:

Least Tern chick

- Determine changes in population size and spatial distribution of coastal breeding birds, including terns and oystercatchers, in the Boston Harbor Islands area
- Establish correlations between breeding bird population sizes and park management activities, visitor use levels, and changes in habitat metrics including weather, storm events, and contaminant levels

Park: BOHA

Protocol development summary available at http://www1.nature.nps.gov/im/units/netn/reports/reports0.cfm

Rocky Intertidal

Vital signs: Rocky intertidal vegetation, invasive/exotic plants – early detection, invasive/exotic animals – early detection, visitor usage

Justification: Rocky intertidal systems include a suite of organisms that are adapted to a harsh environment that is subjected to extremes of exposure and temperature. These systems are attractive to park visitors because of their scenic beauty and for shoreline exploration. The plants and animals of these communities are adversely affected by contaminants, invasive species, and collection and disturbance by park visitors. The rocky intertidal habitats of Acadia and Boston Harbor Islands are a significant natural resource, and they need to be monitored so that appropriate usage levels can be determined.

There is a paucity of information about the species assemblages of the rocky shoreline at these parks, with the exception of a recent inventory at Boston Harbor Islands (Bell et al 2003). Effective protection of this habitat requires baseline data now to determine what species are present and to understand how key components of these land and water interface systems respond to natural environmental variations and human impacts. These data will help parks assess the effectiveness of management actions and assist in the evaluation of impacts of catastrophic events, such as an oil spill.

Objectives:

- Determine changes in intertidal zone widths
- Determine changes in algal and invertebrate species diversity and abundance
- Determine changes in the abundance of

Rocky intertidal: Acadia NP

keystone herbivores and predators within the low intertidal zone
- Detect invasive exotic invertebrate and plant species
- Establish correlations between rocky intertidal species and key abiotic factors, including ice scouring and storms
- Quantify impacts of visitor activities (e.g., trampling, rock turning, and collecting) on rocky intertidal resources
- Establish correlations between intertidal biota populations and levels of anthropogenic contaminants

Parks: ACAD, BOHA

Protocol Development Summary available at http://www1.nature.nps.gov/im/units/netn/reports/reports0.cfm

Wetlands

Vital signs: Wetland vegetation, invasive/exotic plants – early detection

Justification: Wetlands at parks throughout the NETN are exposed to a suite of threats associated with human development of watershed areas outside park boundaries. These threats include altered surface and groundwater hydrology, invasive species encroachment, excess nutrient loading, and contaminant inputs (e.g. Roman 2000). Wetlands contribute significantly to the region's biodiversity, productivity, and uniqueness. Some of the wetlands at the largest park in the network, Acadia National Park, have already been degraded to varying degrees by anthropogenic stresses (Kahl et al. 2000), and increasing park visitation and external development activities put many more park wetlands at risk.

Objectives:

- Determine changes and variability in wetland habitat indicators such as nutrient regimes, water level, temperature, water chemistry, and hydrological fluctuations

Wetlands: Saratoga NHP

- Determine changes and variability in species richness, abundance, and diversity of wetland plant communities
- Determine changes in invasive plant species abundance in wetland communities

Parks: ACAD, MABI, MIMA, MORR, ROVA, SAGA, SARA, WEFA

Protocol Development Summary available at http://www1.nature.nps.gov/im/units/netn/reports/reports0.cfm

Protocols from Other Programs

The protocols referenced in this section are established or being developed by other programs or agencies. NETN will review the protocols for these vital signs and produce SOPs for acquiring, managing, and reporting the data collected with these protocols. The SOPs will be developed in FY 2007 and 2008, and NETN will acquire all available historical data as well as establish a system for receiving annual data updates.

Ozone

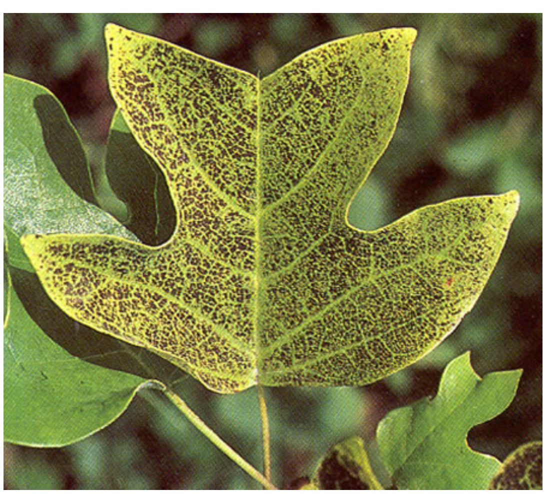
Vital sign: Ozone

Justification: Tropospheric (ground-level) ozone is a damaging phytotoxin of significant concern within the northeastern United States. Ozone damages cell membranes, which leads to reduced rates of photosynthesis and plant growth. However, ozone damage varies in a complex manner depending on exposure, plant species, genotype, plant age, and plant stress (particularly water stress, Chapelka & Samuelson 1998). For this reason, ozone is typically monitored both directly (in air) and indirectly (as injury to indicator species, Coulston et al. 2003).

The NPS Air Resources Division (ARD) operates a network of air quality monitoring stations that measures meteorological parameters and ozone. The gaseous pollutant monitoring program determines levels of two gaseous pollutants, ozone and sulfur dioxide. These pollutants are toxic to native vegetative species even when they are at or below the National Ambient Air Quality Standards (NAAQS). Ozone monitoring in national parks has been ongoing since the early 1980s using EPA reference or equivalent methods. This allows for the direct comparison of NPS data with data collected by state and local air pollution control agencies and the EPA.

Objectives:

- Determine trends in ozone levels
- Determine the impacts of ozone pollution on selected bioindicator species



Yellow poplar with ozone injury

Parks: All NETN parks

Protocol available at http://www2.nrintra.nps.gov/air/permits/aris/networks/index.cfm

Weather Monitoring

Vital sign: Climate

Justification: Weather is a critical factor limiting flora and fauna condition and distribution. Weather data provide valuable insights into the range of climatic conditions to which plant and animal communities are adapted. Weather information is vitally important when interpreting monitoring information collected using other protocols (e.g., breeding bird or forest condition data). Data collected as part of weather monitoring can also be used to help interpret physical and chemical properties of streams or habitats in addition to supporting investigations of specific biological communities. All NETN parks have NOAA weather stations within their boundaries or nearby, and the national Inventory and Monitoring Program is currently working on procedures for acquiring this data.

Objective:

- Determine changes in average monthly maximum temperature, average monthly minimum temperature, average monthly mean temperature, and total monthly precipitation.

Parks: All NETN parks

Protocol Development Summary available at http://www1.nature.nps.gov/im/units/netn/reports/reports0.cfm

Wet and Dry Deposition Monitoring

Vital sign: Acidic deposition

Justification: Atmospheric pollution, in the form of acid deposition and tropospheric ozone, significantly impacts northeastern ecological systems in complex ways that vary substantially across the landscape. Acidic deposition acidifies soil and water, leaching base cations (e.g., Ca^{2+}, Mg^{2+} and K^{+}) from the system and increasing the availability of aluminum (which is toxic). These biogeochemical changes can cause the decline or dieback of sensitive terrestrial species, such as red spruce or sugar maple, in addition to decreasing the richness and abundance of zooplankton, macroinvertebrates and fish in downstream aquatic and wetland ecosystems (Driscoll et al. 2001b).

The NPS monitors wet deposition through the National Atmospheric Deposition Program (NADP). NADP started in 1978 with 22 monitoring sites and has grown to over 240 sites nationwide, providing the only long-term record of precipitation chemistry in the United States. The NADP is a cooperative effort between federal and state governments, universities and private organizations. The NPS monitors dry deposition through the Clean Air Status and Trends Network (CASTNet). CASTNet started in 1987 with 50 monitoring sites and has grown to over 70 sites nationwide. The network monitors dry deposition, ozone, and meteorology. The primary purpose of CASTNet is to determine the effectiveness of national emission control programs.

NETN will collect information from NADP and CASTNet sites within or adjacent to network parks on a yearly basis, then synthesize and present the data to each park.

Objective:

- Determine changes in the deposition of pollutants including, but not limited to, sulfur dioxide, nitrogen oxides, ammonia, and mercury

Parks: All NETN parks

Protocols available athttp://www2.nrintra.nps.gov/air/permits/aris/networks/index.cfm. The dry deposition protocol is not yet available.

Additional Protocols

The development of protocols in this section has been deferred until resources and funding are available to address them. Objectives and specific protocols presented here are preliminary, and they will be refined during the development process. In order to reduce costs of monitoring these vital signs, NETN will strive to use existing monitoring protocols and volunteer field workers whenever possible.

Amphibians and Reptiles

Vital sign: Amphibians and reptiles

Justification: Vernal pools are ephemeral wetlands that provide essential habitat for many species of amphibians, reptiles, and invertebrates. Because vernal pools lack fish, a top-level predator of many aquatic habitats, amphibians such as wood frogs and spotted salamanders preferentially breed in them. In some states such as Massachusetts, New Hampshire, and Maine, vernal pools are starting to receive attention and regulatory protection (Massachusetts Audubon Society 1991, Kenney 1995, Tappan 1997, Maine Audubon Society 1999, Burne 2001). In most states, however, vernal pools lack protection, and therefore the amphibians and reptiles relying on these habitats may be susceptible to population declines.

Green Frog

Stream salamanders are receiving more attention as potential ecological indicators of small stream health. Small streams are becoming increasingly impacted by stormwater runoff, development, and other land use changes in the Northeast. Stream salamanders in the family Plethodontidae (lungless salamanders) are fairly long-lived, exhibit relatively stable populations, have small home ranges, and often replace fish as the top vertebrate predators in headwater stream ecosystems (Southerland 1985, Petranka 1998, Ohio EPA 2001). These characteristics make them useful as indicators of long-term stream health.

Changes in forest salamander populations provide insights into forest ecosystems and perhaps a more realistic assessment of forest health than those based on classical forestry measures of stocking and growth rates. Forest health must account for the communities of all plants and animals (such as salamanders) that exist under the defining umbrella of large woody plants. An increasing or stable number of salamanders would indicate that the forest's balance of invertebrates, leaf litter, moisture, pH, debris, burrows, and other habitat features were sufficient, while declines would signal environmental shifts counter to the needs of the species and increasing ecosystem impairment.

NETN is considering adopting protocols developed by the Northeast Amphibian Research and Monitoring Initiative (NE ARMI). NETN has begun modifying a USGS terrestrial salamander monitoring protocol, and is testing this protocol at Marsh-Billings-Rockefeller in FY 2007. Appropriate reptile monitoring protocols have not yet been identified.

Objectives:

- Determine changes in wood frog and spotted salamander populations at parks with vernal pools
- Establish correlations between wood frog and spotted salamander presence or population sizes and surrounding land use, road density, density of potential breeding sites, water quality variables, hydroperiod, and climatic conditions
- Determine changes in stream salamander populations in NETN parks
- Establish correlations between stream salamander population sizes and landscape, habitat, and water quality variables
- Determine changes in forest amphibian populations
- Establish correlations between forest amphibian population sizes and forest health metrics
- Determine changes in reptile populations

Parks: ACAD, MABI, MIMA, MORR, ROVA, SAGA, SARA, WEFA

Protocols available at http://www.pwrc.usgs.gov/nearmi/projects/(vernal pools and streams) and http://www1.nature.nps.gov/im/units/netn/reports/reports0.cfm(terrestrial)

Landscape Dynamics

Vital signs: Land cover / ecosystem cover, land use

Justification: Many of the parks in the NETN are subject to encroaching residential and urban development, and we recognize that these landscape issues are closely linked to park ecosystem function. Long-term monitoring of landscape-level indicators that represent the ecological impacts of land use changes may help managers determine patterns that may eventually threaten park ecological integrity. Land use changes that alter the flow of water through a park are the greatest threat to water quality. Additionally, the increasing population in the areas surrounding NETN parks has led to increases in recreational use within the parks, and further threatened park resources.

NETN and the University of Rhode Island are currently completing an analysis of land cover change based on Landsat data collected over 20 years. The results from this project will inform decisions about buffer sizes and imagery for long-term monitoring of land use and land cover.

Objectives:

- Determine changes in land use and ecological cover types within and adjacent to NETN parks
- Quantify trends in relevant land use and cover metrics, including habitat conversion and loss, fragmentation, and reduction in functional ecosystem size (e.g., core area).
- Establish correlations between land use and land cover trends and trends in monitoring data by analyzing land change derived from buffers centered on long-term monitoring plots

Parks: ACAD, MABI, MIMA, MORR, ROVA, SAGA, SARA, WEFA

Protocol Development Summary available at http://www1.nature.nps.gov/im/units/netn/reports/reports0.cfm

Phenology

Vital sign: Phenology

Justification: Climate change is projected to disproportionately stress temperate ecological systems over the next century and beyond. Notably, the northeastern United States, where the NETN is focused, has seen greater warming over the last century than most other regions of the country. A growing body of evidence indicates that climate change has already altered phenological patterns of a wide variety of organisms including terrestrial plants, birds, amphibians, insects, and aquatic algae (Parmesan and Yohe 2003, Root et al. 2003). These altered phenological patterns may have far-reaching consequences. Research shows that responses to climate change will vary among species within an ecosystem; thus responses to climate change such as altered timing of budbreak, migration, or reproduction may alter competitive interactions and uncouple food webs and mutualistic relationships.

Objectives:

blue-eyed grass

- Determine changes in phenology of selected focal taxa and habitats, particularly focusing on populations occurring near the edge of species' ranges. Specific metrics may include: tree leaf-out dates and growing season length, flowering dates for herbaceous species, spring arrival dates for bird species, spring calling dates for frog species, spring emergence for insect species, and ice-out dates for lakes
- Determine changes in phenology of key invasive exotic species likely to benefit from climate change. Specific metrics may include: flowering phenology of invasive exotic plant species and emergence phenology of invasive exotic insect species
- Determine the magnitude of phenological change by comparing and contrasting current measurements to historical records and modeling efforts

Parks: ACAD, MABI, MORR, SARA

Protocol Development Summary available at http://www1.nature.nps.gov/im/units/netn/reports/reports0.cfm

Visitor Use

Vital sign: Visitor usage

Justification: The human population of New England has more than doubled over the past century, and in southern New England, human population density is among the highest in the United States. Accordingly, several NETN parks have high visitation rates, especially ACAD, APPA, MIMA, ROVA and MORR. Hikers can increase erosion on and around trails, trample nearby vegetation, cause soil compaction, and disturb wildlife. These impacts can be particularly significant in high elevation areas and in areas where trails are poorly marked. Car traffic within parks can cause wildlife fatality, and reinforce the fragmentation effects associated with roads. Horse-riding is permitted within several NETN parks, and horses can contribute to trampling and trail erosion, and perhaps aid in the spread of invasive exotic species. Snowmobiling is permitted within Acadia, and may cause winter-time disturbance to wildlife. Visitors can impact freshwater aquatic habitats by extracting natural resources such as fish, and by contributing to erosion, road runoff, contamination, and the introduction of invasive species. Visitor impacts to rocky intertidal sites at ACAD and BOHA can also create significant ecological disruptions.

Some specific aspects of the visitor usage vital sign (e.g., effects of visitors on rocky intertidal habitats) will be addressed in other protocols. This protocol is designed to provide a more holistic view of visitor effects on park resources by collecting information about broader metrics of visitor use and, where appropriate, integrating visitor use data from other protocols.

Hikers on the Appalachian NST
© Jeffery L. Marion

Objectives:

- Determine change in visitor numbers, distribution (spatial and temporal) and activities
- Determine effects of trampling on soil compaction, vegetation diversity, and vegetation condition within NETN open upland systems

Parks: All NETN parks

Protocol Development Summary available at http://www1.nature.nps.gov/im/units/netn/reports/reports0.cfm

Chapter 6
Data Management

Objects and Goals

The goals of Northeast Temperate Network data management are to provide accurate, efficient, and effective information and support for resource management and protection. These goals are not limited to data collected by the network; we plan to serve as a repository for existing data sets, and we will work with parks to manage data for a wide range of park resource management projects. To meet these goals, park managers, cooperators, and other data users need to know what data are available from the NETN. They need to know where data is stored, its quality, timeliness, and usefulness, how to incorporate these data into resource management decisions, and how the data will be managed over time. This chapter summarizes key features of the Northeast Temperate Network Data Management Plan, which is available online at http://www1.nature.nps.gov/im/units/netn/reports/reports6.cfm.

The NPS Strategic Plan, Mission Goal 1b, requires that "...management decisions about resources and visitors are based on adequate scholarly and scientific information..." In addition, long-term Goal #1b1 states that acquiring "... outstanding data sets... of basic natural resource inventories of all parks..." is a desired outcome. The objective of the NPS I&M Program is to provide scientifically and statistically sound data for resource management, and to ensure that quality data is available for this task. These objectives establish needs:

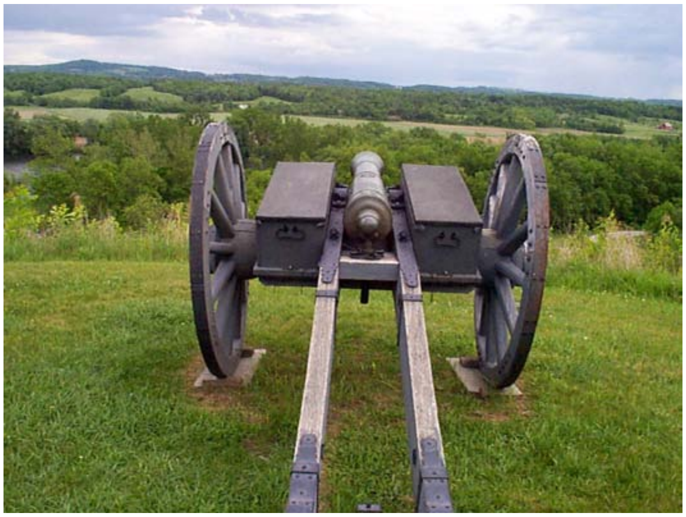
- To develop metadata for all significant spatial and non-spatial data
- To ensure very high quality for all significant data
- To develop and maintain all essential data
- To ensure that data are logically organized and retrievable by staff, cooperators, and the public
- To identify sensitive data and protect it from unauthorized access and inappropriate use
- To optimize data sharing, development, and analyses
- To ensure that all network-held digital and non-digital information (i.e., data sheets, documents, published and unpublished reports, manuscripts, photographs, maps, metadata, etc.) are archived and protected in accordance with recognized archival standards

Infrastructure

In the context of information technology, infrastructure refers to the utilities, hardware, software, user training and support systems that keep the information system running. Accordingly, this section describes the systems, programs, policies, and capabilities that the Network has established to provide the data management services and support that the NETN provides to parks, and to cooperators working at parks within the network.

The NETN has identified five distinct data management capabilities it will offer to parks within the network: Geographic Information System support, relational database support, document preparation support, data integration, and data acquisition. In addition, the network will work with parks to manage any datasets they may possess, and will assist them with all data management needs including issues relating to data collection, storage, and stewardship.

The network has also established a series of standards and policies that relate to the organization of network and park data holdings and to the long-term security of NETN data. For example, the network has established a naming convention, a directory structure, a comprehensive data storage procedure, and a budget tracking system.



Cannon: Saratoga NHP

Finally, the network has acquired computer hardware and equipment to complete its mission. This includes Global Positioning System (GPS) receivers, water quality sampling equipment, and digital cameras. Additionally, the NETN has a number of desktop, laptop, and hand-held computers and digital storage devices. A complete listing of computers and related equipment can be found in the equipment Appendix to the Data Management Plan.

Roles and Responsibilities

The NETN's staff are the 'eyes and ears' of the Network. A knowledgeable staff that knows what to do and when to do it are vital to the success of the inventory and monitoring program.

In January 2003, the Northeast Temperate Network hired a Data Manager to oversee issues related to data acquisition, organization, security, access, dissemination, and documentation. Beyond data stewardship, the Data Manager works with cooperators and park staff on database design and standardization issues, is responsible for determining whether data sets are complete enough for inclusion into master NPS data systems, and evaluates field data forms and data entry modules. The network Data Manager is also primarily responsible for determining data management roles and responsibilities for every project.

To help the network team coalesce, the NETN has adopted a framework that identifies key data tasks and the primary person who must ensure that each task has been completed. The underlying philosophy behind the various roles and responsibilities identified by the network is shared responsibility and cooperation. The NETN believes that all staff members, from field technicians to the Network Coordinator, are equally responsible for ensuring that data collected by the network are scientifically and statistically sound.

Project Management

Data management begins with the conception and design of a project and continues until the desired end product is made available to the intended audience. The value of good data management is fully realized when data is readily accessible to a broad audience, and when that data fulfills the objectives of the project. To achieve this level of performance, the NETN has established guidelines for the project management process, from inception to completion. The guidelines stress the importance of clearly defining the purpose and objectives of a project. Without these fundamental building blocks, it is neither possible to evaluate the success of the project nor is it possible to determine the utility of the data, because the purpose of the project is unknown. The NETN also stresses the importance of tracking each project's progress, and of performing a post project-completion evaluation.

The key project management elements that have been identified by the network and that must be addressed with every project include:

- Planning and approval
- Project tracking
- Project budget
- Project design
- Project testing
- Project implementation
- Preparation
- Data acquisition and processing
- Product delivery and review
- Product integration

- Evaluation and closure

Database Design

Consistency and compatibility are two important keys to ensuring high quality data. If data collected by the NETN are intended to be used by park mangers, network staff, the public, and the scientific community, the data the network collects must be high quality. The task of ensuring high quality data is made more difficult (if not impossible) if the network does not implement rigorous database standards. While database standards alone will not solve all possible problems, standards promote compatibility among data sets, and make it easier to aggregate and summarize data in the future.

Designing an appropriate database is more dependent on communication than it is on database programming acuity. Accordingly, the NETN stresses the importance of remaining involved with each database development project instead of establishing a prescriptive step-by-step process that must be followed during the development process. This philosophy notwithstanding, defining the purpose for a database is one step that cannot be overlooked, and must be established at the outset of a database design project.

With respect to standards that do exist, the NPS Inventory and Monitoring Program has developed the Natural Resource Database Template (NRDT). The NETN will use the NRDT as the preferred framework for all future natural resource database development projects.

Data Acquisition and Management

The Northeast Temperate Network intends to acquire and maintain a complete record of natural resource data for all parks within the network. The network may also acquire data that is not associated with parks, but is regionally focused or related to park activities.

Digital data shall be stored by the NETN and made available to cooperators, park and network staff, and others in compliance with established data distribution policies. Data that is properly documented with metadata and that is free of data distribution restrictions will be posted to the NR-GIS Data Store, where it can be accessed by the broadest audience. Data that is not documented with metadata (or that has data distribution restrictions) will also be acquired by the NETN, but the network will not distribute inadequately or improperly documented data or data that has distribution restrictions. Historic data, in formats other than digital, will also be obtained when available and scanned into digital format. This data will then be made available to cooperators, park and NETN staff, and others in compliance with established data distribution policies.

Data that is generated through network activities will be permanently stored and archived along with all other project-related information. Data that is not generated through network activities will generally not be permanently archived by the NETN.

Quality Assurance and Quality Control

Data collected through monitoring activities must be uniform, consistent, and accurate if they are to serve the needs of the Inventory and Monitoring program and resource managers. If data do not meet these requirements, analyses and decisions based on these data may be flawed, and could produce unwanted results and promote poor decisions. To ensure that data quality problems do not produce these undesirable consequences, the NETN has established a program to ensure that data collected and created through network activities is of known quality. The NETN quality assurance and quality control (QA/QC) program relies on the following to deliver high quality data:

- Thoroughly evaluated scientific measurement protocols
- Standard operating procedures
- Verification, validation, and editing procedures
- Data documentation and metadata standards
- Version control
- Data quality process review and communication

Documentation

Documentation brings a project to completion by fully describing the process, limitations, application, and restrictions that might apply to a project or dataset. It makes it possible to repeat a project, and thorough documentation should include guidance on how to appropriately use a dataset. While documentary requirements may vary depending on whether it applies to a dataset, a database, an application, or a project, it will in all instances provide a road map to proper usage and understanding.

Beyond the obvious reasons for documenting a project, Executive Order 12906 (April 1994) mandates that federal agencies create metadata, or "information about data," for all geospatial data. The NETN intends to comply with the requirements of this Executive Order, and will ensure that all projects administered by the network, including those that do not generate geospatial data, are fully documented with metadata and appropriate guidance.

Data Analysis and Reporting

Presenting meaningful information in a manner that is beneficial to managers and scientists is a fundamental objective of the Inventory and Monitoring program. For the NETN to achieve this objective, the Data Analysis and Reporting chapter of the Network Ecological Monitoring Plan contains the background and overall approach that we will use to analyze data and report its findings. The network data management program will support this objective by ensuring that data necessary for the specified analyses are properly formatted and compatible with applicable statistical software applications.

Data Dissemination

Data collected, maintained, or stored by the Northeast Temperate Network will be entered into the appropriate NPS "national" data system. This may be any combination of the following systems: NPSpecies, NatureBIB, Dataset Catalog, ANCS+, and the NRGIS Data Store. Data may also be presented through the NETN web page or other means by special request.

Prior to disseminating any data, the NETN will work with cooperating agencies, organizations, and individuals to protect the security of any and all sensitive data. The network will implement the Regional Freedom of Information Act (FOIA) policies, and will place special emphasis on procedures for handling sensitive data.

Records Management and Archiving

The NETN is responsible for maintaining and archiving documents, such as final reports prepared by staff or cooperators, program administrative documents, contracts and agreements, memoranda of agreements, and other documents related to network administration, activities, and projects. The NETN must also manage and archive physical items such as natural history specimens, photographs, and audio tapes. Finally, the network must permanently archive all data obtained during network activities. A complete discussion of the NETN's intentions regarding records management and collections is outlined in the Network Scope of Collections Statement, an appendix to the Data Management Plan. All NETN data shall be archived on CD, DVD, tape, or other appropriate media and stored at Acadia National Park.

Storage for many of the aforementioned items is prescribed in NPS Director's Order 19: Records Management and associated appendices. However, for things such as data that may be software dependent, proper procedures for long-term archiving do not currently exist. In these instances, the NETN will work with the curator at Acadia National Park to develop the best long-term solution to the data archiving problem.

Chapter 7
Data Analysis and Reporting

Introduction

A primary purpose of the Northeast Temperate Network is to integrate relevant and reliable monitoring information regarding resource condition and changes in condition over time, and present the results to park management. We have developed the NETN as an information system that is involved with as many park divisions as possible. To accomplish this, communication tools that summarize vital signs data have been developed that will reach broad audiences and provide park managers with the necessary information to manage natural resources. An adaptive management framework requires incorporating timely feedback from monitoring data collection into analyses and reporting, and also requires effectively communicating the results. This chapter outlines how the network proposes to analyze and communicate monitoring information.

The scientific data needed to better understand how park systems work and to better manage the parks will come from many sources. In addition to new field data collected through the I&M program, data to help us determine the status and trend in the condition of park resources will come from other park projects and programs, other agencies, and from the general scientific community. To the extent that staffing and funding is available, the network monitoring program will collaborate and coordinate with these other data collection and analysis efforts, and will promote the integration and synthesis of data across projects, programs, and disciplines.

Data Analysis

Increasingly, ecologists work to describe and quantify biologically important phenomena, rather than doggedly pursue statistical significance (Yoccoz 1991, Johnson 1999, Anderson et al. 2001, Johnson 2002). The Northeast Temperate Network seeks to provide a quantitative understanding of the magnitude and direction of ecological changes and to provide appropriate measures of precision of these estimates. We aim to address directed monitoring questions that reflect our prior knowledge of the system and provide useful information for management decisions, rather than test myriad hypotheses about ecosystem change.

Baker Island: Acadia NP

Our approach to data analysis includes four steps: summarization and characterization of data, determination of status, evaluation of trends, and synthesis. Data summaries help ensure integrity of the data, and provide the foundation for more comprehensive analyses and for effective communication of results (Palmer and Mulder 1999, Reid 2001). Status refers to the condition of the monitored variables at a single point in time, and should be quantitatively understood across the entire spatial domain of interest. Trend analysis requires at least three successive measurements of an indicator, and quantifies change over time. Repeated measures or longitudinal analyses are a common framework for permanent plots with a shorter duration of monitoring. In contrast, time-series analysis is applicable for a single unit measured many times (e.g., 30 yrs), most common with individual climate and air-quality stations. Hierarchical modeling is also becoming increasingly common for the analyzing trends in complex longitudinal data sets. The fourth step, data synthesis, involves the interpretation of monitoring results, placing of results within the body of existing knowledge, and discussing potential management implications.

Types of analytical approaches

The Northeast Temperate Network has a range of monitoring objectives that span a variety of temporal scales, spatial scales, and levels of biological organization (Chapter 5). Consequently, analytical approaches to such diverse questions are not easily summarized. Our goal is to focus on indicators that: a) can be precisely, repeatedly, and relatively inexpensively sampled; b) show a rapid, persistent response to environmental changes; c) have dynamics that reflect the ecosystem or environmental component of interest; and d) have relatively low natural variability, allowing separation of background variation from a change in status (Noon et al. 1999). In addition to estimating magnitude of change and associated confidence intervals, we will use a combination of the four analytical approaches detailed below, as appropriate for each protocol, vital sign, or report.

Hypothesis Testing

This type of analysis will be reserved for testing whether the value of a particular indicator meets a certain condition. This approach is potentially useful for documenting satisfaction of congressional mandates or achievement of management or performance goals. Previously, nearly all monitoring questions were framed in terms of a statistical null hypothesis of no difference between the estimated value of an indicator and its baseline or reference value (Underwood 1997, Noon et al. 1999). However, estimating reference values ('benchmarks') is difficult and imprecise for several reasons (reviewed by Noon et al. 1999), including the recognition that benchmarks for indicators are often better represented by probability distributions rather than a single target value.

Information-Theoretic Approach

Chamberlin (1890) proposed the idea of examining data in the light of multiple working hypotheses, and his approach has recently gained broad support as numerical approaches have been developed to compare competing models. One of these approaches is called "information-theoretic" because it derives from Kullback-Leibler information theory (Kullback and Leibler 1951). This approach uses a statistic called Akaike's Information Criterion (AIC), which is calculated for each model in a set of models. The AIC value for a model is based on the likelihood (probability of the data, assuming the model is true) and represents the estimated relative distance of the model from truth. Comparing AIC values for a model set provides an estimate of the relative strength of competing models in the set. If one model is not the overwhelmingly best model in the set, model averaging procedures allow for parameter and variance estimation that accounts for model selection uncertainty (Burnham and Anderson 2002, Eberhardt 2003, Burnham and Anderson 2004). The information-theoretic approach is particularly useful because it works with any model type, from simple linear regression to complex non-linear models; it provides a structured framework for comparing and generating predictions from a variety of non-nested models.

Integrative Approach

In addition to trying to analyze individual indicators, we envision using approaches that incorporate multiple response variables. Generally, these approaches either a) concatenate all of the information into a unitless index, or b) try to differentiate between or illustrate relationships among sampling units in a holistic, multivariate sense. An example of the former approach includes calculation of beta and gamma diversity from alpha diversity across sampling locations. The second approach may involve an array of tests, depending on the nature of the data being analyzed. For continuous metrics, parametric or non-parametric Multiple Analysis of Variance (MANOVA) can be used to compare two or more types of sites. If the data are not continuous, such as abundance or cover categories

Vanderbilt Mansion: Roosevelt-Vanderbilt NHS

or presence of species at a collection of sites, then ordination of the sites in multidimensional space can shed light on the relationships among sites in terms of their species composition. These ordination techniques are needed because of the non-normal distribution of species at and across sites. Many analytical tools are available to answer multivariate questions, and theory and analytical algorithms continue to be developed to address hypotheses from increasingly complex designs.

Bayesian Approach

Bayesian statistical methods are an alternative to classical hypothesis testing, and the approach has gained increasing popularity among biometricians (Dorazio and Johnson 2003). In brief, Bayesian approaches quantify pre-existing knowledge or beliefs about the system into what is known as a prior probability distribution. Through the use of Bayes' theorem, these existing beliefs are updated as a result of new information, which produces revised beliefs that are quantified in a posterior probability distribution. The Bayesian approach is attractive not only because it allows an informed starting point, but also because it allows a more direct assessment and portrayal about the truth of a hypothesis. In spite of this, the utility of Bayesian statistics in monitoring efforts such as ours seems limited until extensive (greater than 30 years) data sets are accumulated or unless the network were to adopt a model-based approach to inference.

Communicating the Monitoring Program

Presentations and Reports

Network staff will be responsible for the majority of the reporting necessary to assimilate the NETN into park management (Tables 7.1 and 7.2). Reporting will occur in many formats and throughout the year to provide multiple opportunities for programmatic integration. Presentations are an important component of successful communication, and they strengthen the relationships between park and network staff. NETN will produce, present, or oversee four basic types of oral presentations (Table 7.1). The annual board meeting is an important opportunity for network superintendents to receive an update regarding network progress and to provide guidance to the network staff. These meetings also provide accountability for the network's expenditure of funds as well as review and approval for the next fiscal year's work plan. Technical steering committee meetings are held annually, or as necessary under the discretion of the network coordinator. The purpose of these meetings and presentations is to update the technical steering committees on network progress and to resolve specific issues regarding monitoring program design and implementation.

One of the most important components of the NETN communications schedule is the development of park specific presentations or "I&M Road Shows." These presentations are developed for each park and presented to all park divisions by network staff. The "Road Shows" will provide opportunities for network staff to update parks regarding novel information from the vital signs program, integrate monitoring information into park management decision making, and develop strong working relationships with park staff. These presentations will occur on an annual basis, usually during the late spring or early summer. This will allow the network to provide information in a timely fashion (before the summer visitor season) and address any specific questions.

Table 7.1. Northeast Temperate Network presentation schedule.

Presentation	Presentation Purpose	Audience	Location	Frequency	Presenter
Annual Board Meeting	Update network parks on status of I&M program, review administrative report, workplan, and budget, request guidance on programmatic issues	Superintendents, resource managers, regional I&M coordinator, and regional chief of science	Virtual (conference call with slide show)	Annual	Network Coordinator
Technical Steering Committee	Update committee on network progress, review guidance regarding design, implementation, analysis, and other technical issues related to implementation of the monitoring plan	Technical steering committee members	Rotated through network parks	Annual or biennial	Network Coordinator
I&M "Road Shows"	Provide ongoing updates and results from the Vital Signs program to each park, integrate I&M information into all park divisions, and develop working relationships with parks	Park managers from all divisions, superintendents, all park staff, and volunteers	By Park	Annual	Network Coordinator / Science Comm. Specialist
Cooperator Summaries	Present the results of specific I&M projects to each park and provide an opportunity for parks to ask questions and integrate results into park management	Park managers from all divisions, superintendents, all park and network staff, and volunteers	By Park	When appropriate	Cooperators

When appropriate, the network will also work with cooperators to host multi-park seminars where cooperators present their findings to park staff. These cooperator summary presentations will provide an opportunity for park staff to engage the cooperators directly, become familiar with the results of specific projects, and incorporate the data into park resource management.

Written reports will complement the oral presentations to more effectively disseminate information from the I&M program. Six primary types of written reports will be generated at different time intervals as we implement our monitoring program (Table 7.2). The annual administrative report and work plan provides accountability for the expenditure of funds and documents the administrative history of the network. This report is presented to the board of directors and must be approved by both the board and the national I&M program.

Data summary reports will be written after the implementation of each protocol and will include methods, descriptive statistics, and interpretation (Table 7.3). These implementation reports will provide the basic information related to the results from each sampling period of a protocol and will lay the foundation for more intensive analytical trend analyses by documenting baseline conditions. For example, summary statistics will be presented

Table 7.2. Northeast Temperate Network reporting schedule.

Report	Purpose	Audience	Frequency	Authors	Review
Annual Administrative Report and Work Plan	Account for expenditure of funds. Outline program, define objectives, summarize accomplishments, and provide work plan for upcoming fiscal year	Network Board of Directors, national I&M program, regional I&M coordinator, and park staff	Annual	Network Coordinator and Data Manager	Board of Directors and national I&M program
Data Summary Reports for Specific Protocols	Provide summary information for each implementation of a protocol	Parks and network	Annual	Cooperators or network staff	Parks and technical committee
Vital Signs Scorecard Reports	Provide condition assessment and change in condition for specific park resources	Parks and network	Biennial	Cooperators or network staff	Parks and technical committee
Integration and Synthesis reports	Determine trends in resource condition; integrate among protocols and other data sources to correlate condition changes with other observed trends	Parks, network, cooperators, learning centers, and external scientists	3-5 year intervals	Cooperators or network staff	Parks, technical committee, external scientists, and the national I&M program
Program Review	Determine protocol effectiveness at addressing monitoring objectives and integrating into park resource management activities	Parks and network	Every 5 years	Technical committee members, outside experts, and the national I&M program	Parks, technical committee, external scientists, and the national I&M program

annually for each protocol metric for each park and presented with the previous year's summary statistic as the program matures (Table 7.3). We will compare, using analyses identified in specific protocols, changes in metrics over time on a biennial basis and integrate these results into other types of reports (see below), and we will compare our data to data collected by other regional programs (e.g., by comparing our forest metrics to data collected by the USFS Forest Inventory and Analysis program). Every three to five years, depending on the protocol, integration and synthesis reports will be generated by network staff to correlate the results from vital signs protocols with other data sources and to determine changes in resource condition over time (Table 7.3). A programmatic review report will be generated every five years. This report will provide an opportunity to determine what aspects of each protocol and the monitoring program in general are effectively providing information to the parks and what aspects are inadequate and may need to be revised or eliminated. Outside experts will assist the network in determining if the existing information is

Table 7.3. Protocol reports, types of information, audience, and schedule for protocols that will be implemented in FY 2007.

Monitoring Protocol (Data Source)	Information Content	Schedule	Target Audience & format
Forest Breeding Birds (NETN protocol)	Summary of forest breeding bird species richness overall, by guild, and relative abundance and Partners in Flight (PIF) species with regional responsibility.	Annual	Park staff Data Summary Report
	Trends in forest bird species richness and PIF priority species	Biennial	Park Staff, Superintendents Vital Signs Scorecard Report
Forest Condition (NETN protocol)	Summary of present conditions: Stand structural/age class, stand disturbance, tree growth and mortality rates, tree condition, tree regeneration, indicator plant presence, pest/pathogen presence, forest floor condition, understory richness/diversity, coarse woody debris, soil chemistry, landscape dynamics.	Annual (ACAD) Biennial (others)	Park staff Data Summary Report
	Trends in the above metrics and a condition assessment for specific metrics based on pre-defined condition thresholds. Metrics will also be aggregated into 3 indices (soils index, vegetation condition index, and landscape condition index) to provide an assessment of forest condition.	Biennial (ACAD) 4 years (others)	Park Staff, Superintendents Vital Signs Scorecard Report
Lakes and Streams (NETN protocol)	Summary of present conditions: water quantity, temperature, dissolved oxygen (DO), pH, conductivity, nutrients, acid neutralizing capacity (ANC), and color.	Annual	Park staff Data Summary Report
	Trends in water quantity, temperature, DO, pH, conductivity, nutrients, ANC, and color. Condition assessment for each water body based on pre-defined thresholds.	Biennial	Park Staff, Superintendents Vital Signs Scorecard Report
Air Quality (Existing data sources)	Summary of baseline, trends in ozone levels, deciviews (visibility), nitrate and sulfate deposition, particulates, acid deposition	Annual	Park staff Data Summary Report
Weather (Existing data sources)	Annual rainfall, snowfall, temperatures (average, extreme highs, lows), storm frequency, frost dates	Annual	Park staff Data Summary Report
Synthesis (NETN protocols and outside data sources)	Long-term trend analysis of metrics from multiple protocols	3 to 5 years	Park Staff, Superintendents Integration and Synthesis Report

meeting the stated objectives and recommending any necessary changes.

Vital Signs Scorecard

Effectively communicating the status and trends of vital signs is one of the most important aspects of a successful vital signs program. A primary analysis and communication tool for the NETN is a vital signs scorecard that will provide timely and efficient dissemination of monitoring information. One of our major challenges with the Vital Signs Monitoring Program and NPS Strategic Goals is figuring out how to provide reliable, meaningful information that can both guide park stewardship and demonstrate fiscal accountability. Decisions regarding what information would be developed by Vital Signs Monitoring programs were largely guided by science and based on the accuracy, precision, power to detect change, and cost-effectiveness of the proposed vital signs. In contrast, decisions about the kinds of information needed to convince non-technical people that the program is reliable, cost-effective and useful are determined by non-scientific social values that employ business models of uncertainty. Our reporting system must accommodate both models of decision-making.

The NETN scorecard is based on the national ecological monitoring framework (http://science.nature.nps.gov/im/monitor/docs/ecological_monitoring_framework.doc) and the measures identified for each vital sign. The NPS Ecological Monitoring Framework is a systems-based, hierarchical, organizational tool for promoting communication, collaboration, and coordination among parks, networks, programs, and agencies involved in ecological monitoring. Vital signs are organized into a 3-tiered framework, with increasing specificity at lower tiers. The six Level 1 categories are the broadest tier and will be used in a national "Natural Resource Scorecard" to report on the condition of park resources (see Table 3.2). To report to the Department of Interior Land Health Goals, parks will use a combination of quantitative trend information from vital signs monitoring and other efforts, and qualitative assessments based on the best available scientific information and expert

Wick House: Morristown NHP

opinion. The resulting reports will document the condition of resources within each system type (e.g., uplands, wetlands, marine, and coastal) and resource category (e.g., air, water, biological integrity). The details for the national "Natural Resource Scorecard" are currently being developed, but it is expected that condition assessments for each park and resource category will be accomplished using a clear, simple framework (e.g., Figure 7.1). This graphic can also be used as an information gateway to the large body of detailed, complex scientific information that is used as the basis for the resource assessments.

Generally, we followed Harwell et al. (1999), NatureServe (2002), and the proposed national I&M reporting system to develop an integrated scorecard framework for reporting NETN vital signs. An ecosystem integrity report card must meet specific criteria to be successful (Harwell et al. 1999). The scorecard system must be understandable to multiple audiences, address differences in ecosystem responses across time, show the status or current condition of the ecosystem, characterize the ecosystem condition thresholds, and provide justification and transparency for those thresholds (Harwell et al. 1999). Following these criteria, we have developed a scorecard reporting framework that builds off of the vital signs framework and meets these criteria. The scorecard will provide a clear, objective approach to communicating the

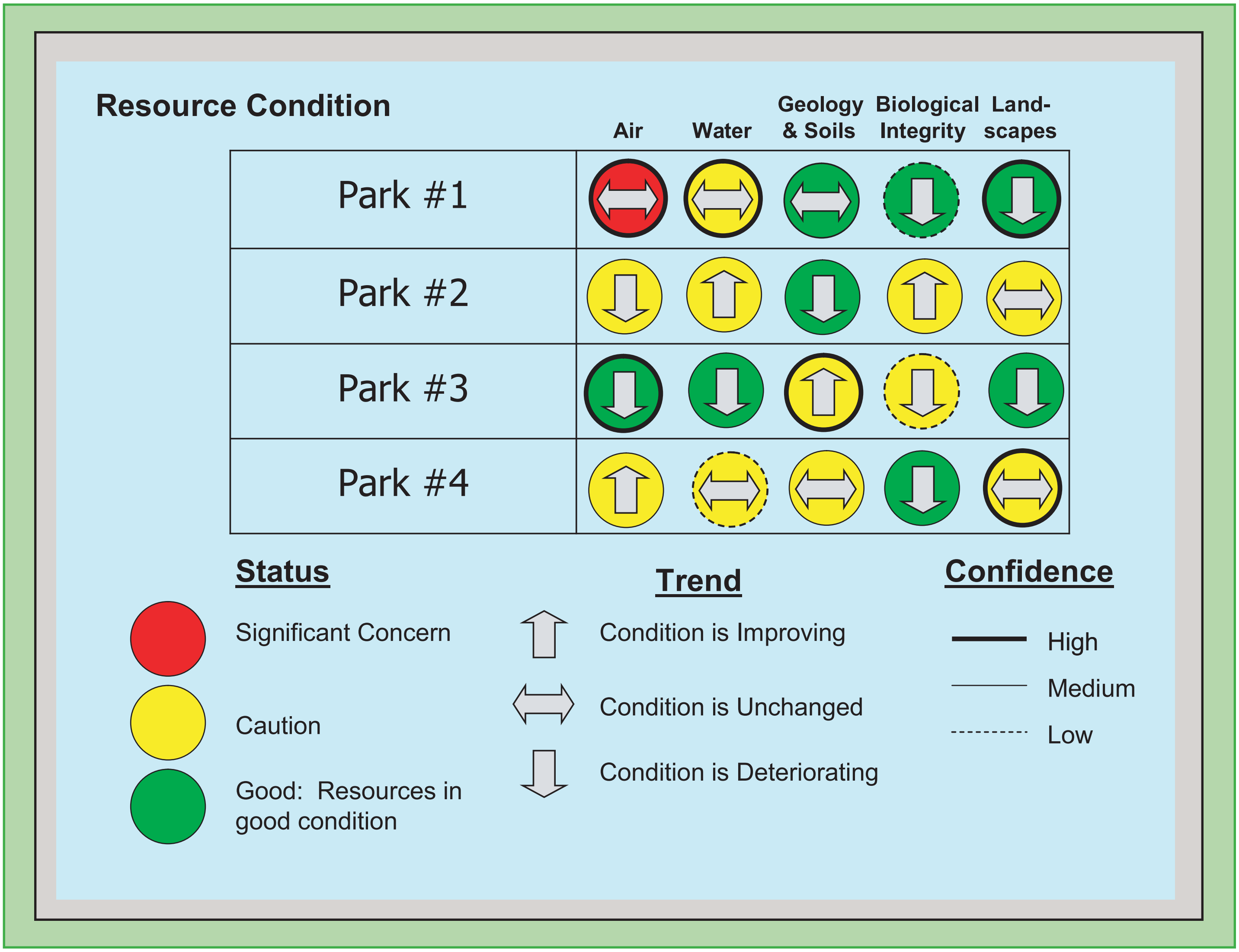


Figure 7.1. Example of the Natural Resource Scorecard being proposed as a tool for communicating the condition of park natural resources.

condition of park resources and changes in condition over time. This approach can be used to set management objectives, trigger management actions, and monitor the success of those actions. Timely and effective reporting of monitoring data is an important component in making this program relevant to park managers, and NETN will therefore produce scorecards on an annual or biennial basis. We view the scorecard as an essential tool for providing parks with timely information that will supplement the more infrequent trend analyses.

The role of the NETN vital signs scorecard is to provide detail about each metric or vital sign within each park. We define measures as those values that are collected directly in the field (e.g., pH or distance to nearest road) and metrics as analytical units derived from one or more measures (e.g., basal area, stand structural class, or species diversity). The condition of the vital signs will be reported using a suite of metrics that can be aggregated to report the condition of specific resources across all levels of the Ecological Monitoring Framework. The Ecological Monitoring Framework (Table 3.2) provides the foundation for integrating across organizational scales. Using this approach, we can report the condition of specific metrics (the lowest tier of the framework) and combine the metrics into vital signs. We can then aggregate across vital signs to report the condition for Level 1, Level 2, and Level 3 categories of the framework.

A critical step in developing this reporting framework was to define condition thresholds for each metric. We used the three condition categories (good, caution, and significant concern, Figure 7.1) proposed in the "Natural Resource Scorecard" to facilitate standardization and aggregation for reporting at different levels of the monitoring framework. Condition thresholds are established for each park and, where necessary, for specific ecological systems. These thresholds are based on the scientific literature and expert opinion, and will be archived and refined over time. When reports are based on a scorecard approach, it is important to be transparent and present the condition thresholds used to categorize the monitoring data. This ensures that readers and managers are well informed regarding the thresholds used to assign condition ratings. Use of thresholds brings together our best knowledge of current and historical dynamics to aid in mitigation and monitoring decisions. Thresholds based on the best available information allow the NETN to provide meaningful data summaries in a timely fashion.

Once the ratings and thresholds are established for each metric, sample plot values are compared to the pre-defined condition thresholds, and scores are given for each metric at each plot. This creates a data-driven, plot-based reporting system that is spatially explicit within each park. As an example, NETN Forest Vegetation vital sign data can demonstrate how the Vital Sign Scorecard reports will be organized. First, metrics and condition thresholds are identified for the vital sign (Table 7.4). The metric rating table is presented whenever values are placed into condition categories to ensure transparency in reporting. Metric value ratings are typically structured around a point-based scale of Good (5 points), Caution (3 points), and Significant Concern (1 point). These value ratings follow the approach proposed by Karr (1981) for aquatic systems, and used by others for developing terrestrial indices (Keddy and Drummond 1996, DeKeyser et al. 2003, Mack 2004). The background,

J. Alden Weir's studio: Weir Farm NHS

methods, and rationale for each metric rating are provided in reporting SOPs for each protocol. A park map showing the distribution of the sample plots, color coded by condition category, helps provide a spatial overview of the status and trend (the map would look similar to Figure 7.2). Finally, summary text and results explaining the methods and condition assessments for each metric or vital sign is included to create a Vital Signs Scorecard Report for each park.

Continuing with the Forest Vegetation vital sign example, we can generate a report about the condition of specific metrics. Tree regeneration, a metric that assesses the degree to which tree seedlings are successfully establishing in the regeneration layer, is indicative of the ability of the forest to replace itself over time and provides an early warning of over-browsing by white-tailed deer. The ratings for tree regeneration are based on a seedling index and range from ≥ 100 points for a "good" rating to < 25 points for a poor rating (Table 7.4). We can report on the condition of tree regeneration by scoring the values for each forest monitoring plot and assigning each plot a condition rating (Figure 7.2). Based on information from 14 sampled plots at Acadia in 2005, we found that 78% of the plots had a "good" tree regeneration rating (≥ 100 points), 7% had a "caution" rating (25-99 points) and 14% had a "significant concern" rating (<25 points, Figure 7.2). As the forest monitoring program

Table 7.4. Metrics and condition threshold values for the NETN forest vegetation vital sign.

Metric	Condition Rating		
	Good (5 points)	**Caution (3 points)**	**Poor (1 point)**
Tree regeneration	≥100 points	25-99 points	<25 points
Tree mortality rate	<2%	2-4%	>4%
Tree condition	<5% of trees have canopy foliage problems >25% AND stem/crown points <3 AND no trees have Asian long-horned beetle.	5 -25% trees have canopy foliage problems >25% OR stem/crown points 3-5, AND no trees have Asian long-horned beetle.	>25% trees have canopy foliage problems >25% OR stem/crown points >5, OR any tree has Asian long-horned beetle.
Snag (basal area + density)	Either basal area 0.5-12.0 m^2/ha OR density 10-200 stems / ha	No "Caution" level for this metric.	Either basal area <0.5 or greater than 12.0 m^2/ha OR density < 10 or greater than 200 stems / ha.
Coarse woody debris (volume or biomass)	Spruce-Fir: >100 Northern Hardwood: >80 Pine-Oak: >25	Spruce-Fir: 50-100 Northern Hardwood: 50-80 Pine-Oak: 10-25	Spruce-Fir: <50 Northern Hardwood: <50 Pine-Oak: <10
Understory native plant species richness	Spruce-Fir: >14 All others: >20	Spruce-Fir: 5-14 All others: 10-20	Spruce-fir <5 All others <10
Understory native plant cover	>98%	80-98%	<80
Understory indicator plants - deer browse	Preferred and browsed species present in expected abundance based on Deer Browse Index [TBD]. Hay-scented fern and New York fern <25%	Preferred and browsed species lower than expected abundance based on Deer Browse Index. [TBD]. Hay-scented fern and New York fern common in the herb layer 25-50%	Preferred and browsed species much lower than expected abundance based on Deer Browse Index. [TBD]. Hay-scented fern and New York fern dominate the herb layer >50%
Disturbance class	No evidence of negative disturbances	Evidence of 1 negative disturbance	Evidence of 2 or more negative disturbances

1= Spruce-Fir, 2=Northern and Hemlock Hardwoods, 3 =Pine-Oak Systems

matures and samples all the plots within a park, a more comprehensive picture of tree regeneration can be presented using this plot-based approach (Figure 7.3).

In practice, specific metrics of interest can be reported independently or integrated into an overall condition score for the forest vegetation vital sign. By first assigning points for each metric in the Forest Vegetation vital sign (Table 7.4) and then summing these points for each plot, we can assign an overall condition score to each plot. Summaries of the metrics can then be presented by showing the proportion of plots in each condition category for each metric. This basic yet informative reporting tool can indicate which of the metrics and plots are performing very well throughout the park and which metrics and plots are consistently failing, and will help direct management actions towards specific problems in specific locations within the park.

Metrics can also be aggregated into indices to report to higher levels of the Ecological Monitoring Framework (Table 3.2). For example, we use three indices (landscapes, biological integrity, and geology and soils) to assess overall forest integrity (EPA 2003). These indices provide an overview of the condition of the vegetation, soils, and landscape context and will assist in reporting at the Level 1 tier of the framework (Table 7.5).

Figure 7.2. Preliminary assessment of the tree regeneration index at Acadia NP showing color coded plots in the three condition categories. The data is from protocol development data collected in 2005. Small dots represent forest monitoring plots that will be measured over time.

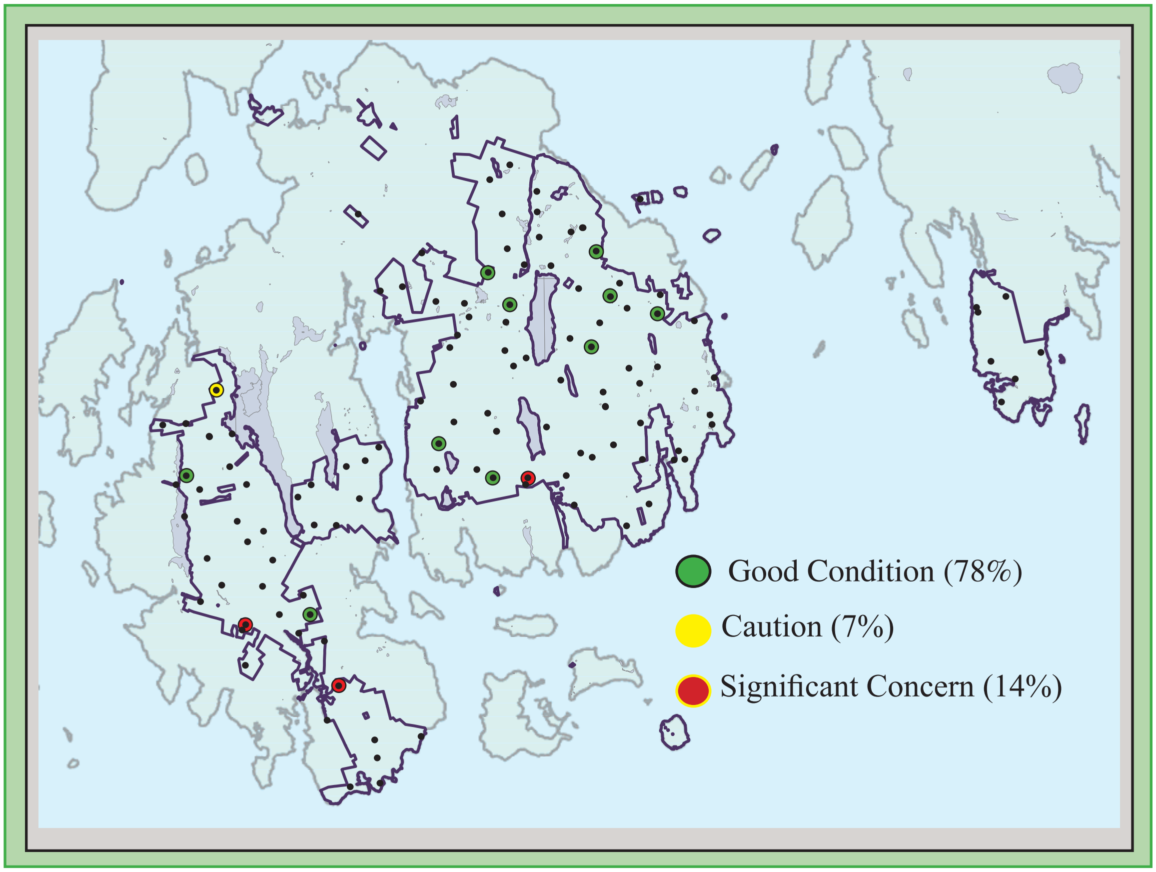


Figure 7.3. Example of spatial coverage at Acadia NP after the first implementation of the forest monitoring protocol (this figure is for example only and is not based on actual data).

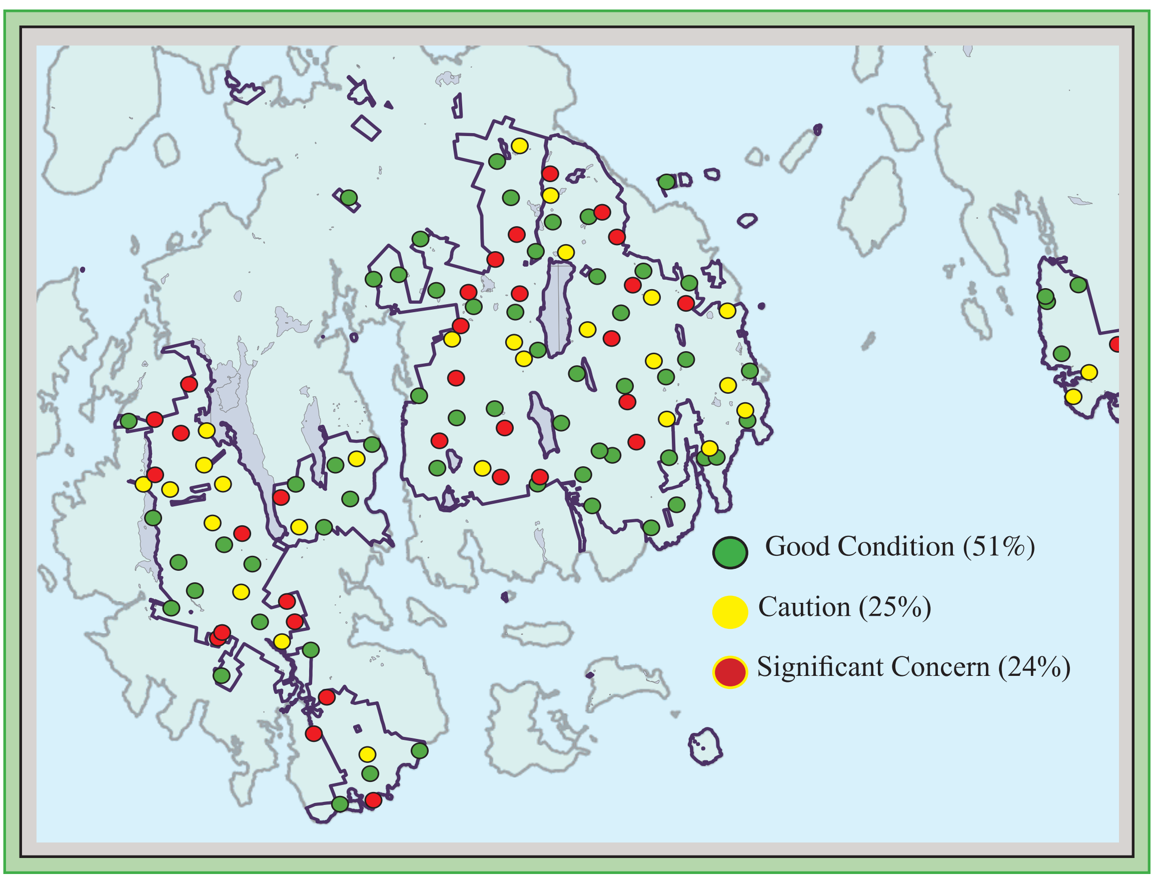


Table 7.5. Metrics and vital signs from the forest condition protocol that are combined into Level 1 indices within the Ecological Monitoring Framework.

LEVEL 1 Index	VITAL SIGN	METRIC
LANDSCAPES	Land Cover / Ecosystem Cover	Structural stage distribution
		Effective patch size
	Land Use	Land use
		Distance to road or major trail
		Buffer width
		Fragmentation
BIOLOGICAL INTEGRITY	Forest Vegetation	Tree regeneration
		Tree growth rate
		Tree mortality rate
		Tree condition
		Stand Structural Class Index
		Stand live basal area
		Stand light penetration
		Stand disturbance class
		Coarse woody debris volume/biomass
		Snag basal area
		Stand understory richness
		Presence of understory indicator plants - forest interior herbs
	Amphibians and Reptiles	Red-backed salamander relative abundance
	Exotic Animals – Early Detection	Presence of specific tree animal pest/pathogen problems
		Forest floor condition class - earthworms
	Exotic Plants – Early Detection	Stand native:total species proportion
		Presence of understory indicator plants - invasive exotics
	White-tailed Deer Herbivory	Presence of understory indicator plants - deer browse indicators
GEOLOGY and SOILS	Visitor Usage	Forest floor depth condition - Trampling impacts/soil compaction
	Soil Chemistry (Acid Deposition & Stress)	Soil C:N ratio
		Soil Ca:Al ratio

The indices will develop over time. Initially, the combination of metrics that are part of the forest vegetation index could be aggregated into an index based on expert scientific judgment, in conjunction with a simple point-scoring method (e.g., NatureServe 2002, Parrish et al. 2003). Over time, as the relation among the metrics is better understood and we acquire more data, a more quantitative set of metrics and more formal indices could be developed. The forest vegetation index could evolve into an algorithm with complex and varying metric weights (akin to indices such as the aquatic Index of Biological Integrity, Mack et al. 2004). At the same time, simpler metrics and indices may remain desirable, when there is the need to keep field data collection streamlined, and when less quantitative monitoring data are judged sufficient to address monitoring objectives.

Springwood: Home of Franklin D. Roosevelt NHS

The challenge with a scorecard approach that relies on both individual metrics and indices to report resource condition is to avoid obscuring the knowledge gained from individual metrics. The NETN Vital Signs Scorecard does not supersede or replace more traditional trend analyses. Rather, the scorecard is a spatially explicit communication tool that provides a timely condition assessment, the ability to set management objectives based on the proportion of plots in different condition categories, and a means to track the changes in condition over time. We will also integrate the condition thresholds into the monitoring protocol databases to provide rapid calculation of the condition categories for each plot and to document the thresholds used for each reporting period over time. In the event that thresholds are changed, revised reports can be generated quickly and older data can be re-assessed given the new set of thresholds. We think this level of reporting is a necessary component of a successful monitoring program that will be refined and adapted over time as more information is gathered within each network park.

The NETN Vital Signs Scorecard also provides a means for reporting to GPRA Land Heath Goals, provided that parks and the network staff work collaboratively to establish goals. Using the present Forest Vegetation example, the plot based condition assessment could be used to report to the "Upland" land heath goal. First, an index of biological integrity (Table 7.5) could be generated by combining all relevant metrics to produce a broad condition assessment for each monitored plot. For example, if Acadia reports to 13,215 ha of upland habitat, 25% of the forest plots are in the "Significant Concern" category, and all of Acadia's uplands are equally likely to have a forest plot, then an estimated 3,304 ha of upland habitat would be in the "Significant Concern" category. The effectiveness of management activities aimed at improving land health could then be tracked over time by examining changes in the number of plots in the "Significant Concern" category. Also, more detailed goals could be set at the level of an individual vital sign or metric, making the management objectives more specific. Finally, the plot based map (Figure 7.3) could be re-coded to show which areas are meeting a specific GPRA goal and which ones are failing.

Chapter 8
Administration and Implementation

Introduction

This chapter describes the composition and responsibilities of the Northeast Temperate Network's Board of Directors and Technical Steering committee. It also describes the anticipated network staffing levels and operational responsibilities during full implementation of the vital signs monitoring program, as well as how network operations will be integrated into park management activities, particularly resource management and interpretation. Finally, this chapter describes the periodic review process that will be implemented by the NETN.

Administration

The Northeast Temperate Network coordinates the I&M program for 10 National Park Service units plus the Appalachian National Scenic Trail, which crosses five networks. The NETN charter, created in 2001 (http://www1.nature.nps.gov/im/units/netn/reports/reports.cfm), follows national I&M program guidance and describes the process used to plan, manage, and evaluate the inventory and monitoring program within the network. Significant management and budgeting decisions are approved by the Board of Directors, comprised of the Superintendents of the network parks, the regional scientist, and the regional and network coordinators (Table 8.1).

Responsibilities of the Board of Directors

The NETN Inventory and Monitoring Board of Directors provides guidance, oversight and advocacy towards development and implementation of the I&M Program for the 11 park units within the network. The major responsibilities of the Board of Directors are to:

- Provide general guidance and input on strategies for network inventory and monitoring

Sieur de Monts: Acadia NP

- Require accountability and effectiveness for the I&M Program by reviewing progress, quality control efforts, and spending of Network funds
- Provide guidance to the Network Coordinator, Network Data Manager, Technical Steering Committee (see below) and natural resource staff of the network's parks in the purpose, design, and implementation of vital signs monitoring and other management activities related to the Natural Resource Challenge
- Decide on strategies and procedures for leveraging NETN funds and personnel to best accomplish inventory and monitoring needs of network parks
- Consult on hiring NETN personnel using funding provided to the network, including base funds and other sources
- Seek additional financial support to leverage the Servicewide funds
- Solicit professional guidance from and partnerships with other governmental agencies,

Table 8.1. Membership of NETN Board of Directors and Technical Steering Committee.

	Member	Position / Affiliation
Board of Directors	Rolf Diamant	Superintendent, Marsh-Billings-Rockefeller NHP
	Sheridan Steele	Superintendent, Acadia NP
	Pamela Underhill	Superintendent, Appalachian NST
	Bruce Jacobson	Superintendent, Boston Harbor Islands NRA
	Nancy Nelson	Superintendent, Minute Man NHP
	Randy Turner	Superintendent, Morristown NHP
	Sarah Olson	Superintendent, Roosevelt-Vanderbilt NHS
	BJ Dunn	Superintendent, Saint-Gaudens NHS
	Frank Dean	Superintendent, Saratoga NHP
	Patricia Trap	Superintendent, Saugus Iron Works NHS
	Linda Cook	Superintendent, Weir Farm NHS
	Mary Foley	Regional Scientist, Northeast Region
	Elizabeth Johnson	Regional I&M Coordinator, Northeast Region
	Brian Mitchell	Northeast Temperate Network Coordinator, Northeast Region
Technical Steering Committee	David Manski	Chief Natural Resource Manager, Acadia NP
	David Hayes	Natural Resource Specialist, Roosevelt-Vanderbilt NHS
	Wayne Millington	IPM Coordinator, Northeast Region
	Charles Roman	North Atlantic Coast CESU Coordinator, National Park Service
	Alan Ellsworth	Water Resources Division, National Park Service
	Mary Foley	Regional Scientist, Northeast Region
	Elizabeth Johnson	Regional I&M Coordinator, Northeast Region
	Brian Mitchell	Northeast Temperate Network Coordinator, Northeast Region
	Fred Dieffenbach	Northeast Temperate Network Data Manager, Northeast Region
	Christopher Eagar	Forest Ecosystem Ecologist, USFS
	Sam Droege	Monitoring Program Developer, USGS - Patuxent Wildlife Research Center
	Brian Underwood	Wildlife Biologist, USGS – SUNY Syracuse
	Greg Shriver	Assistant Professor, University of Delaware

organizations, and individuals

- Serve as advocates for the Natural Resource Challenge and promote understanding of the importance of the Inventory and Monitoring program among park staff, visitors, and decision makers

All decisions of the NETN Board are made by consensus. Consensus is an outcome that all Board members can live with even if it is not ideal from any one perspective. All decisions will be documented with deadlines, and responsible individuals will be identified. The Board of Directors will designate one Superintendent to sign documents for the Board once consensus is reached.

The network charter also creates a Technical Steering Committee to provide subject matter expertise during the development and implementation of the monitoring program. The Technical Steering Committee includes representatives of park resource management staff, regional scientists, and I&M staff (Table 8.1).

Responsibilities of the Technical Steering Committee

The Northeast Temperate Network Technical Steering Committee will provide subject matter expertise and technical assistance to the NETN in the development of a long-term monitoring program. Committee composition will be recommended by the network resource management staff and the network and regional I&M coordinators, and approved by the Board of Directors. At least two natural resource mangers will be members of the Technical Steering Committee. These will be 3-year term positions and rotated through the natural resource staff of network parks such that all parks are represented in the technical steering committee over time. The NETN Technical Steering Committee is responsible for:

- Guidance in the compilation and organization of existing park resource information
- Participating in scoping workshops held to develop a network monitoring strategy
- Participating in the prioritization of monitoring objectives and the development of a network monitoring plan
- Assisting in the selection of vital signs and development of monitoring protocols
- Coordinating peer review of monitoring protocols
- Evaluating initial sampling designs, methods and protocols
- Reviewing the Annual Administrative Report and Work Plan
- Developing materials for and facilitating the Five Year Program Review
- Providing guidance and insight into integrating I&M program results with education and interpretation programs

Staffing Plan

In order to meet the NETN's need for broad subject matter expertise in these areas, to institutionalize professional data management practices, to meet the need for qualified field personnel, and to properly administer the I&M program, the Network has created a staffing plan made up of a Coordinator / Ecologist, a Data Manager / Biologist, a Science Communication Specialist, an Acadia Coordinator, a Hydrological Technician, five seasonal Biological Technicians, plus a cost-share of six pay periods for three natural resources staff members at Acadia (Table 8.2).

The majority of the network staff will be stationed at Marsh-Billings-Rockefeller except for the Acadia Coordinator and the forest condition monitoring crew, who will all be based at Acadia, and the Appalachian Trail Biologist, who will be based at the Appalachian Trail Park Office. This will facilitate integration of NETN staff into Acadia's natural resource management program and the Schoodic Education and Research Center (SERC) at Acadia, as well as Appalachian Trail park operations. The initial implementation of NETN's core monitoring program will be through cooperative agreements. This will allow us to work with university collaborators to fine-tune the protocols in the initial years of monitoring. Over the long term,

View from the Appalachian NST

Table 8.2. Proposed staff for NETN during the first year of implementation (FY2007). Costs are based on the 2006 salary table, with a 3% COLA, a 40% benefit rate for permanent employees, and a 15% benefit rate for seasonals.

POSITION	PRIMARY DUTIES	GRADE / LOCATION	TOTAL COST FY2007 ($)
Coordinator / Ecologist	Provides direction and manages overall planning and implementation of NETN. Coordinates and conducts data analyses and reporting. Ensures information is provided to parks and partners in useful formats. Initiates and coordinates I&M partnerships. Provides overall program oversight and supervision.	GS 12 MABI (perm)	90,000
Data Manager / Biologist	Conducts data archiving and dissemination, database development, overall QA/QC. Works with ecologists to ensure information is provided to parks and partners in useful formats. Implements and oversees data management agreements. Provides oversight and supervision for data management activities.	GS11 MABI (perm)	86,000
Appalachian Trail Biologist	Oversees I&M related activities for the Appalachian Trail including searching for, archiving, analyzing, and reporting existing data sets relevant to the trail, and working with trail staff to implement volunteer-based monitoring activities.	GS11 APPA (perm)	78,000
Science Communication Specialist	Integrates I&M program into park interpretation divisions, generates publication-quality reports and distributes these to parks, develops and presents I&M "road shows" to provide annual updates to parks regarding the I&M program.	GS09 MABI (perm, STF)	62,000
Acadia Coordinator	Oversees all I&M related activities at Acadia including integration of I&M monitoring with ongoing park monitoring. Supervises field crews, organizes data collection and entry, drafts Acadia-specific monitoring reports.	GS09 ACAD (term, STF)	52,000
Hydrological Technician	Oversees implementation of the lakes and streams monitoring protocol at all parks except Acadia. Conducts water quality sampling, maintains field equipment, collects and enters all monitoring data into appropriate databases.	GS07 MABI (term, STF)	21,000
Biological Technicians	Work with program ecologists to collect field data, and document methods, procedures and anomalies. Conduct data entry and verification. A GS07 will be based at ACAD and a GS07 and GS05 will be based at MABI for forest monitoring, and wetland monitoring may require a GS07 and GS05 (the wetland protocol is currently in development).	2 GS07 3 GS05 ACAD and MABI (seas)	65,000

Table 8.2. Proposed staff for NETN during the first year of implementation (FY2007). Costs are based on the 2006 salary table, with a 3% COLA, a 40% benefit rate for permanent employees, and a 15% benefit rate for seasonals.

POSITION	PRIMARY DUTIES	GRADE / LOCATION	TOTAL COST FY2007 ($)
ACAD Biologist *Cost Share 6 pay periods*	NETN will pay for Acadia staff time spent implementing the lakes and streams monitoring protocol at Acadia, above and beyond Acadia's pre-existing water program. This includes supervising technicians, collecting data, and conducting field and office QA/QC.	GS11 ACAD (perm, STF)	34,000
ACAD Biological Technician *Cost Share 6 pay periods*	NETN will pay for Acadia staff time spent implementing the lakes and streams monitoring protocol at Acadia, above and beyond Acadia's pre-existing water program. This includes data collection and data entry.	GS07 ACAD (perm, STF)	14,000
ACAD Biological Technician *Cost Share 6 pay periods*	NETN will pay for Acadia staff time spent implementing the lakes and streams monitoring protocol at Acadia, above and beyond Acadia's pre-existing water program. This includes data collection and data entry.	GS05 ACAD (seas)	8,000
	TOTAL Personnel		510,000
	Percent of NETN Budget ($842,000)		61%

we anticipate using NPS seasonal technicians to implement our core monitoring protocols.

Core Staff

The core NETN staff consists of a Coordinator/ Ecologist, a Data Manager/Biologist, an Appalachian Trail Biologist, a Science Communication Specialist, and an Acadia Coordinator (Table 8.2). These staff members form the backbone of the NETN program by ensuring the scientific integrity of the monitoring protocols, facilitating data collection and management, conducting QA/QC and data analyses, organizing the reporting of the data into formats that will be useful to network parks, and ensuring that information is provided to parks and the public in a timely manner.

Lakes and Streams Monitoring Staff

Acadia has been conducting lake water quality monitoring for more than 20 years and the NETN will integrate the lakes and streams vital signs with the ongoing Acadia lakes monitoring program. We have reviewed and revised the Acadia lakes monitoring protocol to meet both park and NETN objectives. The majority of the existing Acadia protocol was adopted and integrated into the NETN, with changes made on the frequency of sampling and the addition of lakes on a temporal rotating panel. The stream monitoring program is a new addition to Acadia's program, and represents a substantial monitoring effort. Rather than add a new layer of administration and staff, NETN will partner with Acadia by covering a portion of the salaries for the lake and stream monitoring coordinator and two water quality monitoring technicians (Table

Mansion: Marsh-Billings-Rockefeller NHS

8.2). This will allow for the continuation of the ongoing program, the addition of stream water quality monitoring, and maintenance of staff consistency.

Lakes and streams monitoring at other network parks will be accomplished by a hydrological technician who will be based at Marsh-Billings-Rockefeller and who will rove to other network parks every month during the six-month lakes and streams monitoring field season (Table 8.2). This technician will be responsible for collecting data and performing the initial QA/QC and data review.

Forest Condition Monitoring Staff

When fully implemented, the Northeast Temperate Network's forest condition monitoring program will require a 3-person monitoring crew, based at Acadia (Table 8.2). Once the crew finishes Acadia's plots each season, they will rove to three or four of the other network parks. The crew will be composed of a GS7 and two GS5 seasonal field technicians. This crew will be supervised by the Acadia Coordinator, but will often work independently to collect data at forest condition monitoring plots.

Wetlands Monitoring Staff

The NETN wetlands monitoring protocol is currently being developed. We anticipate that the draft protocol will be completed at the end of FY2006, that protocol evaluation will occur in FY2007, and that full implementation will begin in FY2008. We do not yet know the details of the staffing requirements, but we have tentatively budgeted for a GS7 and a GS5 field technician stationed at Marsh-Billings-Rockefeller (Table 8.2), plus their travel and lodging expenses.

Staff for Other Monitoring Efforts

The NETN currently does not plan to provide staff for breeding bird monitoring or rocky intertidal monitoring. The breeding bird protocol for most parks will be implemented with volunteer observers and administered by a cooperator, the Vermont Institute of Natural Science. Coastal breeding bird monitoring at Boston Harbor Islands will likely be implemented with the cooperation of Massachusetts Audubon. We will begin developing the rocky intertidal monitoring protocol (for Acadia and Boston Harbor Islands) in FY2007, and the goal for this protocol is to implement monitoring with university participation and administration by NETN core staff and the Acadia Coordinator. Acadia's Schoodic Education and Research Center (SERC) may participate in this program as well.

Program Integration

NETN is located at Marsh-Billings-Rockefeller and close to Saratoga and Saint-Gaudens, which greatly facilitates integration of the network staff with park staff. As the monitoring program begins to implement protocols, we will seek more integration with park staff on a regular basis. By taking the lead to coordinate the I&M activities associated with the Appalachian Trail, NETN has created a forum where three NPS regions and five I&M networks work together to share ideas and integrate components of similar protocols. For example, the Northeast Temperate Network, Eastern Rivers and Mountains Network, Mid-Atlantic Network, National Capital Region Network, and Appalachian Highlands Network are working together to develop a shared forest vegetation monitoring program. NETN is also working with the Northeast Coastal and Barrier Network, and may adopt coastal monitoring protocols for estuarine nutrients, shoreline position, and salt marsh vegetation for its two coastal parks.

I&M data will be made available to all park operations, including natural and cultural resources, interpretation, law enforcement, and maintenance. Integration will be achieved through multiple avenues, but primarily though the network's Science Communication Specialist. This position is an integral component in building a successful monitoring program because it provides a necessary bridge for information exchange. The Science Communication Specialist's chief responsibility is making inventory and monitoring data accessible and understandable. He or she will assist with typical types of monitoring program reporting, and will also be responsible for disseminating information to all park operations. This will be accomplished with park specific presentations to staff and volunteers, the development of programs that help integrate vital signs information into park interpretation programs, and the creation of educational programs that meet state and federal standards and that can be used by local schools. The NETN Science Communication Specialist will work with the SERC to integrate and disseminate vital signs information to a wide audience. The network Coordinator, Data Manager, Appalachian Trail Biologist, and Acadia Coordinator will also work with parks to provide more specialized and detailed information to support specific park needs.

NETN will help catalyze work on natural resource issues that are important to parks by providing baseline information and leveraging NPS funds. The network will help parks with common natural resource issues, will prepare multi-park proposals, and will seek external funds that can supplement I&M funds and address specific management needs. For example, in FY2005 NETN partnered with Marsh-Billings-Rockefeller and was awarded a Civic Engagement grant to develop a model program integrating vital signs monitoring into local school science programs. This program will help integrate park operations into the local community, and will serve as a pilot project for an approach that could be implemented in other network park communities.

Partnerships

Since the inception of NETN, we have assembled a core team of scientists who have played a key role in the development of the monitoring plan and selected protocols. From initial scoping and conceptual modeling to vital signs selection and protocol development, the core science team has remained intact, greatly increasing the efficiency, integration, and focus of the NETN. We plan to maintain these core partnerships during the peer review of protocols and monitoring plans, and potentially during protocol implementation as well.

Primary NETN partners include the State University of New York College of Environmental Science and Forestry (SUNY-ESF), NatureServe, the USGS, and the Vermont Institute of Natural Science (VINS). SUNY-ESF has developed our forest protocol and helped with the NETN monitoring plan, and NatureServe has assisted with vegetation mapping as well as monitoring plan and protocol development. The USGS has provided assistance with our monitoring plan and developed our aquatic and wetland protocols, while VINS has developed our breeding bird protocol and will administer the implementation of this protocol. We are partnering with the University of Rhode Island to develop and implement a coastal breeding bird protocol, and with the University of Vermont for the initial implementation of half of the lakes and streams protocol.

Hartwell House: Minute Man NHP

Mt Ascutney from the Pergola of the Little Studio: Saint-Gaudens NHS

Operations

The core NETN staff will be fully trained in all protocols that will be implemented or administered in-house. This will include forest condition and lakes and streams protocols during the initial implementation stage, and will expand to include the wetland and rocky intertidal protocols when they are implemented. This gives the core staff the flexibility to fill in for monitoring staff in the event of a problem, provides them with the expertise to conduct field QA/QC, and will give them useful background information that will inform their other duties.

Monitoring crews will also be fully trained or provided with yearly refresher training before independently conducting monitoring efforts. All essential field equipment will be provided by the NETN, and the network will ensure that the equipment is properly calibrated and serviceable prior to each field season. The initial implementation in FY2007 will require two vehicles (one for forest monitoring and one for aquatic monitoring), and these vehicles will be purchased or rented by the network. Park radios will be loaned by the individual parks when available, and roving teams will have cell phones for emergencies. The NETN firmly believes that staff safety is the first priority, and will instruct all staff members in appropriate safety considerations. The network Safety Plan is currently in development, and will be provided to all staff members during training.

The NETN forest breeding bird protocol will be integrated into the existing VINS Forest Bird Monitoring Program (FBMP) and implemented annually. This is a volunteer program, and individual parks and the NETN will assist VINS with volunteer recruitment, as needed. VINS will provide all the necessary volunteer training, data collection materials, QA/QC, analyses, and park specific reporting. This program will be a valuable opportunity for I&M integration with park interpretation and volunteer programs, and will increase public awareness of the parks' natural resources. We anticipate the coastal breeding bird protocol for Boston Harbor Islands NRA to operationally parallel the forest breeding bird protocol. In other words, this will also be a volunteer based and cooperative program.

Revisions

Periodic reviews of the Network's monitoring program and protocols are critical to ensuring that the program is on the right course, and if course corrections are needed, that they are accomplished quickly to save unnecessary expenditures of resources and time. The program will be reviewed formally, at least once every five years, by the NPS Washington Service Office (WASO). From this periodic review a formal report will be generated, making specific suggestions for changes and revisions in the monitoring program. Also, network staff will be analyzing and presenting data on a regular basis (at least biennially) to subject NETN's methodologies to ongoing peer review.

Chapter 9
Schedule

Protocols Implemented in FY2007

The Northeast Temperate Network is currently evaluating three protocols (forest condition, forest breeding birds, and lakes and streams) that encompass all or part of 12 vital signs (Table 9.1, Chapter 5). Forest condition monitoring will occur every late spring and summer at Acadia, but specific permanent plots will only be visited four times in every 12 years according to the rotating connected panel design (Chapter 4). Other parks in the NETN will be sampled during the late spring and summer in alternate years; each park will have half of its sites visited every other year. For example, in FY2007 sampling will occur at Morristown, Roosevelt-Vanderbilt, and Weir Farm, while in FY2008 sampling will occur at Marsh-Billings-Rockefeller, Minute Man, Saint-Gaudens, and Saratoga. In FY2009, sampling will recur at Morristown, Roosevelt-Vanderbilt, and Weir Farm, but at different permanent plots. Each plot at parks other than Acadia will be visited three times in every 12 years according to the rotating panel design (Chapter 4).

The other protocols that will be implemented in FY2007 will use an annual data collection and reporting schedule. Forest breeding bird data will be collected every spring at all participating network parks, and lakes and streams sampling will occur monthly from May through October of every year.

Protocols Drafted in FY2006 and FY2007

The Northeast Temperate Network is currently working with cooperators to develop three additional protocols (Table 9.1). These protocols will address all or part of six vital signs, and they are expected to be in the development or evaluation stage during FY2007. We anticipate implementing these protocols during FY2008 or FY2009.

Female Eider nest: Boston Harbor Islands NPA

For coastal breeding birds, we expect to survey Boston Harbor Islands each year in the late spring or early summer. The sampling schedule for the wetlands and rocky intertidal protocols has not yet been determined; at a minimum sampling will be conducted every four years, and these protocols may require rotating panel designs to reduce impact to park resources.

Other Protocols

Three protocols that NETN will use were developed (or are being developed) by other programs (Table 9.1). Ozone and deposition data is currently being collected continuously near or in all NETN parks. The

Table 9.1. NETN protocol development schedule. The schedule includes protocols the network is currently testing that will be ready for full implementation in FY07 (white fill), protocols that will be drafted by the network in FY06 and FY07 (blue shading) and implemented by FY09, protocols being implemented by another program or agency (yellow fill), and protocols being considered for development as funding and resources permit (green shading).

Protocol	Vital Signs Addressed	Timeline			Principal Developers
		Draft	Final	Implemented	
Forest Breeding Birds	Breeding birds	Nov. 2005	Dec. 2006	Apr. 2007	Vermont Institute of Natural Science
Forest Condition	Forest vegetation, forest soil condition, invasive/exotic plants – early detection, invasive/exotic animals – early detection, ozone, land cover / ecosystem cover, white-tailed deer herbivory, atmospheric deposition and stress, visitor usage	Nov. 2005	Sep. 2006	Apr. 2007	State University of New York and NatureServe
Lakes and Streams	Water quantity, water chemistry, nutrient enrichment, invasive/exotic plants – early detection	Nov. 2005	Sep. 2006	Apr. 2007	USGS – Maine
Coastal Breeding Birds	Breeding birds	Apr. 2007	Mar. 2008	Apr. 2008	Massachusetts Audubon
Rocky Intertidal	Rocky intertidal vegetation, invasive/ exotic plants – early detection, invasive/ exotic animals – early detection, visitor usage	Sep. 2007	Sep. 2008	Mar. 2009	University of Maine
Wetlands	Wetland vegetation, invasive/exotic plants – early detection	Sep. 2006	Sep. 2007	Apr. 2008	USGS – Patuxent
Ozone	Ozone	Protocol available and implemented			NPS – ARD
Weather Monitoring	Climate	In development			NPS – I&M
Wet and Dry Deposition	Acidic deposition	Protocol available and implemented			NPS – ARD
Amphibians	Amphibians and reptiles	Forest amphibian protocol is being evaluated in FY2007, and will be implemented in interested NETN parks in FY2008; reptile and other amphibian protocols are not yet scheduled for development			NETN
Landscape Dynamics	Land cover / ecosystem cover, land use	To be determined			To be determined

Table 9.1. NETN protocol development schedule. The schedule includes protocols the network is currently testing that will be ready for full implementation in FY07 (white fill), protocols that will be drafted by the network in FY06 and FY07 (blue shading) and implemented by FY09, protocols being implemented by another program or agency (yellow fill), and protocols being considered for development as funding and resources permit (green shading) (continued).

Protocol	Vital Signs Addressed	Timeline			Principal Developers
		Draft	Final	Implemented	
Phenology	Phenology	For the Appalachian Trail, a draft protocol will be available by Sep. 2007, and evaluated in FY2008; other NETN parks will adopt this protocol as appropriate			State University of New York
Visitor and Recreation Use	Visitor usage	To be determined			To be determined

Frenchman Bay, Acadia NP

NETN will acquire this information from the NPS Air Resources Division each winter, and generate reports for network parks. The national weather monitoring protocol is still in development, but it will be based on continuous weather data collected at or in all NETN parks. As with the ozone and deposition data, climate information will be summarized and reported on a yearly basis.

The remaining protocols are in early stages of development. NETN will be evaluating a forest amphibian protocol at Marsh-Billings-Rockefeller in FY2007. This protocol will involve sampling coverboard grids twice in the spring and twice in the fall, with results reported annually. We are currently completing a historical land cover change analysis, based on 20 years of Landsat data. This analysis may form the core of a landscape dynamics protocol that would involve sampling and reporting every 10 years. The State University of New York is cooperating with NETN to develop a phenology protocol for the Appalachian Trail; this protocol may be adopted by other NETN parks. Sampling for phenology will likely occur every year, but reporting may occur at a greater interval (perhaps every five years). The sampling and reporting schedule for our visitor and recreation use protocol has not yet been determined.

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Chapter 11
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Glossary

AARWP: Annual Administrative Report and Work Plan

ACAD: Acadia National Park

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

ANC: Acid neutralizing capacity

ANCS+: Automated National Catalog System. A microcomputer-based database management system developed by NPS to accession and catalog its museum collections located in over 300 parks.

APPA: Appalachian National Scenic Trail

ARD: Air Resources Division (NPS)

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

ARMI: Amphibian Research and Monitoring Initiative

Attribute**:** Any living or nonliving feature or process of the environment that can be measured or estimated and that provide insights into the state of the ecosystem. The term “indicator” is reserved for a subset of attributes that are particularly information-rich in the sense that their values are somehow indicative of the quality, health, or integrity of the larger ecological system to which they belong (Noon 2002). See Indicator.

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

BOHA: Boston Harbor Islands National Park Area

CASTNet: Clean Air Status and Trends Network

COLA: Cost of Living Adjustment

Co-location: Sampling of the same physical units for multiple monitoring vital signs

Conceptual models: Purposeful representations of reality that provide a picture of how something works in order to communicate the representations to others.

DO: Dissolved oxygen

DOI: Department of the Interior

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

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

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

Ecosystem drivers: Major external driving forces such as climate, fire cycles, biological invasions, hydrologic cycles, and natural disturbance events (e.g., earthquakes, droughts, floods) that have large scale influences on natural systems.

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

ELRO: Eleanor Roosevelt Home

EPA: Environmental Protection Agency

FBMP: Forest Bird Monitoring Program, a program initiated by VINS.

FIA: Forest Inventory and Analysis, a USFS monitoring program.

FHM: Forest Health Monitoring, a USFS monitoring program.

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

FOIA: Freedom of Information Act

GIS: Geographic Information System

GLOBE: Global Learning and Observations to Benefit the Environment

GMP: General Management Plan

GPRA: Government Performance and Results Act

GPS: Global Positioning System

GRD: Geologic Resources Division (NPS)

GRTS sampling: Generalized random tessellation stratified (GRTS) sampling is a grid-based algorithm that ensures random placement of sampling locations while maintaining the spatial balance of the overall sample.

HOFR: Home of Franklin Roosevelt

IBA: Important Bird Area: http://www.massaudubon.org/Birds_&_Beyond/IBAs/index.php

I&M: Inventory and Monitoring, referring specifically to the National Park Service Inventory and Monitoring Program or related projects.

Indicators: A subset of monitoring attributes that are particularly information-rich in the sense that their values are somehow indicative of the quality, health, or integrity of the larger ecological system to which they belong (Noon 2002). Indicators are a selected subset of the physical, chemical, and biological elements and processes of natural systems that are selected to represent the overall health or condition of the system.

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

Lakes: Bodies of water that have a surface area greater than 15 acres.

LTER: Long-term Ecological Research

MABI: Marsh-Billings-Rockefeller National Historical Park

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

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

Metrics: Analytical units derived from one or more measures (e.g., basal area, stand structural class, or species diversity).

MIMA: Minute Man National Historical Park

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

MORR: Morristown National Historical Park

MWRA: Massachusetts Water Resources Authority

NADP/NTN: National Atmospheric Deposition Program/National Trends Network

NAAMP: North American Amphibian Monitoring Program

NAAQS: National Ambient Air Quality Standards

NCBN: Northeast Coastal and Barrier Network

NER: Northeast Region (NPS)

NERO: Northeast Region Office (NPS)

NETN: Northeast Temperate Network

NHP: National Historical Park, as in Marsh-Billings-Rockefeller NHP

NHS: National Historic Site, as in Saint-Gaudens NHS

NOAA: National Oceanic and Atmospheric Administration, part of the U.S. Department of Commerce.

NP: National Park, as in Acadia NP

NPA: National Park Area, as in Boston Harbor Islands NPA

NPS: National Park Service

NRDT: Natural Resource Database Template

NR-GIS Data Store: Natural Resource GIS Data Store

NST: National Scenic Trail, as in Appalachian NST

Nekton: Free swimming organisms in an aquatic environment. For the purposes of the NCBN Salt Marsh Nekton protocol, nekton are fish and decapod crustaceans in Network park salt marshes.

OMB: Office of Management and Budget

PAH: Polynuclear aromatic hydrocarbons

PCBs: Polychlorinated Biphenyls. Mixtures of synthetic organic chemicals that are highly toxic.

PDS: Protocol Development Summary

Phenology: The study of the times of recurring natural phenomena, especially the dates of first occurrence of natural events in their annual cycle. Examples include the date of emergence of leaves and flowers, the first flight of butterflies and the first appearance of migratory birds. Because many such phenomena are very sensitive to small variations in climate, especially to temperature, phenological records can be a useful proxy for temperature in the study of climate change.

Pond: Body of water that has a surface area between 1 and 15 acres.

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

QA/QC: Quality Assurance / Quality Control

RMP: Resource Management Plan

ROVA: Roosevelt-Vanderbilt National Historic Site, consists of the home of Franklin D. Roosevelt (HOFR), Vanderbilt Mansion (VAMA), and the Eleanor Roosevelt home (ELRO).

SAGA: Saint-Gaudens National Historic Site

SAIR: Saugus Iron Works National Historic Site

SARA: Saratoga National Historical Park

SCA: Student Conservation Association

SERC: Schoodic Education and Research Center

SOP: Standard Operating Procedure

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

SUNY-ESF: State University of New York College of Enviornmental Science and Forestry

T & E: Threatened and Endangered

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

USDA: United States Department of Agriculture

USFS: United States Forest Service, a bureau of the Department of Agriculture

USGS: United States Geologic Survey, a bureau of the Department of the Interior.

VAMA: Vanderbilt Mansion

VERP: Visitor Experience and Resource Protection

VINS: Vermont Institute of Natural Science

Vital Signs: Are a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values. The elements and processes that are monitored are a subset of the total suite of natural resources that park managers are directed to preserve "unimpaired for future generations," including water, air, geological resources, plants and animals, and the various ecological, biological, and physical processes that act on those resources. Vital signs may occur at any level of organization including landscape, community, population, or genetic level, and may be compositional (referring to the variety of elements in the system), structural (referring to the organization or pattern of the system), or functional (referring to ecological processes).

WASO: Washington Office (NPS)

WEFA: Weir Farm National Historic Site

WRD: Water Resources Division (NPS)

As the nation's primary conservation agency, the Department of the Interior has responsibility for most of our nationally owned public land and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

NPS D-29 September 2006

National Park Service
U.S. Department of the Interior

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http://www.nps.gov/nero/science/