National Park Service
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Natural Resource Program Center

Mid-Atlantic Network Vital Signs Monitoring Plan

Natural Resource Report NPS/MIDN/NRR—2008/071

ON THE COVER

Spotted salamander (*Ambystoma maculatum*); cannon at Lee Drive, Fredericksburg and Spotsylvania National Military Park; waterfall at Shenandoah National Park.

Photographs by Carolyn Davis, James Comiskey, and NPS.

Mid-Atlantic Network Vital Signs Monitoring Plan

Natural Resource Report NPS/MIDN/NRR—2008/071

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Acronyms

AARWP: Annual Administrative Report and Work Plan

APCO: Appomattox Court House National Historical Park

BOWA: Booker T. Washington National Monument

CASTNET: Clean Air Status and Trends Network

CDF: Common Data Format

CESU: Cooperative Ecosystem Studies Unit

CWA: Clean Water Act

DOI: U.S. Department of the Interior

EISE: Eisenhower National Historic Site

EMAP: Environmental Monitoring and Assessment Program

EPA: U.S. Environmental Protection Agency

EPMT: Exotic Plant Management Team

ERMN: Eastern Rivers and Mountains Network

FGDC: Federal Geographic Data Committee

FRSP: Fredericksburg and Spotsylvania National Military Park

FTE: Full-time equivalent

GETT: Gettysburg National Military Park

GPRA: Government Performance and Reporting Act

GPS: Global Positioning System

GRTS: Generalized Random Tessellation Stratified Design

HOFU: Hopewell Furnace National Historic Site

I&M: Inventory and Monitoring

IMPROVE: Interagency Monitoring of Protected Visual Environments

MDN: Mercury Deposition Network

MIDN: Mid-Atlantic Network

NADP: National Atmospheric Deposition Program

NAWQA: National Water Quality Assessment Program

NAAQS: National Ambient Air Quality Standards

NB: National Battlefield

NBP: National Battlefield Park

NCBN: Northeast Coastal and Barrier Network

NER: NPS Northeast Region

NETN: Northeast Temperate Network

NGO: Non-governmental organization

NHP: National Historical Park

NHS: National Historic Site

NM: National Monument

NOAA: National Oceanic and Atmospheric Administration

NP: National Park

NPS: National Park Service

NPS-ARD: National Park Service Air Resources Division

NPS-WRD: National Park Service Water Resources Division

NRPC: Natural Resource Program Center

NWS: National Weather Service

ONRW: Outstanding Natural Resource Water

PCB: Polychlorinated biphenyl

PETE: Petersburg National Battlefield

RICH: Richmond National Battlefield Park

SHEN: Shenandoah National Park

TAC: Technical Advisory Committee

TMDL: Total Maximum Daily Load

USDA–ARS: U.S. Department of Agriculture–Agricultural Research Service

USFWS: U.S. Fish and Wildlife Service

USGS: U.S. Geological Survey

USGS–WRD: U.S. Geological Survey–Water Resources Division

SWAS: Shenandoah Watershed Assessment Study

UVA: University of Virginia

VAFO: Valley Forge National Historical Park

WASO: Washington-Area Service Office

Executive Summary

The mission of the National Park Service is "to conserve unimpaired the natural and cultural resources and values of the national park system for the enjoyment of this and future generations" (NPS 2000). To uphold this goal, the director of the National Park Service approved the Natural Resource Challenge to encourage national parks to focus on the preservation of the nation's natural heritage through science, natural resource inventories, and expanded resource monitoring (NPS 1999). Data obtained from a scientifically developed monitoring program will allow park resource staff to make better management decisions based on credible scientific information.

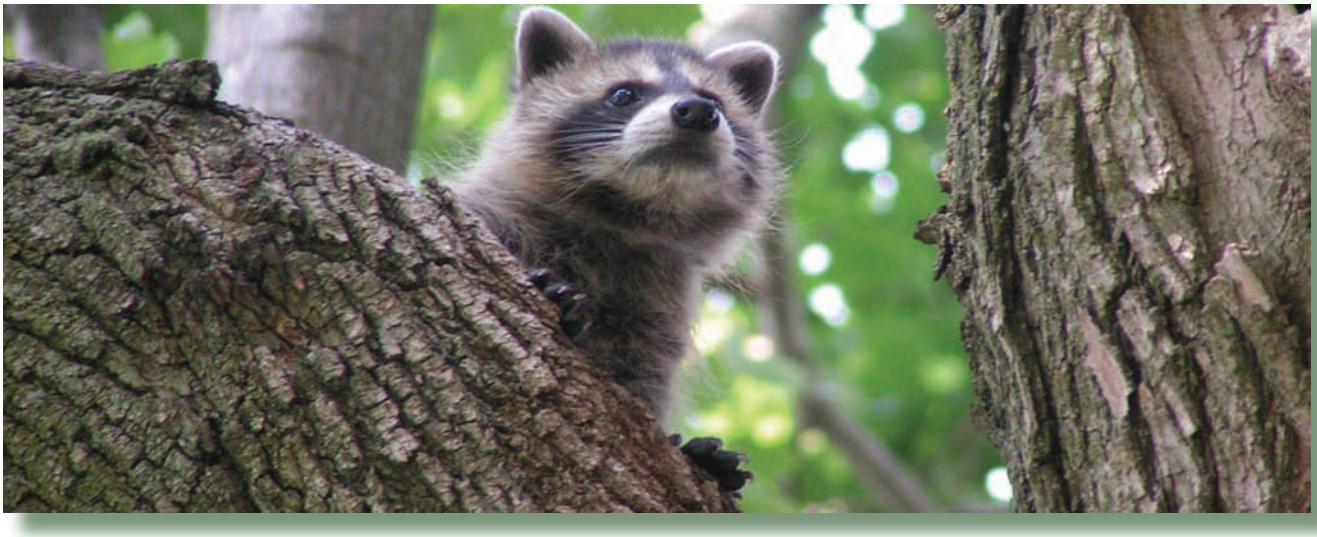
Through the Challenge, 270 parks with significant natural resources in the National Park System were placed into 32 Inventory and Monitoring (I&M) Program networks. The parks in the Mid-Atlantic Network (MIDN) include Appomattox Court House National Historical Park, Booker T. Washington National Monument, Eisenhower National Historic Site, Fredericksburg and Spotsylvania National Military Park, Gettysburg National Military Park, Hopewell Furnace National Historic Site, Petersburg National Battlefield, Richmond National Battlefield Park, and Valley Forge National Historical Park. Shenandoah National Park is also part of the network but, having been previously designated as a prototype park upon which the I&M Program network model was developed, already has an ongoing monitoring program.

The challenge of protecting and managing a park's natural resources requires a broad-based knowledge of the status and trends in park resources and takes an ecosystem approach. Most parks are open systems vulnerable to threats, such as air and water pollution and invasive species, that originate outside of the park's boundaries. Understanding the dynamic nature of park ecosystems and the consequences of human activities are essential for management decision-making that is able to maintain, enhance, or restore the ecological integrity of park ecosystems and to avoid, minimize, or mitigate ecological threats to these systems.

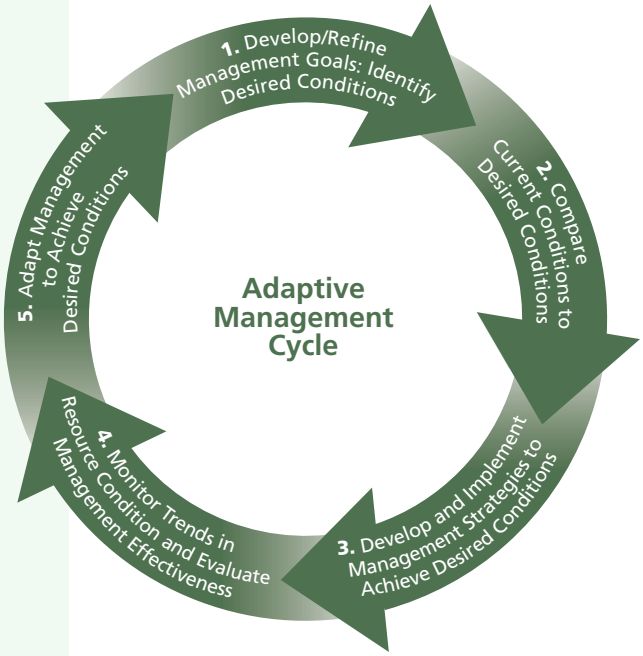
Many of the parks in the MIDN were established for cultural and historical reasons, but they protect important terrestrial and aquatic habitats. Located within a rapidly urbanizing landscape, park resources are threatened by land use change, habitat fragmentation, invasion

NPS Vital Signs Goals

- Determine the status and trends in selected indicators of the condition of park ecosystems to allow managers to make better-informed decisions and to work more effectively with other agencies and individuals for the benefit of park resources.
- Provide early warning of abnormal conditions of selected resources to help develop effective mitigation measures and reduce costs of management.
- Provide data to better understand the dynamic nature and condition of park ecosystems and to provide reference points for comparisons with other, altered environments.
- Provide data to meet certain legal and Congressional mandates related to natural resource protection and visitor enjoyment.
- Provide a means of measuring progress towards performance goals.



Park forests are home to a diverse array of plants and animals



Vital signs monitoring forms an integral part of the adaptive management cycle by providing critical information.

by exotic plants, increasing densities of deer, air and water pollution, and climate change.

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. The purpose of this Vital Signs Monitoring Plan is to establish the vital signs, explain the approach used to develop sampling designs and protocols, and outline the administrative and budgetary framework for the Mid-Atlantic Network. In addition, the report addresses the long-term management of data that is essential to the monitoring program.

The vital signs selected by the MIDN include a suite of physical, chemical, and biological elements and processes that collectively represent the overall health or condition of park resources. The 15 vital signs selected for implementation over the next five years include five related to air and climate, two related to geology and soils, three related to water, and five related to biological integrity. The MIDN has also identified five additional vital signs of importance that will be implemented if additional funding becomes available.

The fifteen vital signs the network plans to monitor are grouped into five protocols: Air Quality, Weather and Climate, Water Quality and Quantity, Aquatic Macroinvertebrates, and Forest Vegetation. Detailed monitoring proto-

Vital signs selected by the Mid-Atlantic Network.

Level 1 Category	Level 2 Category	MIDN Vital Sign
Air and Climate	Air Quality	Ozone
		Wet and dry deposition
		Visibility and particulate matter
		Air contaminants (mercury)
	Weather and Climate	Weather and Climate
Geology and Soils	Geomorphology	Stream / river channel characteristics
	Soil Quality	Soil structure and composition
Water	Hydrology	Stream and river water dynamics
	Water Quality	Water chemistry
		Aquatic macroinvertebrates
Biological Integrity	Invasive Species	Invasive exotic plants
	Infestations and Disease	Native forest pests
		Exotic Diseases / Pathogens – plants
	Focal Species or Communities	Forest plant communities
		White tailed Deer (herbivory)

Eastern bluebird (*Sialia sialis*)

cols 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 collecting data relevant to the MIDN's selected vital signs (for example, air and climate), and the network's monitoring program for these indicators will focus on acquiring existing data, interpreting it, and reporting these results.

As part of the Service's efforts to improve park management through greater reliance on scientific knowledge, a primary purpose of the monitoring program is to develop, organize, and make available natural resource data by transforming data into useful information through analysis, synthesis, modeling, and reporting. Vital signs monitoring will be an integral part of the adaptive management cycle by providing critical information about trends in natural resource conditions. The information will be available to identify desired conditions and evaluate management effectiveness, as well as for research, education, and promoting public understanding of park resources.

Administrative oversight for the program is provided by the Board of Directors (BOD), which includes the superintendents (or their representatives) of the 10 network parks. Technical input is provided by the Science Advisory Committee (SAC), with additional input as needed from an ad-hoc Technical Advisory Committee (TAC) established to address specific technical needs. The network is staffed by a coordinator/ecologist and a data manager/biologist. Seasonal staff are hired to implement the monitoring protocols. The network office is located at the Natural Resources Office at Fredericksburg and Spotsylvania National Military Park, Virginia.

Cultural landscapes are an important component of Mid-Atlantic Network parks. Gettysburg NMP (top) and Fredericksburg and Spotsylvania NMP

The MIDN will be subject to periodic reviews to ensure high program quality and accountability. In 2012 and every fifth year thereafter, a comprehensive review of program operations will be conducted. Peer review of monitoring protocols will be conducted by the NPS Northeast Region I&M Program coordinator upon completion of the protocols and prior to their implementation.

Protocols to be implemented by the Mid-Atlantic Network.

Protocol	Monitoring Objectives	Management Applications
Air Quality	Document the annual status and trends in atmospheric ozone concentrations in MIDN parks using metrics that are relevant to human health (e.g., 8-hour average) and plant response (e.g., SUM06). Document the annual status and trends in wet and dry deposition in MIDN parks. Report on the annual status and trends in mercury concentration and deposition in precipitation in MIDN parks. Report on the annual status and trends in fine particulate matter ($PM_{2.5}$) and coarse particulate matter (PM_{10}) concentrations and composition in MIDN parks as they pertain to visibility impairment and human health.	Evaluate the causes of ozone formation and its impact on natural resources. Determine the impact of acid deposition on aquatic and terrestrial ecosystems. Identify the effects of air contaminants on park biotic communities. Evaluate the impacts of air pollution on visibility, and the consequent effects on visitor experience and biotic communities.
Weather and Climate	Document long-term trends in weather and climate through seasonal and annual summaries of selected parameters (e.g., multiple forms of precipitation, temperature). Identify and document extremes and averages of climatic conditions for common parameters (e.g., precipitation, air temperature), and other parameters where sufficient data are available (e.g., wind speed and direction, solar radiation). Provide information on near real-time weather parameters, historical climate patterns, and climate station metadata from a single, easy to use Internet portal.	Understand the effects of local climate change.
Water Quality and Quantity	Document the status and trends in water quality as influenced by point source and non-point source pollution (including atmospheric deposition). Determine the natural range of variability in water chemistry (including bacterial composition). Detect water quality measures that exceed threshold values and determine their compliance with state and federal water quality standards. Document the status and long-term trends in water flow. Document changes in stream channel characteristics at sampling sites.	Identify threats to maintaining stream flow and determine where restoration efforts are needed. Identify and improve water quality of impaired waters. Maintain high water quality where it exists.
Aquatic macroinvertebrates	Document the status and trends in the structure and composition of aquatic macroinvertebrates. Determine trends in macroinvertebrate communities in relation to changes in water quality and quantity.	Identify changes in macroinvertebrate communities in relation to changing land use and pollution.
Forest Vegetation	Determine the status and trends in forest structure, composition, and dynamics of canopy and understory woody species. Determine the status and trends in the density and composition of tree seedlings and selected herbaceous species that are indicators of deer browse. Detect and monitor the presence of invasive exotic plants, exotic plant diseases and pathogens, and forest pests. Determine the status and trends in forest coarse woody debris and the availability of snags. Determine the status and trends in soil Ca:Al and C:N ratios to asses the extent of base cation depletion, increased aluminum availability, and/or nitrogen saturation impacting MIDN forest soils.	Assess changes in forest communities and determine the need for management and restoration efforts. Determine the need for deer management to reduce the impact of this species on vegetation communities. Identify the need and location for exotic plant and animal management efforts.

Acknowledgments

Development of the Mid-Atlantic Network monitoring program and plan is largely due to the contribution of numerous people. We especially would like to thank Beth Johnson, Northeast Region I&M Program coordinator, for her support, guidance, and input, and John Karish, Northeast Region chief scientist, whose continued support has been crucial to the network's success. We are indebted to Carolyn Davis, who has been instrumental in assisting the network with its communication plan, and also provided substantial input into the development of the park profiles in this report. Thank you to Frank Deviney, Jr., Tonnie Maniero, Jennifer Stingelin Keefer, and Rick Webb for their contributions to different sections of the report. We also acknowledge the contribution of the Science Advisory Committee, Alan Ellsworth, Gary Fleming, Paul Geissler, Carolyn Mahan, John Karish, Karen Patterson, Craig Snyder, Julie Thomas, and John Young, for providing guidance and reviewing components of the report. The Mid-Atlantic Network parks' resource managers including Kristen Allen, Steve Ambrose, Tim Blumenschine, Zachary Bolitho, Meghan Carfioli, Brian Eick, Kristina Heister, Gregg Kneipp, Dave Shockley, and Timbo Sims were instrumental in providing support and input. We especially want to thank Gordon Olson and the staff at Shenandoah National Park, including Jim Atkinson, Wendy Cass, Rolf Gubler, Shane Spitzer, and Alan Williams, for taking on the challenge of incorporating their wealth of knowledge into the development of the MIDN.

We are also particularly grateful to the other Northeast Region I&M Program network coordinators and data managers for providing support to the MIDN. In particular, we are indebted to Matt Marshall and Nathan Piekielek (Eastern Rivers and Mountains Network) for their willingness to collaborate closely with MIDN on numerous projects, as well as Sara Stevens, Bryan Milstead, and Dennis Skidds (Northeast Coastal and Barrier Network), and Brian Mitchell, Greg Shriver, and Fred Dieffenbach (Northeast Temperate Network). We are also thankful to the current and past National Capital Region Network staff who have supported us throughout the process: Shawn Carter, Patrick Campbell, Jean Paul Schmit, Geoff Sanders, Mark Lehman, and Marcus Koenen. We would like to thank the National I&M Program staff, Gary Williams, Steve Fancy, and John Gross, for their guidance and support. We also thank all those who participated in the Web-based vital signs ranking process for the MIDN, contributing their time and expertise to guiding the monitoring process.

Artwork in this report was provided by Cheryl L. Tanner, Sarah Wakamiya, and R. Keane. We are very grateful to these talented individuals for sharing their work. All photographs in the report are by James Comiskey, Kristina Callahan, Carolyn Davis, Joseph Mitchell, and NPS.

A number of other networks throughout the I&M Program have produced excellent reports that have served as an evolving model upon which we have built the MIDN program. In particular, we have drawn upon the knowledge and expertise of the Central Alaska Network, Cumberland/Piedmont Network, Eastern Rivers and Mountains Network, Greater Yellowstone Network, Heartland Network, National Capital Region Network, North Coast and Cascades Network, Northeast Coastal and Barrier Network, Northeast Temperate Network, Northern Colorado Plateau Network, Rocky Mountain Network, Southwest Alaska Network, and Upper Columbia Basin Network.

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Finally, we would like to thank the staff of Fredericksburg and Spotsylvania National Military Park, where the network is based. In particular, we are grateful to Superintendent Russ Smith for his continued support and encouragement.

Chapter 1: Introduction and Background

1.1 Network Overview

The Mid-Atlantic Network (MIDN) is one of 32 vital signs monitoring networks established by the National Park Service (NPS) as part of a service-wide strategy to institutionalize scientifically credible natural resource inventory and monitoring. This effort will ensure that managers of the nation's 270 park units identified as having significant natural resources possess the information needed for effective, science-based resource protection and management. The MIDN received full funding in 2006 to conduct long-term vital signs monitoring.

The Mid-Atlantic Network consists of 10 parks distributed from southern Pennsylvania to southern Virginia, and extending from the Blue Ridge to the Coastal Plain (Figure 1.1). The parks are predominantly small, cultural units with a limited history of natural resource monitoring, but the network also includes the comparatively large Shenandoah National Park, which was designated as a prototype park for development of vital signs monitoring.

Richmond National Battlefield Park and the Eastern Front of Petersburg National Battlefield fall within the Coastal Plain, which is composed primarily of unconsolidated sand, silt, and clay that has been cleared extensively. The Coastal Plain gives way to the Piedmont at the loosely defined fall zone, and it is in this transition zone that Fredericksburg and Spotsylvania National Military Park is located. All other MIDN parks are located within the Piedmont, except for Shenandoah NP, which is located in the Blue Ridge Mountains.

All of the Mid-Atlantic Network parks are located in Eastern Deciduous Forest that has pronounced seasons and strong annual cycles of temperature and precipitation. Forests of the Blue Ridge vary along altitudinal gradients but are primarily Appalachian Oak Forests. The southern Piedmont and Coastal Plain are characterized by Southern Mixed Forests composed of pines and hardwoods. The Pennsylvania parks have primarily broadleaf forests that represent a lowland, northerly expression of the Appalachian Oak Forest.

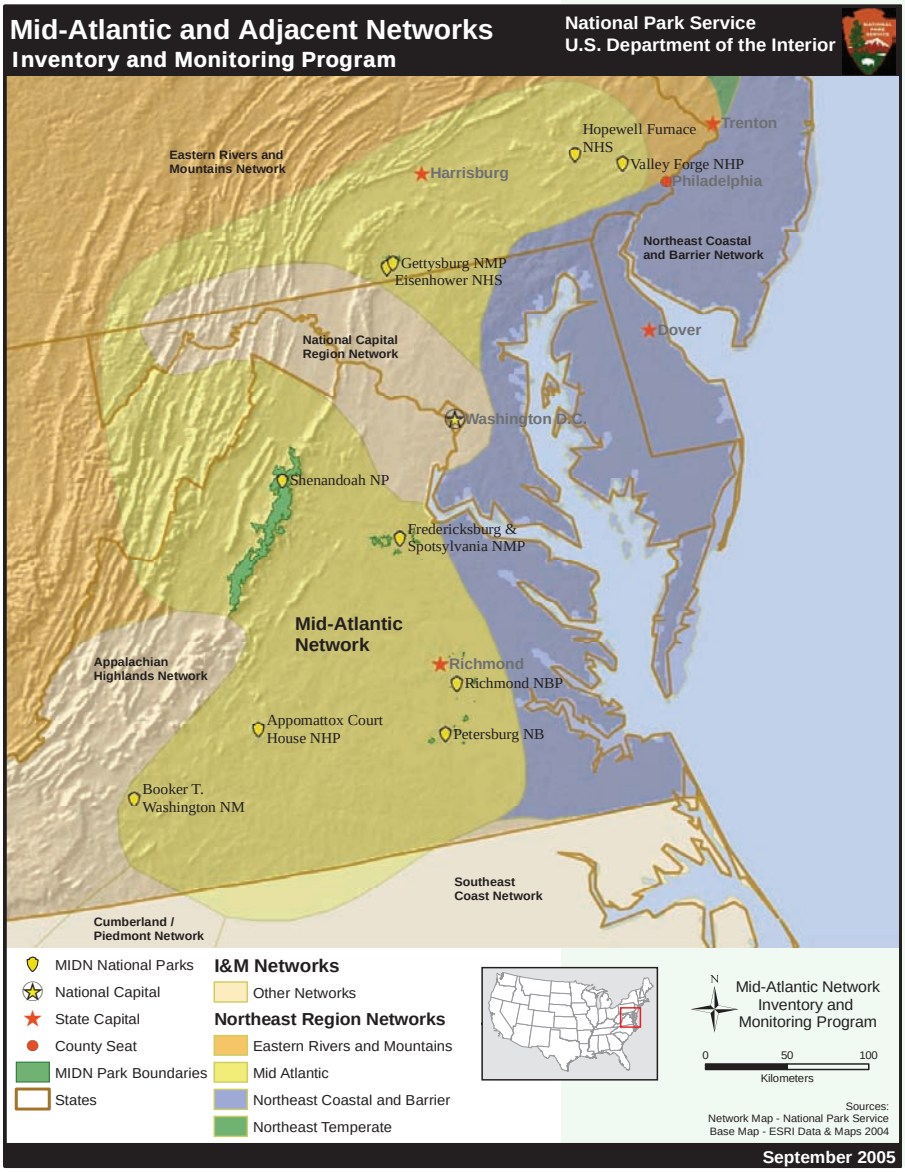
The Mid-Atlantic Network consists of ten parks in Virginia and Pennsylvania. Shenandoah National Park is the largest, and was designated as a prototype long-term ecological monitoring site in the 1990's.

1.2 Integrated Natural Resource Monitoring

1.2.1 Justification for Monitoring

Knowing the condition of natural resources in national parks is fundamental to the National Park Service's ability to manage park resources "unimpaired for the enjoyment of future generations" (Fancy et al. In press). National park managers across the country are confronted with increasingly complex and challenging resource management questions that require a broad-based understanding of the status and trends in park resources as a basis for making decisions and working with other agencies and the public for the benefit of park resources. For years, managers and scientists have sought a way to characterize and determine trends in the

Figure 1.1. Map showing location and distribution of parks in the Mid-Atlantic Network.



Appomattox Court House National Historical Park

condition of parks and other protected areas, in order to assess the efficacy of management practices and restoration efforts and to gain an early warning of impending threats.

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

The intent of park vital signs monitoring is to track a subset of physical, chemical, and biological elements and processes 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.

Natural resource monitoring provides site-specific information needed to understand and identify changes in complex, variable, and imperfectly understood natural systems and to determine whether observed changes are within natural levels of variability or may be indicators of unwanted human influences. Thus, monitoring provides a basis for understanding and identifying meaningful change in natural systems characterized by complexity and variability. Monitoring data help to define the normal limits of natural variation in park resources and provide a basis for understanding observed changes; monitoring results may also be used to determine what constitutes impairment and to identify the need to initiate or change management practices. Understanding the dynamic nature of park ecosystems and the effects of human activities on them is essential to make management decisions that will 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).

The intent of park vital signs monitoring is to track a subset of physical, chemical, and biological elements and processes 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. In situations where natural areas have been so highly altered that physical and biological processes no longer operate (e.g., control of fires and floods in developed areas), information obtained through monitoring can help managers understand how to develop the most effective approach to restoration or, in cases where restoration is impossible, ecologically sound management. The broad-based, scientifically sound information obtained through natural resource monitoring will have multiple applications for management decision-making, research, education, and promoting public understanding of park resources.

1.2.2 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 parks unimpaired (see Appendix A). The mission of the National Park Service (as stated in the National Park Service Organic Act of 1916) is:

...to promote and regulate the use of the Federal areas known as national parks, monuments, and reservations hereinafter specified by such means and measures as conform to the fundamental purposes of the said parks, monuments, and reservations, which purpose is to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment

of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations.

Congress strengthened the National Park Service's protective function, and provided language important to recent decisions about resource impairment, when it amended the Organic Act in 1978 to state:

. . .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.

In 2006, NPS management policies reiterated the importance of the protective function of the National Park Service to "*understand, maintain, restore, and protect the inherent integrity of the natural resources*" (NPS 2006a). The approach to the management of park natural resources is clearly established in NPS management policies, which state:

The Natural resources will be managed to preserve fundamental physical and biological processes, as well as individual species, features, and plant and animal communities. The Service will not attempt to solely preserve individual species (except threatened or endangered species) or individual natural processes; rather, it will try to maintain all the components and processes of naturally evolving park ecosystems, including the natural abundance, diversity, and genetic and ecological integrity of the plant and animal species native to those ecosystems. Just as all components of a natural system will be recognized as important, natural change will also be recognized as an integral part of the functioning of natural systems. By preserving these natural components and processes in their natural condition, the Service will prevent resource degradation, and therefore avoid any subsequent need for resource restoration. In managing parks to preserve naturally evolving ecosystems, and in accordance with requirements of the National Parks Omnibus Management Act of 1998, the Service will utilize the findings of science and the analyses of scientifically trained resource specialists in decision-making. (NPS 2006a, Chapter 4)

Consistent with this policy, the National Park Service has adopted a science-based approach to natural resource management. NPS management policies further clarify the importance of ecosystem-based monitoring:

Gettysburg National Military Park

Science has demonstrated that few if any park units can fully realize or maintain their physical and biological integrity if managed as biogeographic islands. Instead, park units must be managed in the context of their larger ecosystems. The ecosystem context for some species and processes may be relatively small, while for others this context is vast. In any case, superintendents face the challenge of placing each of the resources they protect in their appropriate ecosystem context and then working with all involved and affected parties to advance their shared conservation goals and avoid adverse impacts on these resources. (NPS 2006a)

Recent and specific requirements for a program of inventory and monitoring of park resources are found in the National Parks Omnibus Management Act of 1998 (P.L. 105–391). In part, the intent of the act was to create an inventory and monitoring program that may be used "*to establish baseline information and to provide information on the long-term trends in the condition of National Park System resources.*" NPS management policies (NPS 2006a) direct the service to inventory and monitor natural systems in efforts to inform park management decisions:

Natural systems in the national park system, and the human influences upon them, will be monitored to detect change. The Service will use the results of monitoring and research to understand the detected change and to develop appropriate management actions. (NPS 2006a)

In addition to the legislation directing the formation and function of the National Park System, a number of laws not only protect the

Park	Enabling Legislation
Appomattox Court House National Historical Park	To preserve the village of Appomattox Court House where General Lee surrendered the Confederate Army.
Booker T. Washington National Monument	To provide a public national memorial to Booker T. Washington, a prominent African American educator.
Eisenhower National Historic Site	To preserve the farm of General Dwight D. Eisenhower, 34th President of the United States.
Fredericksburg and Spotsylvania National Military Park	To protect and interpret the historic resources associated with the four Civil War battles fought near Fredericksburg.
Gettysburg National Military Park	To protect lands occupied by the military on July 1-3, 1863 and to preserve important topographical features of the battlefield.
Hopewell Furnace National Historic Site	To preserve the iron making community as a significant way of life and work in the late 18th and 19th centuries.
Petersburg National Battlefield	To commemorate the campaign, siege and defense of Petersburg, Virginia during the Civil War.
Richmond National Battlefield Park	To conserve Civil War resources in the military battlefield area in the City of Richmond, Virginia.
Shenandoah National Park	To protect the natural and cultural resources of the northern Blue Ridge and immediate area.
Valley Forge National Historical Park	To preserve and commemorate the area associated with General George Washington's Continental Army during the winter of 1777-1778.

Table 1.1. Enabling legislation for parks in the Mid-Atlantic Network.

natural resources within national parks and other federal lands, but also address environmental compliance in the United States. Many of these federal laws require natural resource monitoring within national parks. A summary of legislation, policy, and executive guidance having a direct bearing on natural resource monitoring by the National Park Service is presented in Appendix A. In addition, each park has specific enabling legislation that was passed at the time of the park's creation, as outlined in Table 1.1.

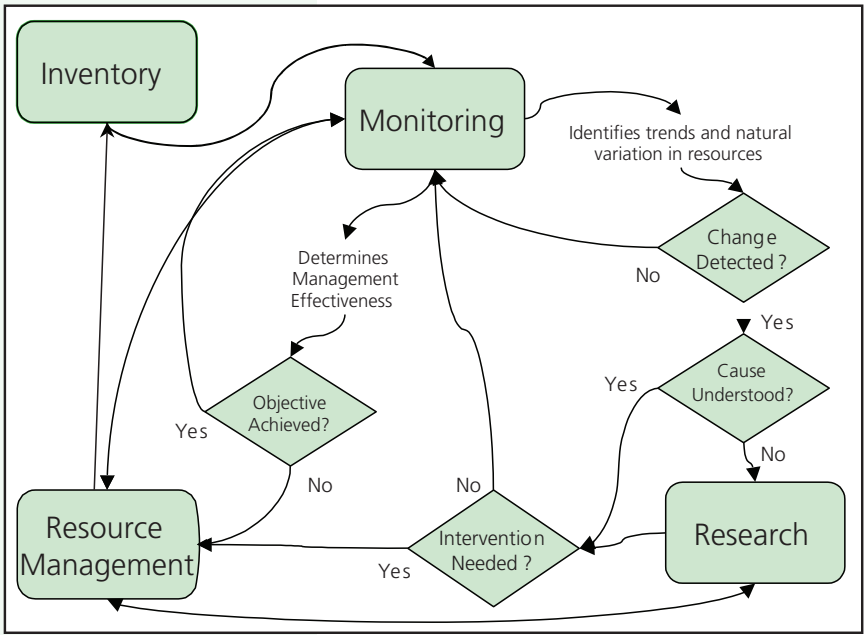


Figure 1.2. Relationships between monitoring, inventories, research, and natural resource management activities in national parks (modified from Jenkins et al. 2002).

1.3 Natural Resource Monitoring

1.3.1 The Role of Inventory, Monitoring, and Research

Monitoring is a central component of natural resource stewardship in the National Park Service and, in conjunction with natural resource inventories and research, provides the information needed for effective, science-based management decision-making and resource protection (Figure 1.2). Ecological monitoring establishes reference conditions for natural resources based on which future changes can be detected. Over the long term, these "benchmarks" help define the normal limits of natural variation and may become standards with which to compare future changes, provide a basis for judging what constitutes impairment, and help identify the need for corrective management actions.

The NPS strategy to institutionalize inventory and monitoring throughout the agency has three major components: (1) completion of 12 basic resource inventories upon which monitoring efforts can be based; (2) formation of a network of 11 experimental or "prototype" long-term ecological monitoring (LTEM) programs, begun in 1992 to evaluate alternative monitoring designs and strategies; and (3) implementation of operational monitoring of high-priority measures of resource condition (i.e., "vital signs") in approximately 270 parks with significant natural resources, which have been grouped into 32 vital signs monitoring networks linked by geography and shared natural resource characteristics (Fancy et al. In press).

1.3.2 Monitoring Goals and Strategies

The National Park Service has adopted five goals for vital signs monitoring: (1) determine the status and trends in selected ecological indicators, (2) provide an early warning system of ecological change, (3) provide data to increase our understanding of natural processes, (4) meet legal mandates, and (5) allow the Service to measure performance (Table 1.2). These goals guide the MIDN monitoring program.

1.3.2.1 Developing an integrated monitoring program

During development of the vital signs monitoring strategy, it became clear that a "one size fits all" approach to monitoring design would not be effective for the National Park Service, because of the tremendous variability among parks in ecological conditions, size, and management capabilities. To develop an effective, cost-efficient monitoring program that addresses the most critical information needs of each park and integrates with other park operations requires considerable flexibility to combine existing and new programs. Partnerships must be developed with federal and state agencies and adjacent landowners to fully understand and manage issues that extend beyond park boundaries, but such partnerships (and the appropriate ecological indicators and methodologies involved) will differ from park to park throughout the National Park Service.

The complicated task of developing an integrated monitoring program requires an initial investment in planning and design to (1) guarantee that monitoring meets the most critical information needs of each park; (2) produce scientifically credible results that are clearly understood and accepted by scientists, policy makers, and the public; and (3) make results readily accessible to managers and researchers. The planning process must also ensure that monitoring builds upon existing information and understanding of park ecosystems while maximizing relationships with other agencies and academia. Each network of parks is required to design an integrated monitoring program that addresses the monitoring goals listed above and is tailored to the high-priority monitoring needs and partnership opportunities for the parks in that network. Although there will be considerable variability among networks in the final design, the basic approach to designing a monitoring program should follow six basic steps, which are further discussed in the NPS document *Recommended Approach for Developing a Network Monitoring Program* (http://science.nature.nps.gov/im/monitor/Approach.cfm):

1) Define the purpose and scope of the monitoring program.

2) Compile and summarize existing data and understanding of park ecosystems.

3) Develop conceptual models of relevant ecosystem components.

4) Prioritize and select ecological indicators (vital signs) and specific monitoring objectives for each one.

5) Determine the appropriate sampling design and sampling protocols.

6) Establish data management, analysis, and reporting procedures.

These steps are incorporated into a three-phase planning and design process. Phase 1 of the process involves defining goals and objectives; beginning the process of identifying, evaluating and synthesizing existing data; developing draft conceptual models; and completing other background work that must be done before the initial selection of ecological indicators. Each network is required to document these tasks in a Phase 1 report, which is then peer-reviewed and approved at the regional level before the network proceeds to the next phase. Phase 2 of the planning and design effort involves prioritizing and selecting vital signs and developing draft monitoring objectives for each. Phase 3 entails the detailed design work needed to implement monitoring, including the refinement of specific monitoring objectives, development of sampling protocols, a statistical sampling design, a plan for data management and analysis, and details on the type and content of various products of the monitoring effort such as reports and Web sites.

NPS Vital Signs Goals

- Determine the status and trends in selected indicators of the condition of park ecosystems to allow managers to make better-informed decisions and to work more effectively with other agencies and individuals for the benefit of park resources.
- Provide early warning of abnormal conditions of selected resources to help develop effective mitigation measures and reduce costs of management.
- Provide data to better understand the dynamic nature and condition of park ecosystems and to provide reference points for comparisons with other, altered environments.
- Provide data to meet certain legal and Congressional mandates related to natural resource protection and visitor enjoyment.
- Provide a means of measuring progress towards performance goals.

Table 1.2. Vital signs monitoring goals.

Valley Forge National Historical Park

1.3.2.2 Strategy for defining what to monitor

Monitoring is an ongoing effort to better understand how to sustain or restore ecosystems, and serves as an "early warning system" to detect declines in ecosystem integrity and species viability before irreversible loss has occurred. One of the key initial decisions in designing a monitoring program is deciding how much relative weight should be given to tracking changes in focal resources and stressors that address current management issues, versus tracking measures that are thought to be important to long-term understanding of park ecosystems. Complicating this decision is the fact that our current understanding of ecological systems—and consequently, our ability to predict how park resources might respond to changes in various system drivers and stressors—is poor. A monitoring program that focuses only on current management issues and threat/response relationships may not provide the long-term data and understanding needed to address high-priority issues that will arise in the future. Ultimately, an indicator is useful only if it can provide information to support a management decision or to quantify the success of past decisions, and produce results that are clearly understood and accepted by managers, scientists, policy makers, and the public.

Should vital signs monitoring focus on the effects of known threats to park resources or on general properties of ecosystem status? Woodley (1993), Woodward et al. (1999), and others have described some of the advantages and disadvantages of various monitoring approaches, including a strictly threats-based monitoring program and alternate taxonomic, integrative, reductionist, or hypothesis-testing monitoring designs (Woodward et al. 1999). The MIDN has adopted a multifaceted approach for monitoring park resources, based on integrated and threat-specific monitoring approaches and building upon concepts originally presented for the Canadian national parks (See Figure 1.3; Woodley 1993). This approach groups indicators into one or more of the following broad categories:

1) **Ecosystem drivers** that fundamentally affect park ecosystems

2) **Stressors and their ecological effects**

3) **Focal resources** of parks

4) **Key properties and processes of ecosystem integrity**

In cases where there is a good understanding of the relationships between ecosystem drivers and stressors, and their effects on park resources (known effects), monitoring of system drivers, stressors, and affected park resources is conducted. A set of focal resources (including ecological processes) is monitored to address both known and unknown effects of system drivers and stressors on park resources. Key properties and processes of ecosystem status and integrity are monitored to improve long-term understanding of park ecosystems and provide an early warning of potential undesirable changes in park resources.

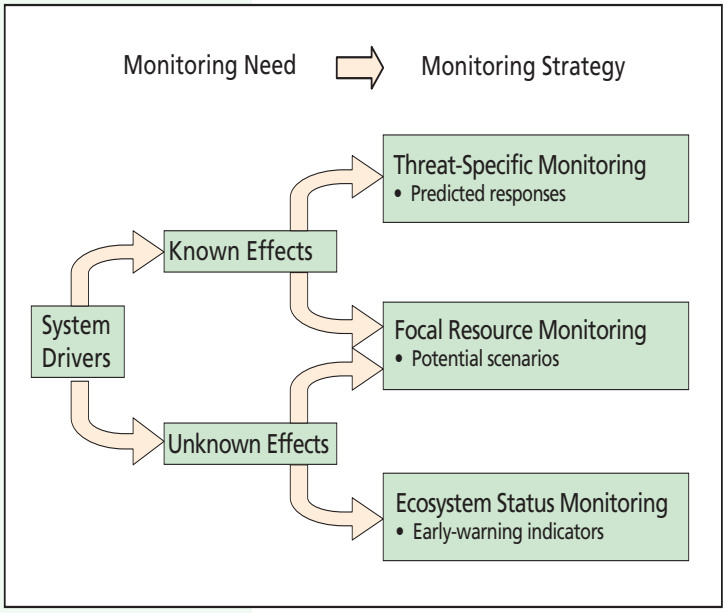


Figure 1.3. Conceptual approach to selecting vital signs in the Mid-Atlantic Network (Modified from Woodley 1993).

Shenandoah National Park

Natural ecosystem drivers are major external forces such as climate, fire cycles, biological invasions, hydrologic cycles, and natural disturbance events such as earthquakes, droughts, and floods. These can have large-scale influences on natural systems. Trends in ecosystem drivers will suggest what kind of changes to expect and may provide an early warning of presently unseen changes in the ecosystem.

Stressors are physical, chemical, or biological perturbations to a system that are either (a) foreign to that system or (b) natural to the system but applied at an excessive (or deficient) level (Barrett et al. 1976:192). Stressors cause significant changes in the ecological components, patterns, and processes in natural systems. Examples include water withdrawal, pesticide use, timber harvesting, traffic emissions, stream acidification, trampling, poaching, land-use change, and air pollution. Monitoring of stressors and their effects, where known, will ensure short-term relevance of the monitoring program and provide information useful to management of current issues.

Focal resources, by virtue of their special protection, public appeal, or other management significance, have paramount importance for monitoring regardless of current threats or whether they would be monitored as an indication of ecosystem integrity. Focal resources might include ecological 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.

Monitoring of **key properties and processes of ecosystem integrity** provides the long-term baseline needed to judge what constitutes unnatural variation in park resources and provide early warning of unacceptable change. Biological integrity has been 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 and Dudley 1981).

These categories provide a framework for selecting vital signs. A program based on vital signs chosen from multiple categories ensures an integrated approach that can address ecological status and trends for which effects are known and unknown. This is the approach taken by the MIDN.

Mid-Atlantic Network identified focal resources for each park, agents of change or stressors that are known or suspected to cause changes, and key properties and processes of ecosystem condition.

1.3.2.3 MIDN approach

Development of the MIDN Vital Signs Monitoring Plan was initiated through a series of scoping questionnaires, meetings, and workshops to identify (1) focal resources (including ecological processes) important to each park, (2) agents of change or stressors that are known or suspected to cause changes in the focal resources over time, and (3) some key properties and processes of ecosystem condition (e.g., weather, soil nutrients) (detailed below in this chapter). Conceptual models were then devel-

oped, to help organize and communicate the information compiled during scoping. From these general models, stressor models for terrestrial and aquatic ecosystems were developed to focus on high-priority monitoring issues and to aid in the ranking process (Chapter 2). The scoping and conceptual modeling efforts resulted in a list of potential vital signs which were then prioritized through a series of park workshops and an online ranking effort to identify the subset of these indicators that would be included in our initial integrated monitoring program (Chapter 3).

1.4 The Mid-Atlantic Network

This section provides information derived from the first step in the scoping process, including an overview of the cultural and ecological setting of the MIDN. It also identifies significant resources, management issues, threats, and existing and historic monitoring in the parks. The information in this section was derived from (1) literature and management plan reviews for each park, (2) an evaluation of existing data sets and current monitoring programs, and (3) a resource management issues ranking by park managers. Compilation of this information was essential in identifying the initial suite of potential vital signs and in defining priorities for monitoring.

1.4.1 History and Formation

The Mid-Atlantic Network encompasses two independent programs, the Shenandoah National Park Prototype Long-term Ecological Monitoring (LTEM) Program and the Mid-Atlantic Network (MIDN). The Shenandoah LTEM Program was established as a prototype in 1992 to represent the Eastern Deciduous Forest biome, with program objectives to (1) obtain and maintain a scientifically based understanding of the type, abundance, and distribution of natural resources; (2) monitor resource condition and changes through time; and (3) monitor natural processes and anthropogenic influences that maintain or affect ecosystem health. The Shenandoah prototype LTEM Program receives funding that is separate from that of the Mid-Atlantic Network and currently has a monitoring program that focuses on six major areas (see park profile Appendix B), including watersheds (this monitoring program has been

Table 1.3. Overview of the parks in the Mid-Atlantic Network.

Park Name	Park Code	State	Year est.	Yearly Visitors [1]	Acres [2]	Hectares [2]
Appomattox Court House National Historical Park	APCO	VA	1935	151,294	1,774	718
Booker T. Washington National Monument	BOWA	VA	1956	19,751	239	97
Eisenhower National Historic Site	EISE	PA	1967	70,140	690	279
Fredericksburg and Spotsylvania National Military Park	FRSP	VA	1927	1,500,071	8,382	3,392
Gettysburg National Military Park	GETT	PA	1895	1,731,695	5,990	2,424
Hopewell Furnace National Historic Site	HOFU	PA	1938	57,834	848	343
Petersburg National Battlefield	PETE	VA	1926	556,353	2,740	1,109
Richmond National Battlefield Park	RICH	VA	1936	282,830	7,127	2,884
Shenandoah National Park	SHEN	VA	1935	1,125,097	199,073	80,562
Valley Forge National Historical Park	VAFO	PA	1976	6,667,530	3,466	1,403

[1] Yearly visitation data is from 2007 and includes recreational and non-recreational visitors. Non-recreational visitors can include traffic that passes through the park and can impact park natural resources.

[2] Park area data is from 2007.

in place for more than 25 years, SWAS 2005), air quality, forest vegetation, stream health, white-tailed deer, and birds.

The MIDN conducted an initial scoping workshop in 2001 to identify the biological inventory needs for network parks. Over the next six years, the network focused initially on conducting baseline inventories, and subsequently on identifying natural resource issues and priorities for developing the monitoring program.

1.4.2 Overview of Parks

The MIDN parks range in size (Table 1.3) from 97 hectares (ha) (239 acres, Booker T. Washington National Monument) to 80,562 ha (199,073 acres, Shenandoah National Park), and include many sites of historical and cultural interest as well as diverse natural resources. Valley Forge National Historical Park is the site of General George Washington's winter encampment and the training ground of the Continental Army during the Revolutionary War. Iron used to make many materials, including arms for the Continental Army and American patriots, was produced in nearby Hopewell Furnace National Historic Site. This is an excellent example of an early 19th-century rural iron-making community, where locally mined ore was refined in the furnace, and charcoal for fuel was produced from the surrounding hardwood forests that now form French Creek State Park. In contrast, a tobacco plantation home at Booker T. Washington National Monument interprets the daily life of plantation slaves, and documents the life of Booker T. Washington from slave to educator and national leader. Five other parks record key events of the Civil War, such as the battles of Fredericksburg, Chancellorsville, Wilderness, and Spotsylvania at the Fredericksburg and Spotsylvania National Military Park; the turning point of the war towards Union victory at Gettysburg National Military Park; the Confederate capital at Richmond National Battlefield Park; the prolonged siege of Confederate forces by the Union army at Petersburg National Battlefield; and the final surrender of General Robert E. Lee to General Ulysses S. Grant at Appomattox Court House National Historical Park. Of more recent historical interest Eisenhower National Historic Site, President Dwight D. Eisenhower's farm retreat and a meeting place for world leaders. The only national park within the MIDN is Shenandoah, which contains a diversity of natural, geologic and cultural resources.

Sweetgum (*Liquidambar styraciflua*)

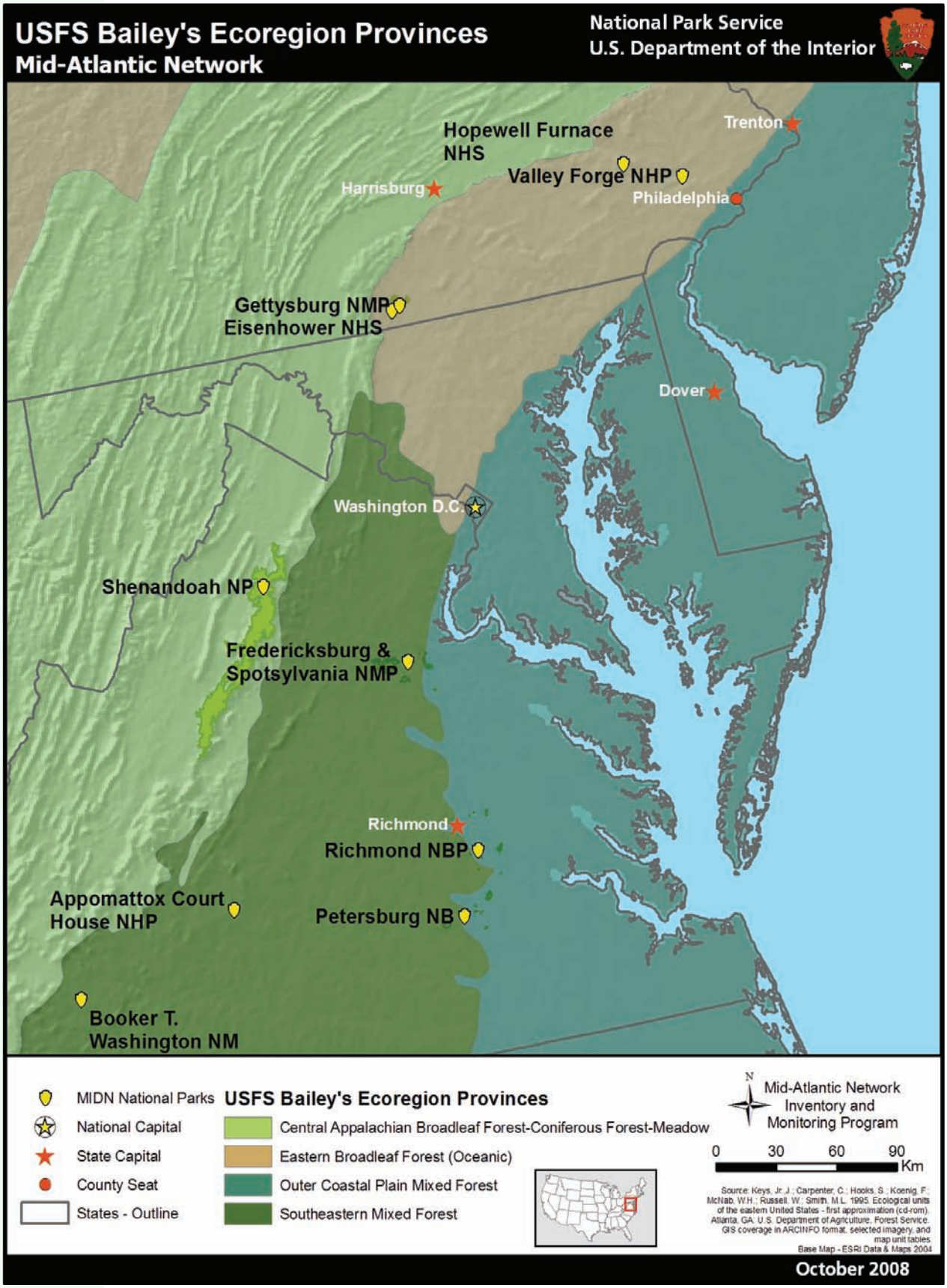
1.4.3 Ecological Setting

The Mid-Atlantic Network parks are located in the Eastern Temperate Forest Ecoregion (CEC 1997), which is characterized as having high rainfall, warm summers, and cold winters with temperatures falling below freezing (Cox and Moore 2005). Most of the parks are located primarily in the Piedmont, with Richmond NBP and the Eastern Front of Petersburg NB located in the Coastal Plain, and Shenandoah NP located in the Blue Ridge Mountains (Appendix B). The network's Pennsylvania parks are located in what is considered to be the Northern Piedmont (Woods et al. 1999).

1.4.3.1 Geology and topography

The MIDN parks are located within two major geologic divisions, the Appalachian Highlands and the Atlantic Plain (USGS 2005). The Appalachian Highlands includes two physiographic provinces, Blue Ridge and Piedmont, while the Atlantic Plain geologic division contains the Coastal Plain province (Isphording and Fitzpatrick Jr. 1992). The Blue Ridge is composed of resistant Precambrian granites and metabasalts (greenstone) with resistant metasedimentary rocks exposed on the western flanks. Shenandoah NP is the only park in the network found in this physiographic province, with elevations that range from 146 meters (m) (479 feet, ft) to 1,234 m (4,049 ft) at Hawksbill Peak. In contrast, the Piedmont is composed of rolling uplands that are underlain by deeply weathered and deformed metamorphic rocks, intruded by igneous material, and ranging in age from Precambrian to late Paleozoic (Hack 1989, Woods

Figure 1.4. Bailey's ecoregions for the Mid-Atlantic Network.



et al. 1999). The Coastal Plain is composed of unconsolidated tertiary sands, silts, and clays, overlain by sedimentary material that contrasts with the older rocks of the Piedmont (Isphording and Fitzpatrick Jr. 1992).

1.4.3.2 Soils

Most of the Mid-Atlantic region is characterized by Ultisols, light-colored, acid soils with low base saturation (Soil Survey Division Staff 1993). Along the Blue Ridge, Ultisols commonly overlay the igneous ridges; Inceptisols, characterized by low fertility, acidity, and stoniness (White and Wilds 1998, Woods et al. 1999), are found on the steeper landforms (Woods et al. 1999). Boulders and outcrops are common on the upper slopes and provide important habitat for rare and threatened species, including the Shenandoah salamander (*Plethodon shenandoah*), which is found in the Central Appalachian High-Elevation Boulderfield Forest (Fleming and Coulling 2001). In the Northern Piedmont, Ultisols give way to a combination of Alfisols and Ultisols that are generally deep, well developed and have moderate to excellent fertility (Woods et al. 1999,White and Wilds 1998). The most common soils of the Coastal Plain are Ultisols of the suborder Udults, which are well or moderately well drained, and low in bases (Hubbard et al. 2000). Spodosols and Entisols can also be found in the Coastal Plain (White and Wilds 1998). Silty soils occur mainly in level expanses.

1.4.3.3 Climate

The climate of the Mid-Atlantic Network is defined as continental, characterized by hot, humid summers, and short, relatively cold winters, with some variations experienced along both latitudinal and altitudinal gradients (Bryson and Hare 1974). The Blue Ridge tends to have the most extreme climate while that of the Coastal Plain is the most moderate. During August and September, the area may be subjected to occasional hurricanes or tropical storms that can account for 10-40% of monthly rainfall (Hayden and Michaels 2005). Water deficit conditions are not usually experienced during any month of the year. The elevational gradients of the Blue Ridge provide for variations in local climate. Average annual temperatures range from below 10°C (50°F) in the north to about 14°C (57°F) in the south, with average annual precipitation varying from 890 millimeters (mm) (35 inches, in) in the valleys to up to 2,040 mm (80 in) on the highest peaks. The southern portions of the Piedmont tend to experience mild winters and hot, humid summers with average temperatures ranging from 14-18°C (57-64°F) and precipitation 1,120-1,400 mm (44-55 in) annually. Farther north in Pennsylvania (Northern Appalachian Piedmont *sensu* McNab and Avers 1994), the winters are colder and average annual temperatures range from 11°C to 16°C (52-61°F) (The Pennsylvania State Climatologist 2005, McNab and Avers 1994). Rainfall averages 920-1,400 mm (36-55 in) per year. Average annual temperatures in the Coastal Plain range from 16-20°C (61-68°F), and rainfall is abundant and well distributed throughout the year, ranging from 1,020 mm to 1,530 mm (40-60 in).

1.4.3.4 Vegetation communities and ecoregions

Two primary vegetation types occur in the Mid-Atlantic Network, the Appalachian Oak Forest and the Oak-Hickory-Pine Forest, with a third type, Southeastern Evergreen Forest, occurring south of the James River in Virginia (Barbour and Billings 2000, Röhrig and Ulrich 1991).

The Appalachian Oak Forest coincides primarily with the Central Appalachian Broadleaf Forest, and is mostly mountainous except at its northern limit, in Pennsylvania, where it extends onto the Piedmont and Coastal Plain (Figure 1.4, Barnes 1991). The best expression of the Appalachian Oak Forest occurs in Shenandoah NP. The forest is mainly composed of diverse oak, oak-hickory, and mixed mesophytic communities that vary along topographic and hydric gradients.

Appalachian Oak Forest and Oak-Hickory-Pine Forest, are the most common vegetation types in the Mid-Atlantic Network. A third type, Southeastern Evergreen Forest, occurs south of the James River in Virginia.

Vegetation mapping in Fredericksburg and Spotsylvania National Military Park

Park	Natural Resources Significant to Legal Mandates/Policy	Natural Resources Significant for Other Reasons
APCO	Wetlands, Water quality, State listed species, Exotic species	Rare wetland communities, Open agricultural lands
BOWA	Wetlands, Water quality, Exotic species	Unique vegetation community, Globally rare species (bigeye jumprock)
EISE	Wetlands, Water quality, State listed species, Exotic species	Important Bird Area, Important Mammal Area, Grassland habitat
FRSP	Wetlands, Water quality, Federal and State listed species, Exotic species	Unique vegetation communities, State sensitive or rare mollusk species
GETT	Wetlands, Water quality, State listed species, Exotic species	Grassland habitat, Important Bird Area
HOFU	Federal and State listed species , Wetlands, Water quality, Exotic species, Exceptional Value Waterway	Potential bog turtle habitat
PETE	Federally listed species, Wetlands, Water quality, Exotic species	Unique vegetation communities
RICH	Wetlands, Water quality, State listed species, Exotic species	Unique vegetation communities, Grassland habitat
SHEN	Federal and State listed species, Wetlands, Water quality, Designated Wilderness Area, Exotic species, Air quality	Big Meadows endemic plant communities, High fish diversity (with native brook trout), outstanding example of the Blue Ridge/Central Appalachian biome, Appalachian Trail
VAFO	Federal and State listed species, Wetlands, Water quality, Exotic species, Caves, Exceptional Value Waterway, Class A Wild Trout Stream, Warm Water Fishery, State Scenic River	Grassland habitat, proposed Important Bird Area, Rare crayfish populations

Table 1.4. Significant natural resources at parks within the Mid-Atlantic Network.

Oak-Hickory-Pine Forest occurs along the Piedmont Plateau, with pines characterizing temporary, early-successional stands that are eventually replaced by deciduous species (Braun 1950). The Oak-Hickory-Pine Forest corresponds with Southeastern Mixed Forest (*sensu* Bailey 1995), and is found in several park units including Appomattox Court House NHP, Booker T. Washington NM, and the western portions of Fredericksburg and Spotsylvania NMP and Petersburg NB.

The Southeastern Evergreen Forest occurs in a very small portion of the area covered by the Mid-Atlantic Network, on the Coastal Plain south of the James River in Virginia. This area forms part of the Outer Coastal Plain Mixed Forest (Figure 1.4). Petersburg NB is located within this community (Rantis and Johnson 1995, Rantis and Johnson 2002), although its vegetation shows a much greater affinity to the Oak-Hickory-Pine Forest (Fleming personal communication).

Fields are an important component of the Mid-Atlantic Network cultural landscape

1.4.4 Cultural Setting

Nine of the 10 parks in the MIDN were created for cultural reasons, commemorating the Civil War (Appomattox Court House, Fredericksburg and Spotsylvania, Gettysburg, Petersburg, and Richmond), the Revolutionary War (Valley Forge), or specific people or ways of life (Booker T. Washington, Eisenhower, and Hopewell Furnace). Although cultural landscapes represent a small portion of the total area of these parks, they are disproportionately important to the parks' mission and visitors' experience. In many cultural parks, this can create tension between cultural and natural resource management. For example, in battlefield parks, landscape restoration efforts recreate open fields that restore the vistas to those present at the time of the historic events. However, it is because of the cultural landscape that the natural resources have gained protection.

1.4.5 Significant Natural Resources

Shenandoah NP was created primarily for natural resource reasons, and it is the only park in the network whose enabling legislation specifically provides for natural resource protection (Table 1.1). Shenandoah is a Class 1 air quality area under the Clean Air Act and therefore is subject to specific legal requirements for maintaining air quality. In addition, the park has a designated wilderness area which requires special management considerations (Appendix A). Nevertheless, all the parks in the network contain natural resources that require protection under current legal mandates (Table 1.4). For example, Valley Creek at Valley Forge NHP is classified as an Exceptional Value Waterway and a Class A Trout Stream by the Pennsylvania Department of Environmental Protection.

All network parks have a number of species that are protected at either the federal or the state level. Five parks harbor a recently delisted federally threatened bird species: Fredericksburg and Spotsylvania, Hopewell Furnace, Richmond, Shenandoah, and Valley Forge have all registered the presence of the bald eagle (*Haliaeetus leucocephalus*). In addition, Shenandoah and Fredericksburg and Spotsylvania have one federally listed vascular plant, the small whorled pogonia (*Isotria medeoloides*), and Shenandoah has one federally listed amphibian, the Shenandoah salamander. In addition, Shenandoah has 10 confirmed plant species listed by Virginia as critically imperiled, and 20 species listed as imperiled. Fifteen species that occur in Pennsylvania parks are listed as endangered at the state level, and an additional five are considered threatened (Appendix C).

Vegetation Community	Parks
Upland Depression Swamp	APCO
Non-Riverine Saturated Forest	FRSP
Coastal Plain Depression Wetland	FRSP
Coastal Plain/Piedmont Acidic Seepage Swamp	FRSP, RICH, PETE
Central Appalachian High-Elevation Boulderfield Forest	SHEN
High-Elevation Greenstone Barren	SHEN
High-Elevation Outcrop Barren	SHEN
Central Appalachian Mafic Barren (Mid-Elevation Type)	SHEN

Table 1.5. Rare vegetation communities of the Mid-Atlantic Network.

Shenandoah NP also has four globally imperiled plant species, and four plants and one amphibian (again, the Shenandoah salamander) that are globally vulnerable (Appendix C). A number of plant communities that have been identified as globally rare occur in the MIDN parks and merit protection (Table 1.5).

Although cultural landscapes represent a small portion of the total area of the Mid-Atlantic Network parks, they are disproportionately important to the parks' mission and visitors' experience.

1.4.6 Priority Resource Management Issues and Threats

The MIDN parks share a number of issues of concern to natural resource management. These can be divided into four major categories: atmospheric resources degradation, biotic change, land use change, and water resources degradation. An overview is provided here, with more details in Chapter 2.

Atmospheric resources degradation includes changes in the condition of air quality through the influence of anthropogenic pollutants. Many pollutants resulting from burning of fossil fuels originate outside the region, and influence the network parks through wet and dry deposition, or through elevated ozone concentrations (Sullivan et al. 2003). Heavy metals such as mercury also pose a threat, and particulate matter in the air alters visibility. The Mid-Atlantic region suffers from some of the worst air quality conditions in the country, and this poses a threat to the natural resources in the network parks (Nash et al. 1995).

Shenandoah salamander (*Plethodon shenandoah*)

Also included in this category is climate change, which has the potential to influence a variety of species and ecological processes in the Mid-

Other stressors to Mid-Atlantic Network park natural resources include deer and increasing changes in the landscape mosaic due to development. Valley Forge National Historical Park

Atlantic Network parks. Over the past century, average temperatures in the Mid-Atlantic region have increased by 0.5°C (0.9°F), and current projections are for warmer, perhaps wetter, and possibly more variable conditions to prevail in the future (Frumhoff et al. 2007, IPCC 2007). The severity of weather events is expected to increase, including hurricanes and tropical storms, floods, nor'easters, droughts, and ice storms (Fischer et al. 2000, Hayhoe et al. 2007). These changes are predicted to cause shifts in the species composition of ecosystems, with the likely migration of both plant and animal species in response to changing environmental conditions (Iverson et al. 2008, Ollinger et al. 2008, Rodenhouse et al. 2008). The frequency and intensity of other stressors may also increase, including forest fires and pest and pathogen outbreaks (Paradis et al. 2008).

Biotic change includes any changes in the structure, composition, or function of biotic communities in and around the parks. Invasive exotic species pose a serious threat to parks in the network due to their rapid spread (Swearingen et al. 2002), and the National Park Service has targeted their eradication through Exotic Plant Management Teams (NPS 2004). Introduced animal species also present a threat; for example, exotic earthworms are displacing native soil fauna and altering soil structure, composition, and processes (Groffman and Bohlen 1999). Because the network parks are frequently located in rapidly expanding urban areas, feral animals can also pose a threat (e.g., see Kays and DeWan 2004). On the other hand, continued habitat fragmentation and land-use change can result in native species being lost from the parks. Also of concern are the native and exotic pests and pathogens such as the hemlock woolly adelgid (*Adelgis tsuga*), gypsy moth (*Lymantria dispar*), dogwood anthracnose (*Discula destructive*), and southern pine beetle (*Dendroctonus frontalis*), as well as a number of other species that have the potential to pose a threat (e.g., see Morisawa 2003, Byington et al. 1994, and Chapter 2 of this document for more detail). The creation of transitional habitats has favored some native species, most notably white-tailed deer (*Odocoileus virginianus*), leading to population densities that are beyond the carrying capacity of the parks (Decalesta et al. 1997, McShea et al. 1997).

Land use change that takes place either within a park or outside its boundaries can ultimately influence park resources. The Mid-Atlantic region is continuing to develop very rapidly, with a human population increasing from 15 million in 1940 to 26 million in 2000 (U.S. Census Bureau 2008). Parks that previously enjoyed an isolated location are now facing suburban development. Such changes can result in numerous impacts including increased air and water pollution, habitat fragmentation, increased visitor pressure, and the threat of invasion by exotic species. Management activities within the parks can also pose a threat to natural resources through the maintenance of roads, trails, vistas, and open spaces to maintain the cultural landscape. Other historical practices, including filling in sink holes at Valley Forge NHP, are being reversed to enhance natural resource conditions at the parks.

Water resources degradation can result from changes in atmospheric conditions as well as land use change. The Mid-Atlantic region suffers from substantial water quality issues, with an estimated 1,085 waterways in Virginia and 4,298 in Pennsylvania classified as impaired (EPA 2005b). Increased acid deposition can alter the pH of water, while heavy metals pose a threat to native species and can enter the human food chain (Naimo 1995). Point and nonpoint pollution sources alter water chemistry; creation of dams and extraction of water from streams and rivers can alter water flow; changes in land use surrounding waterways can greatly influence flooding regimes and sedimentation rates and strain geomorphology. All of these influences can drastically change the structure, composition, and natural ecosystem functions of aquatic habitats in the network parks.

The MIDN scoping exercise proved very useful in identifying the issues of greatest concern to the resource managers of the network's parks. The issues that the managers considered to pose a high threat included invasive exotic species, urbanization, and white-tailed deer (Appendix G). The fragmented nature of the small cultural parks within an urbanizing matrix suggests that understanding trends in land use change are at the forefront of park management. In contrast, regional-scale impacts, including climate change and air pollution, are considered to be present in most parks but to pose a low threat to natural resources; Shenandoah NP is the only park where atmospheric conditions are considered to pose a high threat. One unexpected issue of concern is that five of the 10 parks consider park operations to be either a moderate or high threat to natural resources. Data provided by the MIDN monitoring program will aim to help alleviate this situation by creating a platform for communication and valuable information to guide decision-making at the park level.

Invasive exotic plants are a significant threat to natural resources in the Mid-Atlantic Network parks. Tree-of-Heaven (*Ailanthus altissima*)

1.4.7 Existing Monitoring Programs

The network evaluated current monitoring programs at each park as part of the initial scoping process. All parks, except Hopewell Furnace, currently have ongoing monitoring activities, with Shenandoah having the most extensive program. Monitoring activities varied considerably from ad hoc data collection over several years to long-term, peer-reviewed

All Mid-Atlantic Network parks contain natural resources that require protection under current legal mandates.

Some parks have ongoing monitoring projects. Gettysburg National Military Park staff monitor Eastern box turtle (*Terrapene carolina*) in the park

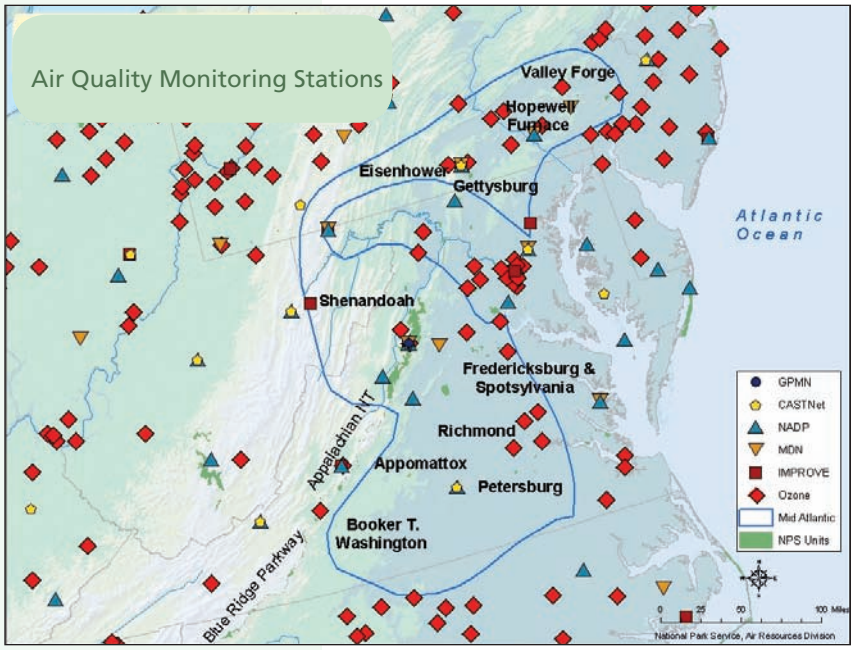


Figure 1.5. Air quality monitoring stations near Mid-Atlantic Network parks.

protocols that have collected data for several decades. As a prototype park, Shenandoah has had a formal monitoring program since the early 1990s, with some monitoring activities spanning more than 25 years (for example, the Shenandoah Watershed Assessment Program, SWAS 2005). Recent funding constraints have resulted in cutbacks of some monitoring activities, and it is hoped that these programs, such as bird monitoring, can be restored in the near future. Air quality is an important natural resource in the park, which has been designated as a Class 1 area under the Clean Air Act, and the park has an extensive air quality monitoring program currently in place (Sullivan et al. 2003). All parks have exotic plant management monitoring as part of the Mid-Atlantic Exotic Plant Management Team (NPS 2004). Other issues that are considered high priority within the network currently have associated monitoring programs, including physical, chemical, and biological water quality parameters, and white-tailed deer counts. Though urbanization and land use change are important concerns to the network, no park is currently monitoring land use change. Outside the boundaries of the parks, other organizations and state and federal agencies are also conducting monitoring projects and these are outlined in Appendix D.

1.4.7.1 Air quality monitoring

The Mid-Atlantic region has a number of ongoing air quality monitoring programs that collect data relevant to MIDN parks. These include data on wet and dry deposition, particulate matter, and ozone (Figure 1.5, Appendix E).

All MIDN parks have both wet and dry deposition monitors on-site or within 90 kilometers (km) (56 miles, mi). Most likely, this coverage is adequate for all of the network parks. The four Pennsylvania parks, Shenandoah, and Fredericksburg and Spotsylvania have mercury deposition monitors on-site or within 45 km (28 mi) (Figure 1.5). However, mercury deposition monitoring may not be adequate for the other four network parks. Some streams in Shenandoah have documented sensitivity to atmospheric deposition. With the exception of Appomattox Court House and Fredericksburg and Spotsylvania, where sensitivity is unknown, surface waters in the rest of the MIDN parks appear well buffered. Given the fish consumption advisories for mercury, PCBs, and chlordane in Pennsylvania and Virginia, long-term monitoring of contaminant levels in fish or other biota is recommended as an indicator of ecosystem health.

Particulate matter is monitored within 30 km (19 mi) of all MIDN parks. Interagency Monitoring of Protected Visual Environments (IMPROVE) sites for visibility monitoring are located within 75 km (47 mi) of all network parks except Hopewell Furnace, Petersburg, Richmond, and Valley Forge. If visibility impairment is a particular concern for any MIDN park, the network may want to consider installing a digital camera to record and interpret visibility conditions.

The network prototype park, Shenandoah National Park, has been an essential element in helping the Mid-Atlantic Network develop its vital signs monitoring program. Shenandoah NP staff conducted fish inventories in network parks

Park	Water Body	Length impaired (km)	Impairment
BOWA	Gills Creek	2.92	Bacteriological
EISE	Willoughby Run	1.14	Organic enrichment, low DO, siltation
FRSP	Hazel Run	0.42	Bacteriological
	Rappahannock River	1.27	Bacteriological, PCBs
GETT	Stevens Run, Rock Creek	3.85	Nutrients, siltation
PETE	James River	0.81	Nutrients, chloride, estuarine benthic macroinvertebrates, bacteriological, PCBs
	Harrison Creek, Poor Creek, Hatcher Run, Appomattox River	18.32	Bacteriological
RICH	James River	0.34	Dissolved oxygen, pH, nutrients, chloride, estuarine benthic macroinvertebrates, bacteriological, PCBs
	Western Run, Crewes Channel, Beaverdam Creek, Boatswain Creek, Coles Run, Bloody Run	7.54	pH, dissolved oxygen
SHEN	Paine Run, Meadow Run, Deep Run, Rocky Branch, Jeremy's Run	49.68	pH
	Naked Creek	11.64	Benthic macroinvertebrates
	Hawksbill Creek, Pass Run, Flint Run Happy Creek, Swift Run	43.39	Bacteriological, temperature
	North Fork Moormans River	20.15	Dissolved oxygen
VAFO	Valley Creek, Schuylkill River	8.59	PCB, siltation
	Trout Creek	3.09	Siltation

Table 1.6. Impaired waters of the Mid-Atlantic Network.

Except for Appomattox Court House, all MIDN parks have an ozone monitor on-site or within 30 km. With the exception of Appomattox Court House, Booker T. Washington, and Shenandoah, all MIDN parks are in the proposed 8-hour ozone nonattainment areas, that is, they do not meet the minimum national ozone standard under the National Ambient Air Quality Standards (NAAQS) program of 85 parts per billion (ppb) over an 8-hour period. Based on the 1995 to 1999 ozone values contained in the Air Atlas, all MIDN parks could be nonattainment for the 8-hour ozone standard. These ozone injury risk assessments indicate a moderate to high risk of ozone injury for sensitive vegetation in all MIDN parks (Kohut 2007).

1.4.7.2 Water quality monitoring

Water chemistry and quantity have management and policy significance because the National Park Service is legally required to protect pristine water quality and improve impaired water quality (Rosenlieb and Long 2006). Streams and rivers managed by the NPS must meet state and federal water quality criteria as defined by the Clean Water Act (CWA). In addition, the National Park Service is required by the Government Performance and Reporting Act (GPRA) to establish and evaluate attainment of goals for meeting water quality criteria. Water chemistry and other water quality data for MIDN parks are notably limited. Development of a water quality monitoring protocol for MIDN parks is thus essential to provide basic information on current and changing conditions in aquatic and watershed ecosystems and

Table 1.7. Monitoring objectives of vital signs selected by the Mid-Atlantic Network.

Level 1	Level 2	MIDN Vital Sign	Monitoring Objectives
Air and Climate	Air Quality	Ozone	Document annual status and trends in atmospheric ozone concentrations.
		Wet and dry deposition	Document annual status and trends in wet and dry deposition.
		Visibility and particulate matter	Report on annual status and trends in fine and coarse particulate matter concentrations and composition.
		Air contaminants (mercury)	Report on annual status and trends in mercury concentration and deposition in precipitation.
	Weather and Climate	Weather and climate	Document long-term trends in weather and climate through seasonal and annual summaries of selected parameters, and document extremes.
Geology and Soils	Geomorphology	Stream / river channel characteristics	Document changes in stream channel characteristics at sampling sites.
	Soil Quality	Soil structure and composition	Determine the status and trends in network soils.
Water	Hydrology	Stream and river water dynamics	Document the status and long-term trends in water flow.
	Water Quality	Water chemistry	Document status and trends in water quality as influenced by point source and non point source pollution (including atmospheric deposition). Determine the natural range of variability in water chemistry (including bacterial composition). Detect water quality measures that exceed threshold values and determine their compliance with state and federal water quality standards.
		Aquatic macroinvertebrates	Document the status and trends in the structure and composition of aquatic macroinvertebrates in relation to changes in water quality and quantity.
Biological Integrity	Invasive Species	Invasive exotic plants	Detect and monitor the presence of invasive exotic plants, exotic plant diseases and pathogens, and forest pests.
	Infestations and Disease	Native forest pests	
		Exotic diseases / Pathogens – plants	
	Focal Species or Communities	Forest plant communities	Determine the status and trends in forest structure, composition, and dynamics of canopy and understory woody species. Determine the status and trends in forest coarse woody debris and the availability of snags.
		White tailed deer (herbivory)	Determine the status and trends in the density and composition of tree seedlings and selected herbaceous species that are indicators of deer browse.

to support compliance with NPS management and policy mandates.

The MIDN parks include a total of approximately 945 km (587 mi) of free-flowing streams (Appendix F). About 119 km (74 mi) of MIDN waters (13%) are Outstanding Natural Resource Waters. Despite this, the Pennsylvania and Virginia 2006 305b/303d integrated reports to the EPA indicated that none of these waters met state designated water use quality criteria (EPA Category 1). No MIDN waters were listed as meeting all state and federal water quality criteria. About 19% of MIDN waters were assessed as failing to meet the criteria for at least one of their designated uses, and close to 12% were listed as being impaired (Table 1.6). Nearly 20% of MIDN waters have not been assessed due to a lack of acceptable data, and thus the proportion of impaired waters will likely increase with more complete study.

1.5 Network Monitoring Objectives

Selection of vital signs for the MIDN was conducted over a two-year period that included extensive evaluation of existing information, development of conceptual ecological models (Chapter 2 and Appendix G), and consultation with park staff and scientists. A series of workshops were conducted, yielding a list of potential vital signs that were ranked via an online survey (Chapter 3). The 15 high-priority vital signs selected for monitoring are presented in Table 1.7, organized into a hierarchical Ecological Monitoring Framework that provides a structured approach for reporting results. General objectives of the MIDN monitoring program are presented in Table 1.7, with more objectives and monitoring methods outlined in Chapter 5.

1.6 Limitations of the Monitoring Program

Managers and scientists need to acknowledge limitations of the monitoring program that are a result of the inherent complexity and variability of park ecosystems, coupled with limited time, funding, and staffing available for monitoring. Ecosystems are loosely defined assemblages that exhibit characteristic patterns at a range of temporal, spatial, and organizational scales (De Leo and Levin 1997). Natural systems as well as human activities change over time, and it is extremely challenging to separate natural variability and desirable changes from undesirable anthropogenic sources of change to park resources. The monitoring program simply cannot address all resource management interests because of funding, staffing, and logistical constraints. Rather, the intent of vital signs monitoring is to monitor a select set of ecosystem components and processes that reflect the overall condition of the park ecosystem and are relevant to important management issues. Cause-and-effect relationships usually cannot be demonstrated with monitoring data, but monitoring data might suggest a cause-and-effect relationship that can then be investigated with a research study. As monitoring proceeds, as data are interpreted, as our understanding of ecological processes is enhanced, and as trends are detected, future issues will emerge (Roman and Barrett 1999). This 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.

Chapter 2: Conceptual Ecological Models

2.1 Introduction

Conceptual models are theoretical constructs used to represent complex processes by showing the relationships between a number of variables. Ecosystem structure and function involve varied and complex relationships, and thus the use of conceptual models can help enhance our understanding of ecosystems (Heemskerk et al. 2003, Maddox et al. 1999). In addition, conceptual models can improve communication among scientists and managers, and between managers and the public.

Conceptual models are essential to designing credible and effective ecological monitoring programs. Ecological systems are highly integrative and complex, and their response to novel environmental or biotic conditions often is poorly understood. The intent of conceptual models for monitoring design is not to represent the full complexity of a system, but rather to use current knowledge to identify a limited set of elements that provide information on multiple aspects of ecosystem condition (Noon 2003). Moreover, conceptual models can help scientists generate hypotheses regarding consequences of natural and anthropogenic processes on system structure and function.

Several conceptual ecological models have been an important part of the development of the Mid-Atlantic Network's vital signs monitoring program. These models enable us to explore the external processes that influence ecosystems ("drivers"), the key products of human activities or natural events that alter ecosystem integrity ("stressors"), and likely pathways of ecosystem degradation and other changes in system structure and function. In this way, conceptual models aid us in identifying key system indicators–our set of vital signs. Concentrating monitoring efforts on these vital signs ensures that the monitoring program will yield information useful for understanding ecological conditions and changes, and for informing park management.

2.2 MIDN Approach

Experience in long-term monitoring at Shenandoah NP provided the ideal setting for an initial scoping meeting which was held in 2005. The goal was to 1) identify the relationships between physical, chemical, and biotic components of the park's terrestrial and aquatic ecosystems, 2) outline how the interaction of landscape and climate affects ecological processes in the park, 3) identify how anthropogenic influences alter the natural processes of the park, and 4) define how these ecological relationships and external influences differ in the small cultural parks that make up the rest of the MIDN. The two-day meeting resulted in a series of draft conceptual models that were further refined in collaboration with the network Science Advisory Committee. These models formed the basis for selecting vital signs for monitoring.

2.3 Natural Ecosystem Model

The MIDN started with a modified version of the interactive control model developed by Jenny (1941, 1980) and modified by Chapin et al. (1997, 1996) to help summarize general functions and processes for terrestrial and aquatic ecosystems (Figure 2.1). This model provides a framework for the planning process and helps identify vital signs that are most relevant to the natural resource issues experienced in the network. This holistic model identifies four state factors and four interactive controls that influence ecosystem processes under natural conditions. The state factors are geology, topography and elevation, climate, and latitude.

Cardinal flower (*Lobelia cardinalis*)

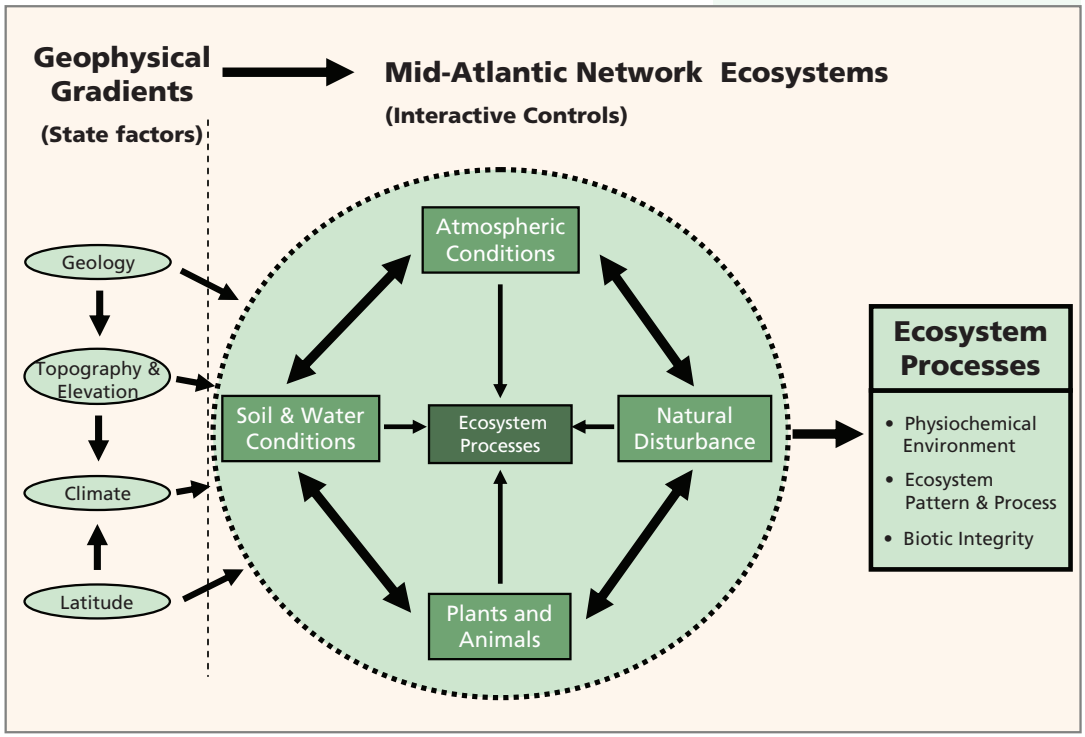
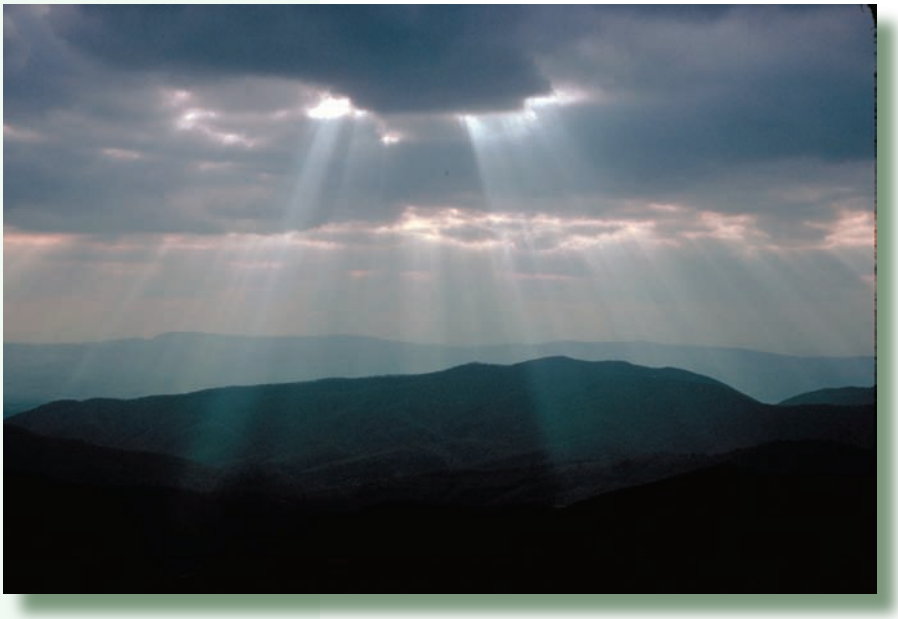


Figure 2.1. Holistic natural ecosystem model for the Mid-Atlantic Network. Geophysical gradients or state factors are major drivers that influence ecosystems. Interactive controls determine ecosystem composition and processes.



Shenandoah National Park

Conceptual models are essential to designing credible and effective ecological monitoring programs.

They vary along environmental gradients and usually change only over long periods (tens of thousands of years) (Austin 1985, Austin and Heyligers 1989, Guisan and Zimmermann 2000). State factors influence soil and water conditions, atmospheric conditions (including regional climate), natural disturbance processes, and biotic interactions between plants and animals, which are collectively referred to as interactive controls (Chapin et al. 1997). These interactive controls are ecosystem drivers that can have large-scale influences on natural systems, such that major changes in these interactive controls will result in new ecosystems with different properties (Chapin et al. 1996).

2.3.1 Natural Ecosystem Processes

Life on Earth operates through a series of natural processes that support ecosystem function (Lugo et al. 1999). These processes include a variety of biogeochemical cycles (including the carbon, phosphorous, nitrogen, water, and oxygen cycles) that ensure critical elements are not lost from the environment and are made available to the biota by various pathways (see for example Agren and Bosatta 1998, Loreau 1998). Species interact directly as producers, consumers (including herbivores, carnivores, and omnivores), and detritivores. Energy flow in an ecosystem can be summarized as a food chain or web, which illustrates the components that occur at different trophic levels. Species compete for resources through predation or parasitism, or share resources through mutualism or commensalism.

Ecosystems are dynamic, and changes in conditions through natural disturbances or variations in resource availability induce succession from one community type to another. Seasons also produce periodic change in biotic communities, a process known as phenology that includes spring blooms and migration patterns. Longer-term fluctuations also influence ecosystem processes. For example, masting cycles of oaks affect the feeding habits, reproductive success, and population dynamics of large mammals such as black bear (*Ursus americanus*) (Kasbohm et al. 1996a, Kasbohm et al. 1996b) and white-tailed deer (*Odocoileus virginianus*) (Johnson et al. 1995, McShea and Schwede 1993), as well as rodents (Wolff 1996) and birds (McShea 2000, Norman and Steffen 2003). Other ecological interactions between plants and animals include pollination and seed dispersal (Yahner 2000).

2.3.2 Factors Influencing Natural Ecosystem Processes

As outlined above, the interactive controls act as ecosystem drivers that can affect natural ecosystem processes (Chapin et al. 1996). In the following sections we will evaluate the influence of the four interactive controls.

2.3.2.1 Soil and water conditions

Soil distribution and type is determined by underlying geology, topography and elevation, hydrology, and present and historic climatic conditions (Figure 2.1; Soil Survey Division Staff 1993). The physical and chemical characteristics of the soil, including structure, available elements, pH, and moisture content, determine the plant and animal species that exist in an area (Coleman et al. 2004, Hassett and Banwart 1992). The uppermost layer of soil is composed of organic debris covering a topsoil of humus, and it is within this upper layer that most plant roots are located (White 1979). Soils are very rich in biological diversity, yet the function of soil biota is poorly known; understanding the role of soil biodiversity in carbon and nitrogen cycles is an important research need for evaluating impacts of natural and anthropogenic disturbances (Fitter et al. 2005). Fertile and productive soils are characterized by low soil carbon sequestration rates and high nutrient supply rates, which benefit plant growth (Wardle et al. 2004). In temperate regions, rainfall is sufficient to percolate through the soil down to the water table, leaching with it minerals and nutrients. Depending on buffering capacity, such soils become acidic without the input of natural or anthropogenic fertilizers (EPA 2005a). Alterations in air quality, climate change, and land use change are the

primary factors that can influence soil quality, and changes in soil resources can drastically alter ecosystem sustainability (Chapin et al. 1996).

Water quality and quantity are the major components of water condition, and are regulated by climate, elevation and topography, and geology (Figure 2.1). Rainfall patterns influence where water reaches land; the underlying geology and soils, temperature, and biotic communities define how the water moves along the land and what proportion of it will percolate to the water table. For example, winter temperatures may cause drought conditions by freezing water and making it unavailable to plants (Cordero and Nilsen 2002); the canopy structure and ground cover of a particular plant community influences how much water is intercepted prior to reaching the ground (Wynn et al. 2000). Atmospheric conditions influence the pH and chemical composition of rainfall (as detailed below), while geology determines how rainfall chemistry influences terrestrial and aquatic processes. In turn, alterations in water conditions will result in changes in ecosystem structure, function, and composition.

2.3.2.2 Atmospheric conditions

Atmospheric conditions include local climate trends such as rainfall, temperature, cloud cover, and weather patterns, as well as the chemical composition of the atmosphere. The major influences on atmospheric conditions are regional climate, topography and elevation, and latitude, and these determine temperature and moisture conditions and associated atmospheric processes (Figure 2.1). Likewise, processes in terrestrial and aquatic ecosystems feed back to the atmosphere through the exchange of water and gases via respiration, photosynthesis, and evapotranspiration. For example, fires produce particulate matter that contributes to haze and impaired visibility; deforestation may alter local climate conditions through changes in evapotranspiration rates and gas exchange. Atmospheric conditions are closely linked to water conditions because of the atmosphere's role in determining rainfall chemistry.

2.3.2.3 Plants and animals

The biotic community at a particular location is largely determined by the availability of resources (such as water and light for photosynthesis) that vary along geophysical gradients (such as climate and latitude; see Figure 2.1). Soils determine the type of vegetation that a particular location can sustain (Coleman et al. 2004), while the disturbance regime influences community structure and composition (Pickett and White 1985). Plant and animal communities also influence each other. For example, forest type determines vertebrate and invertebrate composition at a particular location; fluctuations in native and exotic pests affect tree and shrub defoliation and mortality patterns, which in turn determine understory conditions and influence the nesting success of birds (Thurber et al. 1994) and survival of small mammals (Muzika et al. 2004), reptiles, and amphibians (Raimondo et al. 2003). Changes in the population sizes of prey species directly influence predator success, and a lack of predators (or other changes in ecosystem structure and function) benefit prey species. For example, white-tailed deer populations have increased drastically in the Northeast (Decalesta et al. 1997, McShea et al. 1997), and their heavy grazing is altering understory composition in many forests (Webster et al. 2005). In turn, this disturbance is creating conditions beneficial for invasive exotic plant species and is thus likely to result in long-term changes to northeastern forest ecosystems (Rooney et al. 2004).

The influence of gypsy moths (*Lymantria dispar*) on ecosystem processes illustrates the complexity of biotic interactions in the Mid-Atlantic region. In years of heavy gypsy moth infestation, a large proportion of oak trees are

Eastern redbud (*Cercis canadensis*)

Marbled orb weaver (*Araneus marmoreus*)

Ice storms can be a frequent natural disturbance in Shenandoah National Park

defoliated and may die (Jones et al. 1998). Those that survive are weakened and may produce a lower yield of acorns the following year, which in turn affects the population densities of species, such as many rodents, that depend on the acorns as a primary food source. Higher rodent mortality benefits scavengers, but predators of rodents suffer from lower reproductive success due to lower prey densities (Jones et al. 1998).

2.3.2.4 Natural disturbance regimes

Ecosystems are dynamic, maintained by natural disturbance events that vary in their frequency and severity (Pickett and Thompson 1978, Pickett and White 1985, White et al. 1999) and create spatially heterogeneous communities (Sousa 1984). In the MIDN, natural disturbances can range from yearly events such as the creation of trails by mammals or lateral erosion of streams and rivers, to decadal events such as tree falls that produce gaps in the forest canopy (Runkle 1985, Runkle 1998, Runkle 2000). Other types of disturbance may influence greater areas but occur less often, such as high winds and tropical storms (Brokaw 1982, Brokaw and Walker 1991, Lugo and Scatena 1996), ice storms (Lafon 2004, Likens et al. 2004, Millward and Kraft 2004), and fire (Abrams et al. 1995, Regelbrugge and Smith 1994). In September 2003, Hurricane Isabel made landfall in North Carolina as a Category 2 storm, and tracked through Virginia as a tropical storm with sustained winds of 55-80 kilometers per hour (km/h) (30-50 miles per hour, mph) and 110 mm (4.3 in) of rainfall (Beven and Cobb 2004). The MIDN parks most affected by the storm were Petersburg NB, Richmond NBP, Fredericksburg and Spotsylvania NMP, and Shenandoah NP, experiencing numerous tree falls that have subsequently influenced bird (Bradshaw 2007), amphibian, and reptile communities (Mitchell 2007).

In aquatic ecosystems, natural disturbance is related to water movement of varying frequency and severity. Periodic flooding creates lateral and vertical erosion, clears excess debris from stream channels (Crandall et al. 2003, Fausch et al. 2001, Friedman and Lee 2002, Lytle 2002), and influences riparian communities at the interface between aquatic and terrestrial ecosystems (Foster et al. 1998, Friedman and Lee 2002, Levine 2000). Debris flows resulting from severe flooding can cause extensive damage. A debris flow occurred in the Staunton River of Shenandoah NP in 1995 following 762 mm (30 inches) of rainfall over 16 hours (Johnson and Snyder 2001). Trees were removed along a stretch of riparian zone 30 meters (98 ft) wide; deep scouring resulted in the creation of a new stream channel and the loss of all fish species (Roghair et al. 2002). Benthic communities were impacted at a level similar to heavy anthropogenic disturbance (Johnson and Snyder 2002).

Drought also acts as a form of natural disturbance. In terrestrial ecosystems, a lack of water restricts plant growth (Grime 1997, Nowacki and Abrams 1997) and alters animal behavior and reproductive success. For example, disjunct eastern tiger salamander (*Ambystoma tigrinum tigrinum*) populations in Shenandoah NP have been threatened by successive years of drought (Buhlmann and Mitchell 2000). In aquatic ecosystems, declining water levels reduce available habitat for aquatic species and may create hypoxic conditions (Fritz and Dodds 2005). Drought can reduce the extent of wetlands, affecting the availability of resources needed by wetland birds (Krapu et al. 2001). In both terrestrial and aquatic ecosystems, changes in the frequency and severity of natural disturbances

Hopewell Furnace National Historic Site (right)

result in long-term changes in ecosystems (Chapin et al. 1996).

2.4 Anthropogenic Stressor Model

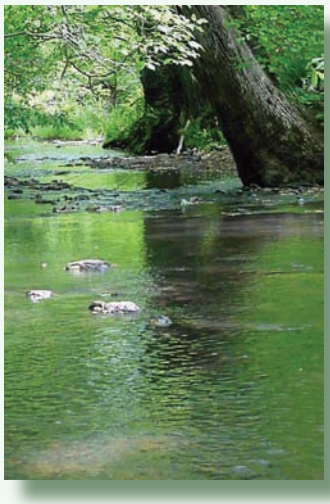
Few, if any, ecosystems today operate without anthropogenic influences, which thus are a major driver of ecosystem structure and function. Anthropogenic influences can be observed in all MIDN parks, and operate through a series of stressors that alter ecosystem processes (Figure 2.2).

Stressors are defined as 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). Stressors cause significant changes in the ecological components, patterns, and processes in natural systems. The MIDN has identified five major stressors, related to the interactive controls described above, that operate in the region: air quality degradation, water quality and quantity changes, climate change, land use change and management, and biotic change.

2.4.1 Air Quality Degradation

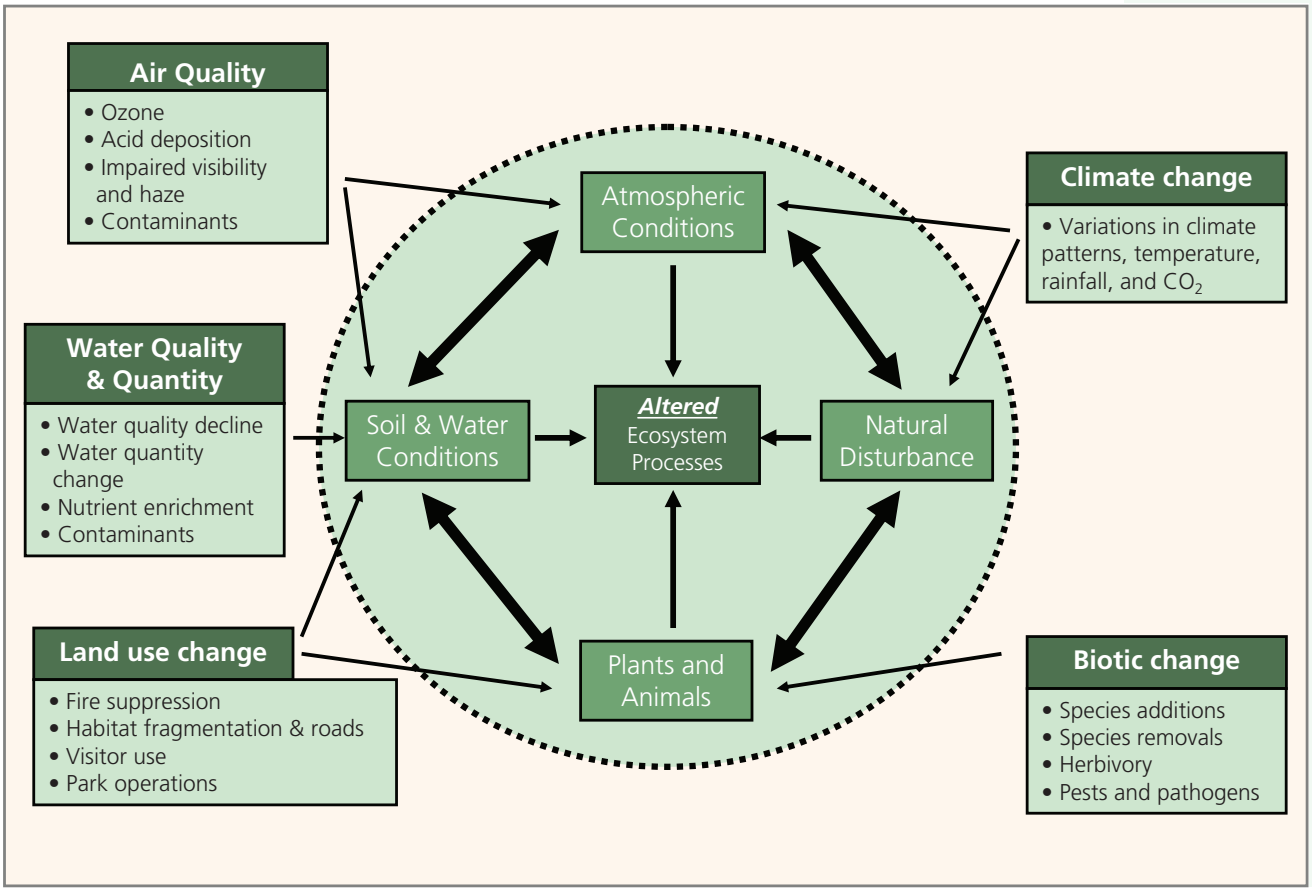
A number of air quality factors contribute to ecosystem stress in the Mid-Atlantic region, including acid deposition, ground-level (tropospheric) ozone, haze, and other airborne contaminants. The majority of the air pollutants that affect MIDN parks are derived from outside the parks. Monitoring efforts at Shenandoah NP reveal that less than 1% of such pollutants originate within the park's boundaries (NPS 2002). This percentage is likely to be similar for other MIDN parks, although pollutants generated within Valley Forge NHP may be higher because of the presence of a commuter road through the park. Air pollutants in this region are primarily derived from burning of fossil fuels in the Ohio River Valley, and are transported eastward by winds in the troposphere. Sulfates and nitrates combine with atmospheric moisture and oxygen to form sulfuric acid and nitric acid, which reach the ground as acid deposition in snow or rain (Peterson 1995). Dry deposition of sulfur particles may also occur. Shenandoah NP has one of the highest acid loads of any NPS unit in the country (Nash et al. 1995), with an estimated annual wet and dry deposition of 13 kg/ha/yr for sulfur and 8 kg/ha/yr for nitrogen (Sullivan et al. 2003).

Ground-level ozone (O_3) is formed by the phyto-oxidation of nitrogen oxides and volatile organic compounds, and may be transported to locations quite remote from where it is formed



Appomattox River

Figure 2.2. Anthropogenic stressor model for the Mid-Atlantic Network. Human influences play a major role in determining ecosystem structure and function in the MIDN.



City Point, Petersburg National Battlefield

(Hakami et al. 2004). Ground-level ozone levels are highest in the eastern United States (Lehman et al. 2004). Ozone is a phytotoxin, causing damage to the upper surface of leaves and reducing photosynthesis rates (Bussotti et al. 2003, Orendovici et al. 2003, Schaub et al. 2005). Levels above 25 parts per million per hour (ppm/hr) are thought to be damaging to plants (Sullivan et al. 2003). In 1999 and 2000, the mean and maximum ozone exposures at Big Meadows in Shenandoah NP were 47 ppm/hr and 87 ppm/hr respectively. Ozone concentrations can be higher at higher elevations.

Few, if any, ecosystems today operate without anthropogenic influences, which thus are a major driver of ecosystem structure and function.

Particulate matter is also transported from industrial areas and can, in combination with ozone, contribute to haze and reduced visibility. Scenic vistas are a major visitor attraction in Shenandoah NP, but the park's current annual average visual range is only about 20% of its estimated natural visual range of 185 miles (298 km) (Sullivan et al. 2003), thus impairing visitor enjoyment. In this park, reduced visibility has been linked to increases in the atmospheric concentration of ammonium sulfate.

Mercury, among the most important atmospheric contaminants, is also produced by burning fossil fuels, primarily from incinerators and coal-powered boilers (EPA 1998). Mercury is of particular concern as it accumulates in the environment and is transferred up the food chain to humans. Aquatic habitats are most susceptible to mercury accumulation (Naimo 1995). Recreational activities in some MIDN parks, especially Valley Forge NHP, have been impaired due to mercury levels in fish.

2.4.2 Water Quality and Quantity Changes

Major water pollutants, including nutrients, toxic chemicals, and pathogens, are introduced via point and non-point sources (EPA 2005a). Water pollutants affect both surface and groundwater sources. To date, more than 34,000 impaired waterways have been identified in the United States, with 1,085 in Virginia and 4,298 in Pennsylvania, the two states where MIDN parks are located (EPA 2005b). In Virginia, impairment is primarily due to pathogens, heavy metals, and organic enrichment that results in low dissolved oxygen. In Pennsylvania, impairment is caused by sedimentation, heavy metals, and nutrients. In the Mid-Atlantic region, air pollution contributes to water pollution; heavy metals, particularly mercury, are introduced to waterways through atmospheric deposition. Continued development in the region has increased the amount of impervious land surface, which both impedes and accelerates water flow, and increases pollutant accumulation in surface water before it enters streams and other waterways (Chesapeake Bay Program 2005). Other alterations to the landscape that contribute to degraded water quality include deforestation, conversion to agricultural use of land, and loss of riparian buffers (Jantz et al. 2005).

2.4.3 Climate Change

Global climate is changing as a result of fossil fuel emissions, primarily carbon dioxide (CO_2) and methane, which are enhancing the atmosphere's ability to trap heat (Hannah and Lovejoy 2003, IPCC 2007). Global average

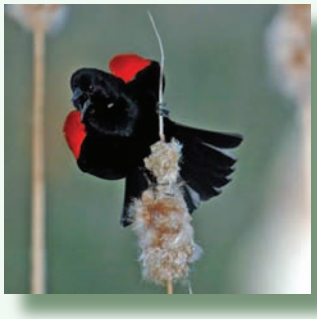
temperature is expected to increase by about 2.5°C-5.5°C (4.5-9.9°F) by the end of the 21st century (Fischer et al. 2000). However, changes in rainfall patterns and other aspects of climate that will result are uncertain. Although the specific effects are similarly unknown, changing climate is likely to affect a variety of ecosystem processes including the population structure, composition, and dynamics of various plant and animal communities (Iverson et al. 2008, Rodenhouse et al. 2008, Shuggart 2003), pollination (Memmott et al. 2007), seed dispersal (Scheller and Mladenoff 2005), predator-prey relations (Wilmers et al. 2007), herbivory, plant-microbial interactions (Hughes 2003), and the vulnerability of various species to pests and pathogens (Dobson et al. 2003, Paradis et al. 2008). Disturbance regimes will be altered (Johnson and Cochrane 2003), and elevated CO_2 will influence plant primary production (Drake and Rasse 2003). As climate changes, protected areas will play a key role in species and ecosystem protection, requiring adjustments to current management (Hannah and Salm 2003).

2.4.4 Land Use Change and Management

Land use change and management is an issue of significant concern in the Mid-Atlantic region. The primary cause of land use change is an increasing human population, which has swelled from 15 million in 1950 to 26 million in 2000 (Mid-Atlantic Integrated Assessment 2005c). Larger human populations require more space for homes, shops, roads, and recreation, resulting in urban sprawl. In 15 watersheds in the Mid-Atlantic region, the human use index (the proportion of the watershed used for agriculture or urban development) is over 50% (Mid-Atlantic Integrated Assessment 2005b). Land use change influences water quality and quantity, decreases the extent and connectivity of natural habitats, and changes the structure and composition of natural communities (Turner et al. 1998). Some species, such as invasive exotic species (Porter and Hill 1998) and white-tailed deer (Weber 2004) are favored by urbanization and land use change, and their increased population densities may in turn influence ecosystem structure and function.

White-spotted slimy salamander (*Plethodon cylindraceus*)

Some land use and management stressors originate within the boundaries of NPS units. Annual visitation at MIDN parks ranges from about 18,000 at Booker T. Washington NM to 6.6 million at Valley Forge NHP (2007; NPS 2007), the latter including non-recreational visitors. Much of the visitation at these parks is related to their cultural resources, though increasing numbers of visitors are using the MIDN parks for recreational purposes. Visitor use impacts on wildlife and water resources are usually related to trails and other means of visitor access (Marion and Cahill 2004). At Valley Forge NHP, a road used by commuters accounts for a large proportion of park visitation, and such commuter or connector roads also exist in some other MIDN parks. Management actions within the parks influence natural resources, such as through maintenance of roads, clearing of vistas, mowing of fields, and construction and maintenance of trails (Leung and Marion 1999). Fire management operations also influence terrestrial and aquatic habitats. Septic systems and wastewater treatment within parks may also be an influence.



Red-winged blackbird (*Agelaius phoeniceus*)

2.4.5 Biotic Change

Changes in biotic communities can result from species introductions, extirpation of native species, or changes in the density of certain

Flowering dogwood (*Cornus florida*) in fall

Table 2.1. Ecological effects of stressors can be divided into those that affect ecosystem physiochemical environment, ecosystem pattern and process, and biotic integrity. Each category shows the types of effects expected.

Physiochemical Environment	Ecosystem Pattern & Process	Biotic Integrity
Air, water and soil chemistry	Succession	Species distribution
Climate and weather patterns	Hydrological cycles	Species abundance
Hydrography	Nutrient cycles	Species composition
Soil structure	Phenology	Community structure
	Reproductive cycles	Genetic diversity
	Migration patterns	
	Population dynamics	
	Landscape pattern	
	Productivity	
	Natural disturbance	

species. In some situations, invasive exotic species can behave as pests or cause disease that results in heavy mortality of native species, altering resources for other species and resulting in changes in ecosystem function.

Invasive species have become a major issue of concern throughout the United States (Li 1995) and present a considerable challenge for National Park Service natural resource management (Drees 2004, Loope 2004). The presence and abundance of invasive species is often used as an indicator of ecosystem health (Concannon et al. 1999). Exotic species can alter ecosystem processes and change the structure and composition of natural communities (for example, Walker and Smith 1997, Woods 1997). Native species are frequently displaced by the higher competitive ability of exotic species (Amarasekare 2002, Byers and Noonburg 2003, Loehle 2003, Sax and Brown 2000). Some introduced species act as pests or pathogens, for example the American chestnut blight (*Cryphonectria parasitica*) or hemlock woolly adelgid (*Adelges tsugae*). Not all species are common, and recent reviews suggest that less common species may play a significant role in ecosystem processes (Lyons et al. 2005). Likewise, some native species have become locally overabundant due to anthropogenic influence, such as white-tailed deer in the Mid-Atlantic region (Decalesta et al. 1997, McShea et al. 1997), causing negative effects on the rest of the ecosystem.

Field teams establish permanent vegetation monitoring plots at Saratoga National Historical Park, NY. This combined field team operates in two networks, the Northeast Temperate Network and the Mid-Atlantic Network

2.5 Ecological Effects

Drivers and stressors have a variety of ecological effects on the physical, chemical, and biological elements of an ecosystem, and change ecological patterns and processes (Table 2.1). The MIDN has identified three major groups of ecological effects:

- **Physiochemical environment**: includes changes to the physical and chemical matrix of the ecosystem such as alterations in soil and water conditions, changes in local or regional hydrography, and modifications to climatic patterns and air quality.

- **Ecosystem pattern and process**: includes alterations in the landscape pattern, changes in ecosystem processes including nutrient cycles, hydrological cycles, succession, phenology, reproductive cycles, productivity, and migration patterns.

- **Biotic integrity**: includes changes in species abundance and distribution as well as modifications in community structure and composition.

2.6 Terrestrial and Aquatic Ecosystem Models

The ecological effects of stressors vary between terrestrial and aquatic ecosystems. Appendix G provides additional detailed information and relevant literature, along with diagrammatic models of the ecological effects of stressors on MIDN ecosystems.

2.7 Use and Further Development

The MIDN used conceptual modeling to help select vital signs for its monitoring program, as is outlined in the next chapter. Currently, the network is continuing to develop these models to expand their use relating to the selected vital signs to (1) show the connections between the vital signs, and (2) assist in interpreting results of the long-term monitoring effort.

Chapter 3: Vital Signs

3.1 Introduction

The term "vital sign" is defined in this program as one of "a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values" (http://science.nature.nps.gov/im/monitor/). In this chapter, we describe the vital signs selected for monitoring in the Mid-Atlantic Network, and the process used to select and prioritize these vital signs.

The MIDN has identified 20 vital signs that represent a systems approach to our monitoring program. Five of these vital signs relate to air and climate, two to geology and soils, four to water, eight to biological integrity, and one to ecosystem pattern and processes. Five of the vital signs will be monitored by compiling data from other sources, 10 will be monitored through protocols to be developed and implemented at the parks over the next three to five years, and the remaining five are considered high priority but will not be implemented at this time due to staff and funding limitations.

3.2 Selecting Vital Signs

Selection of vital signs began with the initial scoping of park resources (Chapter 1) and the development of conceptual models (Chapter 2; Figure 3.1). Next, the network Science Advisory Committee (SAC) met on January 12, 2006, to provide guidance on the best approach for selecting vital signs given the natural resources priorities and issues in the MIDN, the current funding available to the network, and the experience of other neighboring networks in prioritizing and selecting their vital signs. The SAC agreed that the MIDN should follow guidance provided by the national Inventory and Monitoring (I&M) Program office for selecting vital signs, with some modifications. The process prescribed by the SAC is outlined in Appendix H.

The SAC also discussed how to integrate Shenandoah National Park into the vital signs selection process, since it was the only park in the network that already had an extensive monitoring program. The consensus was that Shenandoah would benefit from being included in the process but that ranking of potential vital signs would need to be conducted separately due to differences in Shenandoah's mandate, ecological setting, and natural resource issues, priorities and threats compared to the small, cultural parks that make up the rest of the MIDN.

3.2.1 Vital Signs Pre-Selection

At the SAC meeting in January 2006, MIDN staff presented a preliminary list of 48 potential

Figure 3.1. Stages in the development and selection of Mid-Atlantic Network 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.

Acidic Oak-Hickory Forest, Fredericksburg and Spotsylvania National Military Park

vital signs. SAC members were asked to review this list to reduce duplication and suggest additional relevant indicators for monitoring, resulting in a list of 39 proposed vital signs that were discussed and evaluated with park staff in the next stages of the selection process.

3.2.2 Park Evaluation

The list of 39 proposed vital signs was discussed with park staff at a series of meetings in March and April 2006. The meetings brought together all park staff with an interest in helping to further refine and comment on the proposed vital signs list, including resource branch chiefs, natural resource managers, park ecologists, and technicians. Three meetings were held: (1) at Petersburg National Battlefield (April 18) for the Virginia parks, (2) at Valley Forge National Historical Park (April 20) for the Pennsylvania parks, and (3) at Shenandoah National Park (March 27) for issues specific to this park. Participants reviewed the proposed vital signs to ensure that this group of indicators would meet the natural resource monitoring needs of the parks. Some indicators were added while others were removed and merged.

3.3 Ranking the Vital Signs

A final list of 43 vital signs was selected and approved by the SAC for ranking. Supporting material was developed for each vital sign, including a justification for monitoring, information on related environmental issues, examples of monitoring questions and management applications, proposed metrics and their efficiency, and prospective methods for monitoring (Comiskey et al. 2006). Most of these reviews were based on vital signs summaries prepared by the Eastern Rivers and Mountains Network (Brooks et al. 2005, Rentch 2005), with additional vital signs that were relevant to the Mid-Atlantic Network.

3.3.1 External Ranking

Vital signs ranking was conducted between May 19 and June 9, 2006. A total of 97 people participated in the process, with 51% responding to all 43 vital signs and 70% ranking more than half them (Appendix H provides a brief report on the results of the ranking). Participants included members of the network SAC, park managers and technicians, and a wide range of subject matter experts from other government and state agencies, universities, and NGOs in the Mid-Atlantic region (Comiskey et al. 2006). The ranking was conducted via a Web-based interface, allowing a greater number of subject matter experts to participate than would have been possible through a workshop format. Each vital sign was presented along with summary information (Comiskey et al. 2006) and links to the more detailed review document and relevant conceptual models outlined in Chapter 2. Participants ranked the ecological significance of each vital sign based on four criteria: (1) ability to provide a clear link to ecological function, (2) ecological importance, (3) ability to act as an early warning signal, and (4) sensitivity to change (Table 3.1), using a categorical scale (from "Very Low" to "Very High") for each criterion to represent the importance, relevance, or significance to the vital sign.

The subject matter experts and the members of the SAC applied the four ecological significance criteria separately to the small, cultural parks of the Piedmont and Coastal Plain and to Shenandoah National Park. Park staff ranked the ecological importance of each vital sign specific to their park. In addition, they ranked the vital signs based on management and policy significance using the following criteria: (1) importance for satisfying legal and policy mandates, (2) ability to provide information needed for management decision-making, (3) representativeness of a resource or issue of management significance, and (4) ability to produce results that are clearly understood for management decision-making (Table 3.1).

Results from the ecological significance and management significance rankings were combined, with each aspect weighted equally (50% ecological and 50% management). For the small, cultural parks, the top five vital signs were Water Chemistry, Wetland Communities, Aquatic Macroinvertebrates, Invasive Exotic Plants, and Forest Plant Communities (Table 3.2). Similarly, the final prioritized list for Shenandoah NP included Aquatic Macroinvertebrates, Water Chemistry, Brook Trout, Forest Plant Communities, and Fish Communities.

3.3.2 Feasibility Ranking

Network staff conducted a feasibility ranking of the proposed vital signs (Table 3.1), Using the following criteria: (1) feasibility for implementation, (2) cost effectiveness, (3) ability to co-locate with other high-priority vital signs, (4) opportunities for collaboration and cost-sharing, and (5) potential for data compilation from other sources. Each vital sign was scored

Table 3.1. Categories used for ranking vital signs based on ecological significance, management and policy significance, and feasibility.

VS Ecological Significance Ranking Criteria
• **Clear link:** there is a strong, defensible link between the vital sign and the ecological function, critical resource, or stressor it is intended to represent.
• **Ecological importance:** the vital sign represents a resource or function of high ecological importance based on available supporting ecological literature and conceptual ecosystem models.
• **Early warning:** the vital sign provides an early warning of undesirable changes to important resources. It can signify an impending change in the ecological system.
• **Sensitive:** the vital sign is sufficiently sensitive to detect change; it has a high signal to noise ratio and does not exhibit large, naturally occurring variability.
VS Management Significance and Legal Mandate Ranking Criteria
• **Legal/policy mandate:** monitoring the vital sign is important for satisfying legal or policy mandates.
• **Management decisions support:** the vital sign provides data needed for key natural resource decision making, or for evaluating the outcome of management practices.
• **Resource management importance:** the resource or issue represented by the vital sign is important for resource management relative to other resources or issues in the park.
• **Clear understanding:** the vital sign produces results that are clearly understood and accepted by park managers, policy makers, and the general public, all of whom can recognize the implications of results for protecting and managing the park's natural resources.
VS Feasibility Ranking Criteria
• **Feasibility:** is the vital sign logistically possible to implement by the network? Can the sampling meet the objectives set for monitoring that vital sign? Will the network be able to collect meaningful data that will allow us to detect the desired level of change?
• **Cost:** is the vital sign cost effective to measure? Will the cost of its implementation preclude the implementation of other important vital signs?
• **Co-location:** can the vital sign be combined with other vital signs to form part of a protocol that will facilitate its measurement in the field?
• **Collaboration:** is this vital sign being measured by other neighboring networks or other agencies? Is there an opportunity for collaboration in developing the protocols? Would sharing of results with other networks enhance the value of implementing this vital sign?
• **Data compilation:** Is the vital sign already being collected by another agency and hence will involve compiling existing data? Would the compiled data provide a useful addition to other vital signs that are implemented in the field?

on a scale of 1 to 5 for each of the criteria (Appendix H). This process allowed the network to consider the inclusion of vital signs that received low scores in the ecological and management rankings, but that might be relatively easy to monitor given existing sources of data and the other vital signs that would be monitored. For example, air quality indicators scored low in the ecological and management rankings (Table 3.2), but monitoring them by compiling data from other sources would cost relatively little and would provide valuable information on stressors to MIDN ecosystems. Therefore, several of these indicators were included in the final list of vital signs for monitoring. Likewise, since the Forest Plant Communities indicator received high scores, several lower-scoring but related indicators such as Exotic Plant Diseases and Native Forest Pests could easily be incorporated into a vegetation monitoring protocol without adding significant cost.

At the end of the feasibility evaluation, the network proposed to the SAC the list of vital signs divided into three categories: (1) those that should be the focus of immediate attention for protocol development and implementation, (2) those considered high priority but that would not be not developed at this time due to funding and personnel limitations, and (3) those that should be removed from the vital signs list

Table 3.2. Results of vital signs ranking based on ecological significance, and management and policy significance.

MIDN Vital Sign	Score	Ranked	SHEN Vital Sign	Score
Water Chemistry	3.98	1	Aquatic Macroinvertebrates	4.01
Wetland Communities	3.96	2	Water Chemistry	4.01
Aquatic Macroinvertebrates	3.93	3	Brook Trout	3.91
Invasive Exotic Plants	3.91	4	Forest Plant Communities	3.91
Forest Plant Communities	3.85	5	Fish Communities	3.89
White-tailed Deer	3.85	6	T&E - Federal	3.88
Land Cover and Land Use	3.74	7	Wetland Communities	3.85
T&E – Federal	3.74	8	Wet and Dry Deposition	3.84
Amphibian & Reptile Communities	3.72	9	White-tailed Deer	3.83
Wetland Water Dynamics	3.65	10	Invasive Exotic Animals	3.78
Invasive Exotic Animals	3.65	11	Invasive Exotic Plants	3.75
Breeding Birds	3.58	12	Stream & River Water Dynamics	3.75
T&E – State	3.57	13	Amphibian & Reptile Communities	3.72
Riparian Communities	3.57	14	Ozone	3.72
Stream & River Water Dynamics	3.52	15	Visibility & Particulates	3.70
Fish Communities	3.48	16	Wetland Water Dynamics	3.68
Stream Channel Characteristics	3.44	17	Visitor Use Impact	3.62
Visitor Use Impact	3.42	18	T&E - State	3.58
Exotic Diseases – Plants	3.39	19	Exotic Diseases - Plants	3.55
Species of Special Concern	3.31	20	Riparian Communities	3.55
Groundwater Dynamics	3.29	21	Groundwater Dynamics	3.52
Exotic Diseases – Animals	3.26	22	Air Contaminants	3.52
Grassland Plant Communities	3.22	23	Bioaccumulation	3.51
Bioaccumulation	3.19	24	Breeding Birds	3.46
Mammals	3.18	25	Land Cover and Land Use	3.45
Terrestrial Invertebrates	3.16	26	Mammals	3.34
Wet and Dry Deposition	3.12	27	Weather and Climate	3.23
Air Contaminants	3.04	28	Exotic Diseases - Animals	3.22
Ozone	3.03	29	Stream Channel Characteristics	3.21
Periphyton	3.02	30	Viewscape	3.13
Visibility & Particulates	3.01	31	Grassland Plant Communities	3.11
Lichens and Fungi	2.95	32	Species of Special Concern	3.09
Viewscape	2.89	33	Seasonal Trends	3.05
Harvesting and Poaching	2.85	34	Terrestrial Invertebrates	3.01
Weather and Climate	2.85	35	Soil Structure and Composition	2.97
Soil Structure and Composition	2.82	36	Harvesting and Poaching	2.96
Native Forest Pests	2.78	37	Lichens and Fungi	2.83
Seasonal Trends	2.75	38	Periphyton	2.65
Soundscape	2.67	39	Soundscape	2.59
Hillslope Processes	2.50	40	Native Forest Pests	2.58
Caves and Sinkholes	2.49	41	Hillslope Processes	2.49
Paleontological Resources	2.39	42	Caves and Sinkholes	2.38
		43	Paleontological Resources	2.27

because they are of low priority to the network. In addition, network staff proposed a series of protocols that would combine the various vital signs into an efficient monitoring program.

3.3.3 Final Prioritization and Approval

The Science Advisory Committee evaluated the results of the vital signs ranking, considered the feasibility ranking conducted by network staff, and determined whether the proposed vital signs and monitoring protocols were appropriate for the network. Based on the committee's feedback, MIDN staff revised the plan and submitted it to the network parks for review and comment. Additional adjustments were made based on park feedback, and the final prioritized list of vital signs for the MIDN was submitted to the network Board of Directors for approval, which was granted by mid-September 2006.

3.4 Mid-Atlantic Network Vital Signs

3.4.1 Prioritized List

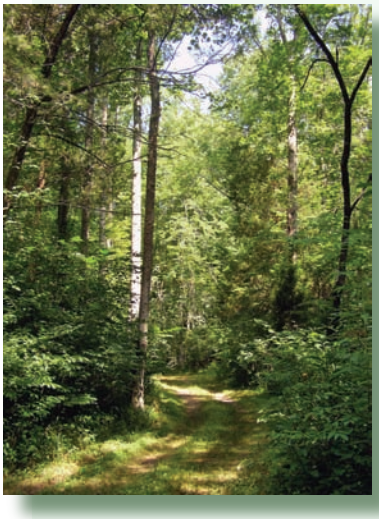
The MIDN has identified 20 vital signs: five relate to air and climate, two to geology and soils, four to water, eight to biological integrity, and one to ecosystem pattern and processes (Table 3.3).

Fifteen vital signs are proposed for monitoring. The remaining five will not be implemented at this time because of funding and personnel limitations—the network is choosing to monitor fewer vital signs to ensure high-quality data for those that are monitored. Of the vital signs proposed for monitoring, five will involve compilation of data available from other sources, and ten will be monitored through protocols to be developed and implemented over the next three to five years.

In Shenandoah National Park, which already has a monitoring program in place, the results of the ranking process will be used to evaluate the park's current monitoring priorities and to identify potential gaps in the program. As shown in Table 3.3, there is considerable overlap between the indicators ranked as most important in Shenandoah NP and the rest of the MIDN parks.

3.4.2 Link to Conceptual Models

The vital signs selected by the MIDN for monitoring can be integrated with the conceptual models developed in Chapter 2. They provide a broad range of measures including the major stressors that affect ecosystem function in MIDN parks (Figure 3.2). An effective natural resource monitoring program requires a balance between indicators that measure ecosystem stressors and those that measure the effects of stressors on ecosystem components (Noon et al. 1999, Olsen et al. 1997). However, it is frequently difficult to determine whether an indicator measures stressors or effects, and many can be categorized as both. For example, invasive exotic plants act as stressors on native plant communities, though it can also be argued that their presence is an indicator of the effects of land use change on natural habitats. Notwithstanding, most of the vital signs chosen by the MIDN are considered to be either stressors or effects, as shown in Figure 3.2.



Booker T. Washington National Monument

3.5 Vital Signs Proposed for Monitoring

The 15 vital signs proposed for monitoring include five indicators related to air and climate, two related to geology and soils, three related to water, and five related to biological integrity. Five of the vital signs—those related to air and climate—will be monitored by compiling data available from other sources. The remaining 10 vital signs will be monitored through protocols to be developed by the network. However, as the network proceeds with protocol development and pilot testing over the next few years, we may alter which vital signs are fully implemented, since this process will enable us to determine whether monitoring a particular vital sign is cost effective and sufficiently sensitive to meet our objectives.

Fifteen vital signs are proposed for monitoring. These include five indicators related to air and climate, two related to geology and soils, three related to water, and five related to biological integrity.

3.5.1 Air and Climate

Air pollution is an important ecosystem stressor in the Mid-Atlantic region. Much of the air pol-

Fish sampling at Eisenhower National Historic Site

Table 3.3. Vital signs selected for monitoring in the Mid-Atlantic Network and vital signs currently monitored by Shenandoah National Park.

Level 1 Category	Level 2 Category	MIDN Vital Sign	APCO	BOWA	EISE	FRSP	GETT	HOFU	PETE	RICH	VAFO	SHEN
Air and Climate	Air Quality	Ozone	+	+	+	+	+	+	+	+	+	●
		Wet and dry deposition	+	+	+	+	+	+	+	+	+	●
		Visibility and particulate matter	+	+	+	+	+	+	+	+	+	●
		Air contaminants (mercury)	+	+	+	+	+	+	+	+	+	●
	Weather and Climate	Weather and Climate	+	+	+	+	+	+	+	+	+	●
Geology and Soils	Geomorphology	Stream / river channel characteristics	●	●	●	●	●	●	●	●	●	●
	Soil Quality	Soil structure and composition	●	●	●	●	●	●	●	●	●	
Water	Hydrology	Stream and river water dynamics	●	●	●	●	●	●	●	●	●	●
		Wetland water dynamics	◊	◊	◊	◊	◊	◊	◊	◊	◊	
	Water Quality	Water chemistry	●	●	●	●	●	●	●	●	●	●
		Aquatic macroinvertebrates	●	●	●	●	●	●	●	●	●	●
Biological Integrity	Invasive Species	Invasive exotic plants	●	●	●	●	●	●	●	●	●	●
	Infestations and Disease	Native forest pests	●	●	●	●	●	●	●	●	●	●
		Exotic Diseases / Pathogens – plants	●	●	●	●	●	●	●	●	●	●
	Focal Species or Communities	Riparian/Wetland communities	◊	◊	◊	◊	◊	◊	◊	◊	◊	●
		Forest plant communities	●	●	●	●	●	●	●	●	●	●
		Fish communities										●
		Amphibian communities	◊	◊	◊	◊	◊	◊	◊	◊	◊	●
		Breeding birds	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊
		Mammals										●
		White tailed Deer (herbivory)	●	●	●	●	●	●	●	●	●	●
		Vegetation communities										●
	At-risk Biota	T&E species and communities										●
Human use	Visitor and Recreation Use	Visitor usage										●
Ecosystem Pattern and Processes	Fire	Fire and fuel dynamics										●
	Landscape Dynamics	Land cover and landuse change	◊	◊	◊	◊	◊	◊	◊	◊	◊	

● I&M funded vital signs that are being monitored or for which monitoring protocols will be developed.
+ Vital signs monitored by the park or an outside partner, where network does not have the lead.
◊ High priority vital sign with no current or planned monitoring due to limitations in staff time or funding.

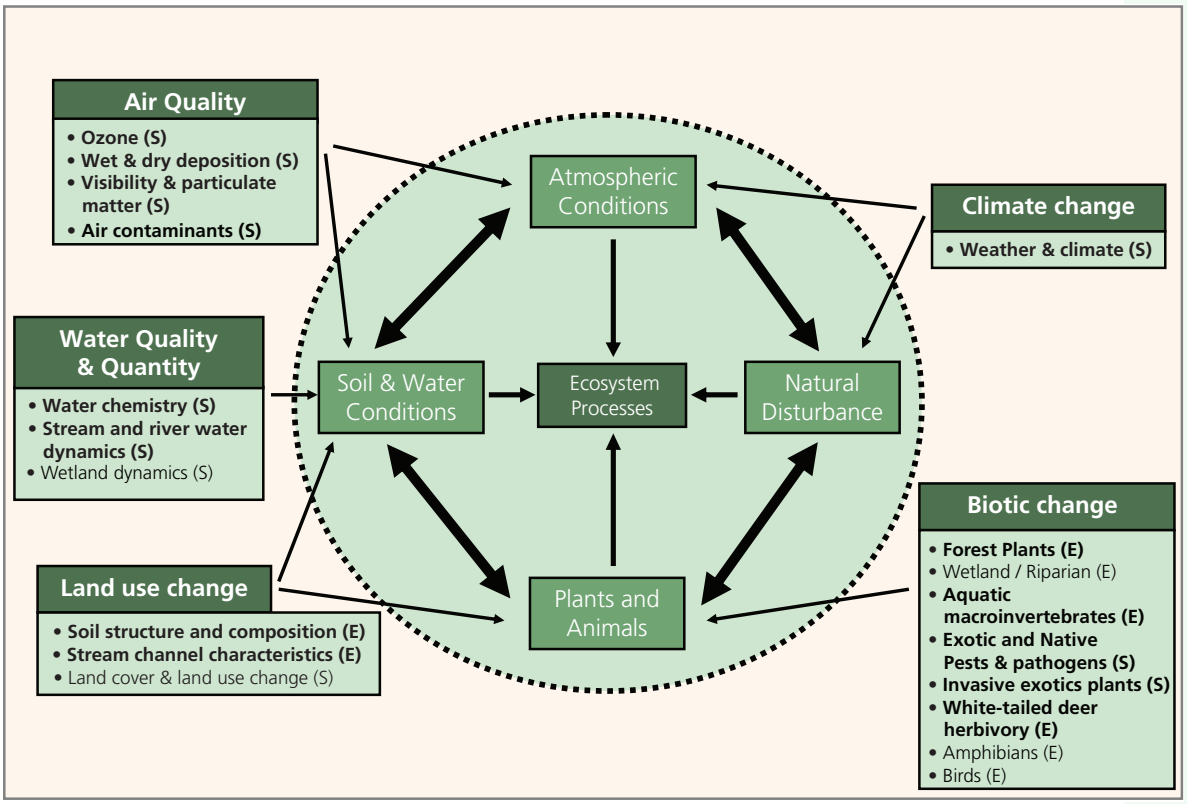


Figure 3.2. Relationship between anthropogenic stressor model and vital signs selected by the Mid-Atlantic Network. Vital signs in bold are those that have been selected for development over the course of the next 3 to 5 years. "S" indicates that the vital sign focuses primarily on a stressor, while "E" indicates that the vital sign is primarily an indicator focused on effects.

lution that affects the region is derived from the burning of fossil fuels in the Ohio River Valley and is transported by tropospheric winds. All five of the air and climate vital signs—**Ozone, Wet and Dry Deposition, Visibility and Particulate Matter, Air Contaminants** (specifically mercury), and **Weather and Climate**—can be monitored with data that are being collected by others.

Ozone can be damaging to a number of sensitive plant species, and its concentration increases with elevation (Sullivan et al. 2003). The cost of ozone monitoring is prohibitive for the network, but all MIDN parks (except Booker T. Washington) are within 35 km (22 mi) of an EPA-approved ozone monitoring station (Maniero 2004). Assessment of ozone damage to plants can be incorporated as part of the forest health monitoring protocol (described in Chapter 5) if ozone concentrations are sufficiently high to affect vegetation in the parks.

Wet and dry deposition represents the process by which air contaminants are deposited to the earth's surface. Deposition can affect plants directly by causing dieback, or indirectly through acidification of soils and water. Wet deposition is monitored as part of the National Atmospheric Deposition Program (NADP 2006), which has monitors within Shenandoah NP and Valley Forge NHP and within 90 km (56 mi) of all other MIDN parks (Appendix E). **Mercury** is a major **air contaminant** and is monitored as part of the Mercury Deposition Network (MDN), which has monitors on-site or within 100 km (62 mi) of all network parks.

Particulate matter is a type of air pollution consisting of solid particles or liquid droplets that are derived from a variety of sources, including gasoline combustion. Particulate matter can impair **visibility** and, depending on particle size, can cause respiratory illness (Appendix E). The Interagency Monitoring of Protected Visual Environments (IMPROVE) network assesses trends in regional visibility,

Eisenhower National Historic Site

Water quality sampling at Shenandoah National Park

and has monitoring sites located within 75 km (47 mi) of all network parks except Hopewell Furnace NHS, Petersburg NB, Richmond NBP, and Valley Forge NHP.

Weather and climate are major factors determining the distribution and abundance of species and biotic communities in the MIDN (Shuggart 2003). Changes in climate can alter the frequency and intensity of natural disturbances (Johnson and Cochrane 2003), affecting numerous ecosystem processes (Hughes 2003). The current climate warming trend is predicted to extend the range of southern species to the north (Solomon and Kirilenko 1997), potentially leading to re-organization and disruption of species assemblages in the MIDN parks. A number of weather stations managed by other agencies and organizations currently collect information in the vicinity of all MIDN parks, and compilation of data from these sources will be valuable for interpreting data concerning other vital signs.

The current climate warming trend is predicted to extend the range of southern species to the north, potentially leading to re-organization and disruption of species assemblages in the MIDN parks.

3.5.2 Geology and Soils

Stream and River Channel Characteristics consist of the physical components of stream habitat such as stream size, sinuosity, channel slope, and others. Measurements of these variables are usually collected in conjunction with water-related indicators (discussed below). Along with water quality, these physical components of stream habitat are primary determinants of stream biotic assemblages (Snyder et al. 2003). By the same token, stream channel characteristics are sensitive to many of the sources of environmental degradation that affect the MIDN parks—for example, increases in the amount of impervious surfaces associated with urbanization within a watershed may lead to higher storm flows and bank erosion, increased sedimentation, and other consequences (Allan 2004, Urban 2006).

Soils form the basis for terrestrial ecosystems. Anthropogenic effects on soil chemistry can alter the integrity of soil and the associated biotic community. In particular, increases in acid deposition of forest soils can reduce fine roots caused by high aluminum and depletion of calcium and magnesium (McNulty et al. 2007, Vanguelova et al. 2007). The **Soil Structure and Composition** vital sign will focus on the impacts of acid deposition of forest soils.

3.5.3 Water

Water quality is ecologically significant as it directly affects aquatic communities (Karr et al. 1985). The Mid-Atlantic region is affected by both industrial, agricultural, and airborne pollutants (Carpenter et al. 1996). The Water Resources Division of the National Park Service has identified minimum core **Water Chemistry** parameters that must be monitored, including temperature, pH, dissolved oxygen, and specific conductance (NPS 2006b). Eutrophication from excess nutrients, herbicide contamination, and excess turbidity caused by suspended sediment are water quality parameters that can be affected by human activity, particularly agriculture and urban land use. The National Park Service has a legal requirement to (1) protect pristine water quality and (2) improve impaired water quality (Rosenlieb and Long 2006).

Hydrologic measures of **Stream and River Water Dynamics** are also recommended as part of the monitoring protocol. Hydrology is a primary driver of aquatic ecosystems, and provides a link between climate indicators and the condition of the biotic community (Poff et al. 2007).

The vital signs ranking process identified **Aquatic Macroinvertebrates** as among the most important components for the MIDN monitoring program because they (1) are good indicators of local conditions, (2) exhibit wide variation among species and life stages in tolerance to environmental stresses, (3) in the case

Eastern skunk cabbage (*Symplocarpus foetidus*)

Forest vegetation monitoring at Petersburg National Battlefield

of many species, have long life cycles relative to other groups and therefore can illuminate trends in ecosystems over time, and (4) are relatively easy and inexpensive to sample (Barbour et al. 1999).

3.5.4 Biological Integrity

The Mid-Atlantic region is primarily a forested ecoregion, and all parks have forests as an essential part of their landscape. Forest communities provide habitat for a diversity of wildlife, and so monitoring changes in vegetation structure and composition is an important indicator of terrestrial ecosystem health (Noss 1999).

Forest Plant Communities is the primary vital sign that focuses on the dynamics of plants. However, a number of other vital signs that represent stressors on forest communities can be co-located with monitoring of forest plant communities. These include **Invasive Exotic Plants**, **Exotic Diseases/Pathogens of Plants**, and **Native Forest Pests**. In addition, white-tailed deer are significant stressors to vegetation communities at many MIDN parks, and forest monitoring will also include the effects of **White-Tailed Deer Herbivory**.

3.6 Vital Signs Identified for Future Development

Five vital signs received high scores during the ranking process and are considered to be a priority for the network. However, given current funding levels, protocols for monitoring these indicators will not be developed and implemented until a later date. These vital signs are: **Riparian/Wetland Communities**, **Wetland Water Dynamics**, **Land Cover and Land Use Dynamics**, **Amphibian Communities**, and **Breeding Birds**.

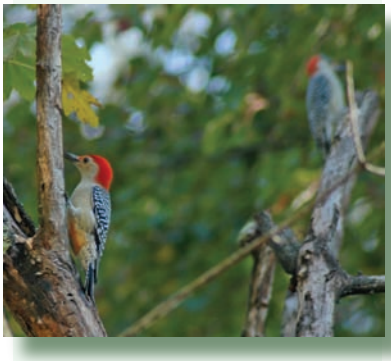
3.6.1 Riparian/Wetland Communities

Due to the nationwide importance and vulnerability of wetland habitats, the National Park Service has selected wetland health as a primary goal of its current strategic plan (NPS 2003). Wetland protection policy and guidance has been established in order to enable National Park Service staff to assess the condition of wetlands and provide data to support their management and restoration (NPS Director's Order #77 and NPS 2000).

Riparian areas are also a part of wetlands as defined by the National Park Service, and this transition between land and water provides important habitat for amphibians (Campbell

The Mid-Atlantic region is primarily a forested ecoregion, and all parks have forests as an essential part of their landscape.

Malvern Hill, Richmond National Battlefield Park



Red-bellied woodpecker (*Melanerpes carolinus*)

Grant and Jung 2005, Davic and Welsh 2004), reptiles (Metts et al. 2001), birds (Bryce et al. 2002), and mammals (Dunstone and Gorman 1998). The plant communities along these corridors are particularly susceptible to exotic species invasions (Simberloff et al. 2005). Most of the wetlands in the MIDN are riparian wetlands, and hence the riparian areas and wetland communities are being considered together as a single vital sign. However, during the ranking process the importance assigned to these two indicators was quite divergent: riparian communities were ranked fourteenth, while wetland communities were ranked second, behind only water chemistry.

3.6.2 Wetland Water Dynamics

Wetland water dynamics greatly influence the composition and condition of biological communities in wetland habitats (Euliss et al. 2004, Naiman and Decamps 1997). Currently, the network plans to implement water dynamics monitoring for free-flowing streams only. We are also considering the possibility of monitoring wetland hydrology using water wells in order to assess the status and trends of wetlands in selected parks.

3.6.3 Land Cover and Land Use Change

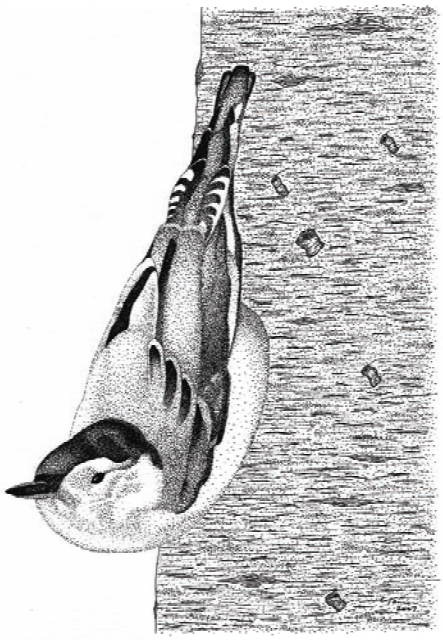
The Land Cover and Land Use Change vital sign ranked seventh on the prioritized list. Land use change in the Mid-Atlantic region is a major stressor to natural ecosystems, and is directly related to an increasing human population (Mid-Atlantic Integrated Assessment 2005a). Land use change in the area surrounding a park can have a drastic impact on that park's natural resources, due to habitat fragmentation and alterations to natural ecosystem processes (Chapter 2). Forest interior area is predicted to decline significantly due to habitat fragmentation (Wear et al. 2004), with resulting changes in wildlife species composition along forest edges (Yahner 1988).

3.6.4 Amphibian Communities

The vital signs ranking process indicated that the amphibian and reptile communities are best treated as two separate indicators due to the different habitat requirements and monitoring approaches for these two taxonomic groups. Evaluation of the comments and feedback from the ranking process suggested that most respondents were advocating for the value of amphibian monitoring, and so it is on this group that a future monitoring effort would focus. Worldwide declines in amphibian populations have highlighted their role as potential indicators of ecosystem stress (Davic and Welsh 2004, Phillips 1990, Welsh and Droege 2001). Monitoring protocols are well established (Heyer et al. 1994, Muths et al. 2005), and citizen science protocols are available that can provide volunteer participation in park-based monitoring (NWF 2006).

3.6.5 Breeding Birds

Many of the MIDN parks harbor bird species that are declining throughout their range (Bradshaw 2007, Keller et al. 2000, Root and Weckstein 1995), and therefore knowing the status of these avian species in the parks is important. The parks provide a diversity of habitat types for breeding birds, including forests, wetlands, and grasslands (the latter of which, under appropriate management, can provide suitable habitat for ground-nesting birds) (Peterjohn 2006, Vickery et al. 1999). Breeding Birds was not among the top-ranked vital signs, but given birds' visibility and the number of amateur ornithologists, the network considered that bird monitoring could potentially be accomplished by the network as part of a volunteer program, for example through the eBird Program (eBird 2008) or the Christmas Bird Count (National Audubon Society 2008).



Chapter 4: Sampling Design

4.1 Introduction

Sampling design consists of the decisions that determine when, where, and how an ecological indicator will be measured. The primary purpose of sampling design is to ensure that the data collected from a monitoring program are representative of the indicator's status, and sufficient to draw defensible conclusions about the resources of interest (EPA 2002, Yoccoz et al. 2001). The design should be based on clear monitoring objectives. In addition, because of staff turnover and changes in resource conditions over time, the sampling design should be simple and flexible in order to keep the monitoring program feasible over the long term.

The parks in the Mid-Atlantic Network are generally small, fragmented, and located in rapidly changing landscapes. In addition, the network's staff and budget are small and will limit the scope and complexity of the monitoring program. In light of these conditions, the network is opting for simple sampling designs that will address the status and trends of natural resources as well as the management needs of the parks.

This chapter reviews the basic concepts of sampling design, and lays out the general sampling strategies that underlie the MIDN's proposed monitoring protocols. Each protocol will provide more specific details relevant to the vital signs being measured.

4.2 Sampling Design Considerations

4.2.1 General Concepts

In developing a sampling strategy, an important first step is to identify the resources that we are interested in monitoring. This *target population* consists of all the *elements* (plants, animals, or environmental attributes of interest) about which we wish to draw conclusions (Figure 4.1). The target population should reflect the objectives of the monitoring program. The next step involves identifying the *sample frame*, composed of the *sampled population* from which the sample can be drawn. *Sample units* consist of a non-overlapping collection of units such as plots, quadrats, or stream segments. Ideally, the target population and the sample frame are the same, but a number of constraints such as distance, cost, and safety, may result in some areas being excluded.

4.2.2 Spatial Allocation

Sampling differs from a complete census, in which all elements in the target population are sampled. In drawing a sample that will enable us to make inferences about the larger target population, a key consideration is to make sure the sample is representative of that population (Lohr 1999). However, not all sampling methods used by ecologists are based on representative sampling. Judgment sampling, which employs expert opinion to establish *index* or sentinel sites, is a non-random approach that allows inferences to be made *only* about individual sampling units, not the larger population (Olsen et al. 1999, Stoddard et al. 1998). Convenience sampling is generally based on factors such as ease of access and, again, there is no assurance that samples collected in this manner will be representative of the target population (Heyer et al. 1994). For most situations in the MIDN, a probability-based approach is recommended as it incorporates a random element in selecting sampling points. Randomization reduces the bias inherent in judgment or convenience sampling, thus increasing the validity of inferences made about the target population (Pollock et al. 2002). However, due to cost, accessibility, and existing sampling locations, judgment sampling or the use of index sites will be considered.

In order to introduce a probability-based element to sample selection, the following ap-

Forest vegetation plot establishment

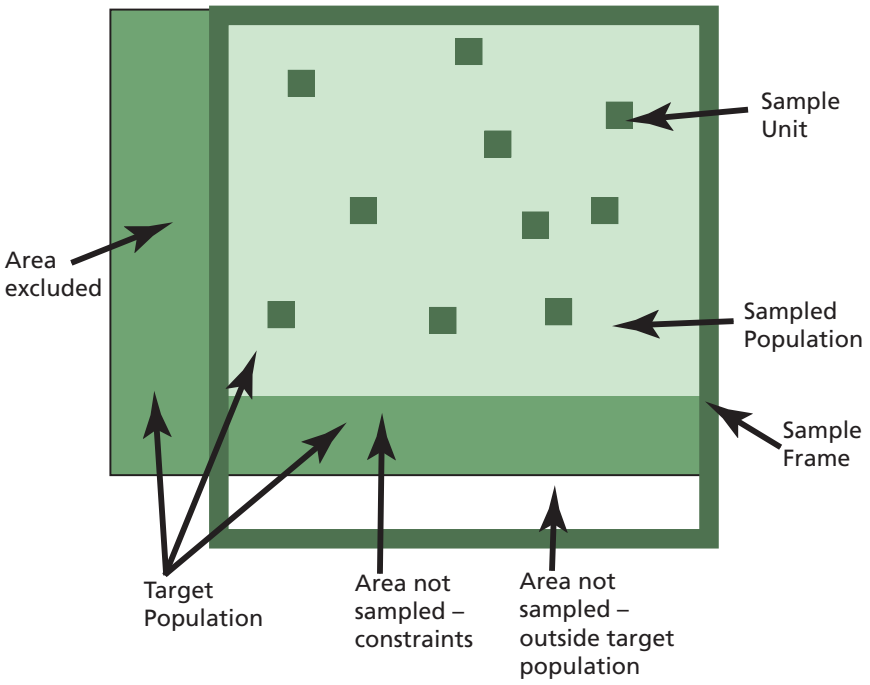


Figure 4.1. Conceptual illustration of terms used to describe different units associated with sampling design (adapted from Olson [unpublished presentation] and Lohr 1999).

Panel	Sampling Occasion									
	1	2	3	4	5	6	7	8	9	10
a) Design [1-0]										
1	X	X	X	X	X	X	X	X	X	X
b) Design [1-3]										
1	X				X				X	
2		X				X				
3			X				X			
4				X				X		
c) Design [1-0,1-1]										
1	X	X	X	X	X	X	X	X	X	X
2	X		X		X		X		X	
3		X		X		X		X		X
d) Design [1-0,1-n]										
1	X	X	X	X	X	X	X	X	X	X
2	X									
3		X								
4			X							
5				X						
6					X					
7						X				
8							X			
9								X		
10									X	

Figure 4.2. Examples of revisit designs: a) a single panel is visited on all occasions, b) each of four panels is visited once every four years, c) a split panel approach where one panel is visited every year, and two additional panels are sampled in alternating years, and d) a panel sampled every year and additional panels sampled on one occasion only.

proaches are commonly used. A *simple random sample* involves the random selection of a number of samples, with each possible sample unit having an equal probability of being included in the draw. However, simple random samples frequently lack spatial balance. A *systematic sample* solves this problem by selecting samples according to a systematic pattern. Generally, this systematic approach provides estimates of population parameters, but it can miss rare populations and habitats. A *stratified random sample* ensures that spatial balance is achieved and rare elements are included by dividing the sampling frame into mutually exclusive strata, from which samples are then randomly drawn (Nusser et al. 1998). In this approach, strata should be defined that are unlikely to change substantially over time, because changing stratum boundaries will result in a completely new survey and complicate comparison of results before and after the change. A new approach to random sampling that is being widely adopted by the I&M Program is the Generalized Random Tessellation Stratified (GRTS) design, which produces a spatially balanced random sample (Stevens and Olsen 1999). This approach allows for variable inclusion probabilities and an ordered list of samples that can support additions and deletions of samples without losing spatial balance.

4.2.3 Temporal Allocation

Obtaining trend data requires sampling a location repeatedly over time. Ideally, for each iteration of the sampling effort all units would be sampled in the same year, but this may not always be a practical approach. Panel sampling designs allow spatial and temporal allocation of samples (McDonald 2003). The *panel* refers to a group of sample units that are sampled during the same *sampling occasion*. That is, during a sampling occasion, all or none of the samples in a panel are sampled. A *revisit design* identifies the strategy for re-sampling the panels over

time. The revisit design is represented by a pair of numbers, the first indicating the number of consecutive occasions a panel will be sampled, and the second indicating the number of consecutive sampling occasions that a panel is not sampled before repeating the sequence. For example, using this notation the digit pair [1-3] means that members of four panels will be visited during one sampling occasion, not visited for three occasions, visited again for one occasion, not visited for three occasions, and so on (Figure 4.2). A single panel visited every sampling occasion would be [1-0], two panels revisited on an alternating schedule would be [1-1], and a panel visited only once would be [1-n]. A split-panel, such as [1-0, 1-5], indicates that one panel will be visited every occasion, while units in six other panels will be visited once every six occasions.

4.2.4 Response Design and Sample Size

A successful monitoring program must have the power to detect meaningful change over time (Yoccoz et al. 2001). Meaningful change incorporates the concepts of both statistical and biological significance—we want to know whether or not we are statistically likely to detect a change that we would consider biologically meaningful (Nichols and Williams 2006). Statistical significance relies on probability and is influenced by sample size (Lohr 1999). Thus, even minor changes (from a biological perspective) will be statistically significant if the sample size is large enough. Regardless of statistical significance, we consider a change biologically significant if it represents a major shift in ecosystem structure or function such as a loss of one or more species, the addition of non-native species, changes in ecosystem processes, etc. We therefore need to define the level of change that we consider to be biologically meaningful and what level of statistical confidence we want to achieve in identifying these changes.

Population parameters (measures that characterize the population) in the resource that we are monitoring vary over space and time, a concept captured by the term *population standard deviation*. In sampling, we are taking measures from a subset of the population in order to estimate a population parameter. Because our sample statistics will also vary from sample to sample (*sample standard deviation*), we should have a sampling design that minimizes this variability, in order to maximize the precision of our population estimates. *Response design* refers to the measurements that will be taken at a sampling location, and determines the sample size required to achieve a given level of statistical confidence. For example, the size and shape of permanent vegetation monitoring plots (*response design*) will influence the sample standard deviation. Larger plots will reduce the standard deviation, but increase the cost and effort involved in monitoring. It is therefore important to define clear sampling objectives that identify the level of change that we want to detect (*minimum detectable change*, MDC) and the level of confidence we wish to have in our results (Elzinga et al. 1998). Decisions about response design and sample size are frequently an iterative process informed by pilot projects that provide data on overall population variability.

Permanent markers are essential for relocating monitoring sites

Response design must also take into account the goal of minimizing Type I and Type II errors, which refer to erroneously rejecting (Type I error) or failing to reject (Type II error) a null hypothesis (Figure 4.3). With respect to monitoring, the "null" hypothesis is that there is no trend, so a Type I error occurs when a trend is detected where none exists (also known as false change error). A Type II error, meanwhile, occurs when a real trend is not detected (also called missed change error). The "P value" (or α level) is the probability of making a Type I error, while β is the Type II error rate. *Statistical power* refers to the probability of *not* making a Type II error (or 1 - β). It is important to note that statistical power depends on what level of Type I error is acceptable (α), what level of change one is trying to detect (that is, the MDC), and the relationship between the variability of the resource (*sample standard deviation*, s) and the *sample size* (n) used to detect the trend. Statistical power enables us to determine the sample

Figure 4.3. Monitoring outcomes framework. Type I errors arise from a change detected when none occurred (false change; polluter's risk). Type II errors arise from a change *not* detected when a real change has occurred (missed change; conservationist's risk).

	No change has occurred	A real change has occurred
Monitoring detects change (Reject H_0)	False change error (Type I) α	No error (Power) 1-β
Monitoring detects no change (do not reject H_0)	No error	Missed change error (Type II) β

Protocol	MIDN Vital Sign	Sample Design	Spatial Allocation	Revisit Design
Air Quality	Ozone	Index	N/A	Continuous
	Wet and dry deposition	Index	N/A	Continuous
	Visibility and particulate matter	Index	N/A	Continuous
	Air contaminants (mercury)	Index	N/A	Continuous
Weather and Climate	Weather and climate	Index	N/A	Continuous
Water Quality and Quantity	Stream / river channel characteristics	Index / List	GRTS and other	TBD
	Stream and river water dynamics	Index / List	GRTS and other	TBD
	Water chemistry	Index / List	GRTS and other	TBD
Aquatic Macroinvertebrates	Aquatic macroinvertebrates	Index / List	GRTS and other	TBD
Forest Vegetation	Forest plant communities	Grid	GRTS	[1-3]
	Invasive exotic plants	Grid	GRTS	[1-3]
	Native forest pests	Grid	GRTS	[1-3]
	Exotic diseases / Pathogens – plants	Grid	GRTS	[1-3]
	White tailed deer (herbivory)	Grid	GRTS	[1-3]
	Soil structure and composition	Grid	GRTS	TBD

Table 4.1. Proposed sampling design, spatial allocation, and revisit design for MIDN vital signs.

Virginia creeper (*Parthenocissus quinquefolia*)

size needed in order to detect a trend of a given magnitude with reasonable confidence. Statistical power can be increased by reducing the variability (s), increasing the number of units sampled (n), increasing the level of Type I error (α) tolerated, and increasing the magnitude of change we are aiming to detect (MDC) (Legg and Nagy 2006).

The traditional approach to detecting environmental change sets the Type I error rate (α) at 0.05 and the statistical power ($1 - \beta$) at 80%. Such an approach can reduce our ability detect a real change (i.e., increase the probability of a Type II error), fail to trigger a needed management action, and result in a biologically meaningful deterioration in some element of the ecosystem (Field et al. 2007). A Type II error is sometimes referred to as the "conservationist's risk," given that the environmental cost of missing a real change is frequently higher than the cost of detecting a change where none exists. This can be simply overcome, in cases where the consequences of missing a real change are unacceptable, by raising the α level (Field et al. 2004, Mapstone 1995, Peterman and M'Gonigle 1992, Tucker et al. 2005).

4.3 MIDN Sampling Design

The MIDN has five monitoring protocols that are scheduled for implementation over the next two to five years (Chapter 5). Together these five protocols will cover 15 vital signs identified by the network (Table 4.1).

Two protocols, **Air Quality** and **Weather and Climate**, will focus on data collected by other agencies and organizations, and therefore are not addressed in this discussion of sampling design. Those two protocols cover five vital signs: Ozone, Wet and Dry Deposition, Visibility and Particulate Matter, Air Contaminants, and Weather and Climate.

The remaining three protocols, **Forest Vegetation**, **Water Quality and Quantity**, and **Aquatic Macroinvertebrates**, will be developed or adapted from other National Park Service networks and are described below.

Figure 4.4. Map showing GRTS selected points overlaying 250-m sampling grid used for the forest vegetation monitoring sample design at Valley Forge National Historical Park. Grid restricted to forested areas; park identified forested areas that should be excluded from the sampling frame.

Sampling approaches that are currently being considered by the MIDN include probability-based methods such as grid-based sampling and list-based sampling, and judgment sampling such as index sites. Grid-based sampling uses a grid of potential sampling points from which samples are drawn using the GRTS method (see section 4.2.2). List-based sampling uses a list of potential sampling points from which a GRTS draw is taken. Index sites are based on expert opinion and hence are non-probabilistic. Table 4.1 summarizes the sampling design, spatial allocation, and temporal allocation for the various vital signs.

4.3.1 Forest Vegetation

The **Forest Vegetation** monitoring protocol will be conducted in all network parks and covers six vital signs: Forest Plant Communities, Invasive Exotic Plants, Native Forest Pests, Exotic Diseases and Pathogens of Plants, White-Tailed Deer Herbivory, and Soil Structure and Composition. The sampling design for this protocol is based on a 250-m grid developed for the entire network, and the target population is the forested areas within each park (Figure 4.4). Park resource managers actively participated in defining the sampling frame for each park, determining which areas should be excluded. For two parks, Fredericksburg and Spotsylvania NMP and Petersburg NB, managers desired the ability to make inferences about

Wetlands at Hatcher Run, Five Forks unit of Petersburg National Battlefield

individual park units or groups of units. For the remaining parks, inferences drawn at the park level were deemed sufficient. Therefore the sampling frame for each park was developed for the areas of interest (units or parks).

The response design and sample size were determined based on data collected by the neighboring National Capital Region Network (NCRN). The MIDN shares many similarities with the NCRN in geographic location and park management priorities. The MIDN conducted power analysis on data from 100 NCRN plots using various plot and sample sizes (Comiskey et al. In press). It was estimated that with current funding and staffing levels, the MIDN would be able to monitor a maximum of 300 plots throughout the network. Plots were allocated to each sampling frame (i.e., each park or unit) based on the frame's total area, with eight plots (the minimum number we estimated was necessary for valid statistical inferences) allocated to the smallest park (Booker T. Washington NM). Sampling units were drawn with equal probability from each sampling frame using the GRTS method to produce an ordered list.

A four-panel sampling design was developed that will allow for detection of inter-annual variation. Each panel will be revisited every fourth year [1-3]. This level of temporal resolution was deemed important for monitoring several of the vital signs included in this protocol, namely White-Tailed Deer Herbivory, Invasive Exotic Plants, Native Forest Pests, and Exotic Diseases and Pathogens of Plants.

The Clean Water Act requires that the National Park Service protect pristine waters or improve the condition of impaired waters; hence park staff need information that will guide management decisions in accordance with these requirements.

Initial pilot testing and implementation of this protocol were conducted in 2007. All parks were visited and sample points were selected in order. Sampling locations that did not meet predefined criteria—for example, locations that were not forested or that fell on a road or trail—were rejected and the next point on the list was selected for sampling. Again, the GRTS design allows points to be added or subtracted in this manner without a loss of spatial balance.

Preliminary analysis was conducted using data from the first year of pilot testing and implementation (2007). Because no temporal data are available, spatial variability is used as a proxy for variation over time. Temporal variation is likely to be less than that across space, which makes this a conservative estimate of the statistical power of this study. As a minimum, we expect to detect a 50% change after two measurements, with a statistical power of 80% and an α level of 0.1 (Comiskey et al. In press). We expect that our ability to detect change will increase over time.

4.3.2 Aquatic Macroinvertebrates, Water Quality and Quantity

With over 163 km of streams and rivers across nine MIDN parks (excluding 771 km in Shenandoah NP which are already covered by an existing program), implementing aquatic monitoring will present a significant challenge to the network's limited resources. Aquatic systems can exhibit large spatial and temporal variability, requiring extensive and intensive monitoring. In addition, the Clean Water Act requires that the National Park Service protect pristine waters or improve the condition of impaired waters; hence park staff need information that will guide management decisions in accordance with these requirements. Fortunately, numerous state and federal agencies are conducting aquatic monitoring in or near MIDN parks, and these sites will be incorporated into the network's sampling strategy under this protocol.

Two aquatic protocols are currently planned, **Aquatic Macroinvertebrates** and **Water Quality and Quantity**. The latter protocol addresses three vital signs: Stream and River Channel Characteristics, Stream and River Water Dynamics, and Water Chemistry. Wherever feasible, the vital signs included in these two protocols will be co-located and measured concurrently.

Unlike terrestrial systems, which are two-dimensional, rivers are linear, requiring that the sampling frame consist of river or stream reaches within parks and units. For the Water Quality and Quantity protocol, the sampling design will include index sites and list-based sites. Index sites refer to monitoring stations currently maintained by park staff or other agencies, and address site-specific questions and issues. Where individual parks are conducting monitoring, their existing protocols will be evaluated to ensure that they meet standards being developed by the MIDN to assure data comparability. The list-based sites are those implemented by the MIDN as part of this protocol, and we are considering two possible approaches for site selection. The first option is to select sampling sites using a probabilistic approach, such as a GRTS draw, to facilitate making inferences about larger areas (stream reaches). With this approach, a variable selection probability may be introduced to facilitate

sampling efficiency. Alternatively, index sites could be evaluated and selection made from the most upstream and downstream locations of a stream within the park boundary. Such an approach would provide information on the condition of waters entering and leaving the park, but would preclude inferences to the stream reach. The final sampling design will be largely determined by the need to inform park management and understand the status and trends in aquatic ecosystem condition.

Multiparameter probes will be combined with "grab" samples; three probes will be rotated between streams and across parks. Sampling will likely involve a split panel design, with some sites monitored each year and other sites sampled on a rotating basis (for example, [1-0, 1-3]). Sampling will be conducted throughout the year, ideally on a monthly basis but more likely on a quarterly basis.

Aquatic macroinvertebrate sampling sites will likely be co-located with a subset of the water quality monitoring sampling stations. This subset of sites may be subjectively selected based on expert opinion and park management needs. Sampling will take place in spring or in late summer and fall.

Chapter 5: Monitoring Protocols

5.1 Introduction

Monitoring protocols are fundamental to the implementation of the Vital Signs Monitoring Plan. Protocols identify methods for gathering information on a vital sign, outline a process to collect that information, and establish how the information will be analyzed, reported, and stored. Protocols are essential for monitoring vital signs over time. They ensure that changes detected by monitoring do not stem from measurement variability introduced by changing personnel or methods but actually reflect what is occurring in nature (Oakley et al. 2003).

The monitoring protocols developed by the Mid-Atlantic Network for vital signs monitoring will include a narrative providing the rationale for vital sign selection, an overview of the monitoring protocol components, and a history of the development of the protocol. Documenting the history of the protocol design phase and the process of decision-making during protocol development helps ensure that future refinement continues to improve the protocol rather than merely repeating previous trials or comparisons (Oakley et al. 2003). The narrative will also detail specific, measurable protocol sampling objectives, sampling design including location and time of sample collection (Chapter 4), field methods, data analysis and reporting, staffing requirements, training procedures, and operational requirements (Oakley et al. 2003).

Each protocol narrative will also provide a listing and brief summary of all standard operating procedures (SOPs), which are developed in detail as independent sections of the protocol. SOPs carefully and thoroughly explain, in a step-by-step manner, how each procedure identified in the protocol narrative will be accomplished. At a minimum, SOPs address pre-sampling training requirements, data to be collected, equipment operations, data collection techniques, data management, data analysis, reporting, and any activities required at the end of a field season (e.g., equipment storage). One SOP identifies when and how revisions to the protocol are undertaken. As stand-alone documents, SOPs are easily updated compared to revising an entire monitoring protocol, and changes are identified in a revision log.

Finally, the monitoring protocols will identify supporting materials critical to the development and implementation of the protocol (Oakley et al. 2003). Supporting materials may include 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.

5.2 Shenandoah National Park Monitoring Protocols

Ten monitoring protocols have been implemented at Shenandoah National Park as part of the prototype monitoring program (Table 5.1). The Shenandoah monitoring program is currently revising, or has plans to revise, these legacy monitoring protocols to meet the standards established by Oakley et al. (2003) and outlined above. Funding constraints are also forcing the park to revise the sampling schedule and postpone monitoring of one of the protocols.

5.3 Mid-Atlantic Network Protocol Development

An important goal of protocol development for the MIDN parks has been to ensure compatibility with protocols currently implemented in Shenandoah NP and in other nearby networks, in order to facilitate information sharing. An abbreviated version of the protocol development summary (PDS) for each of the five monitoring protocols in development for the MIDN is provided in the next section. This abbreviated version includes the vital signs to be monitored, a justification for monitoring, and a list of monitoring objectives and management applications. The full protocol development summaries are provided in Appendix I.

Protocols are essential for monitoring vital signs over time; they provide a detailed plan to ensure monitoring detects real changes.

Eastern Box Turtle (*Terrapene carolina*)

Table 5.1. Protocols currently being implemented at Shenandoah National Park.

Protocol	SHEN Vital Sign	References
Air Quality	Ozone Wet and dry deposition Visibility and particulate matter Air contaminants (mercury)	Ray, J. 2004. Ozone Monitoring Protocol for the National Park Service. Air Resources Division, National Park Service, Fort Collins, Colorado. Porter, E. 2006. Dry Deposition Monitoring Protocol: Monitoring Atmospheric Pollutants in Dry Deposition. Air Resources Division, National Park Service, Fort Collins, Colorado. Porter, E. and K. Morris. 2007. Wet Deposition Monitoring Protocol: Monitoring Atmospheric Pollutants in Wet Deposition. Natural Resource Technical Report NPS/NRPC/ARD/NRTR2007/004. National Park Service, Fort Collins, Colorado.
Weather and Climate	Weather and climate	Gawtry, S. and J. Stenger. 2006. Climate Summary, Shenandoah National Park. Natural Resources Report NPS/NER/NRR--2007/017. National Park Service, Philadelphia, PA.
Water Quality and Quantity	Stream / river channel characteristics Stream and river water dynamics Water chemistry	Webb, R., F. Deviney, P.Thompson, and S. Wilson. 1996. Shenandoah Watershed Study Protocol for Collection of Hydrochemical Data. Department of Environmental Sciences, University of Virginia, Charlottesville, Virginia.
Aquatic macroinvertebrates	Aquatic macroinvertebrates	Voshell, J.R. and S.W. Hiner. 1990. Shenandoah National Park Long-Term Ecological Monitoring System, Section III, Aquatic Component User Manual, NPS/NRSHEN/NRTR-90/02. Department of Forestry, Virginia Polytechnic Institute and State University, Blacksburg, Virginia.
Forest Vegetation	Forest plant communities Invasive exotic plants Native forest pests Exotic diseases / Pathogens – plants White tailed deer (herbivory)	Cass, W. Draft. Shenandoah National Park Long-Term Ecological Monitoring of Forest Communities. Smith, D.W. and J.L. Torbert. 1990. Shenandoah National Park Long-Term Ecological Monitoring System, Section II, Forest Component User Manual, NPS/NRSHEN/NRTR-90/02. Department of Forestry, Virginia Polytechnic Institute and State University, Blacksburg, Virginia. Ravlin, F.W., S.J. Fliescher, and S.L. Rutherford. 1990. Shenandoah National Park Long-Term Ecological Monitoring System, Section IV, Gypsy Moth Component User Manual, NPS/NRSHEN/NRTR-90/02. Department of Forestry, Virginia Polytechnic Institute and State University, Blacksburg, Virginia.
Breeding Birds	Breeding birds	DeSante, D.F., K.M.Burton, P. Velez, and D. Froehlich. 2003. MAPS Manual, 2003 Protocol. Institute for Bird Populations, Point Reyes Station, California.
Amphibian Communities	Amphibian communities	Jung, R.E.. 2002. Streamside Salamander Inventory and Monitoring, Northeast Refuges and Parks. Patuxent Wildlife Research Center, U.S. Geological Survey, Laurel, Maryland. Jung, R.E.. 2002. Wood Frog and Spotted Salamander Egg Mass Counts and Percent Vernal Pools Occupied by Amphibian Species on DOI Lands in the Northeastern United States. Patuxent Wildlife Research Center, U.S. Geological Survey, Laurel, Maryland.
Fish Communities	Fish communities	Atkinson, J. 2002. Shenandoah National Park Fisheries Monitoring Protocol. Natural Resources Branch, Division of Natural and Cultural Resources, Shenandoah National Park.

5.3.1 Air Quality Monitoring

Parks: All MIDN parks.

Vital signs: Ozone, Wet and Dry Deposition, Air Contaminants (Mercury), Visibility and Particulate Matter.

Justification: Air quality can affect not only human health but also the health of natural resources in parks. The Clean Air Act of 1970 set out to preserve, protect, and enhance air quality in the United States, and in 1977 Congress amended the act to classify all National Park System units greater than 6,000 acres (2,428 ha) as Class I areas receiving the greatest level of protection. In the Mid-Atlantic Network, only Shenandoah National Park is a Class I park, but all parks in the network will benefit from improved air quality. Park managers will benefit from knowing the type and extent of various air pollutants in order to evaluate their impacts on park resources. The National Park Service Air Resources Division (NPS-ARD) administers an Air Monitoring Program that provides current air quality conditions and assesses long-term trends in pollutants that affect national park resources (NPS-ARD 2007). The data used in this existing program come from a variety of sources including monitoring stations in the parks and a number of interagency programs.

Monitoring objectives addressed by this protocol include:

1. Document the annual status and trends in atmospheric ozone concentrations in MIDN parks using metrics that are relevant to human health (e.g., 8-hour average) and plant response (e.g., SUM06).
2. Document the annual status and trends in wet and dry deposition in MIDN parks.
3. Report on the annual status and trends in mercury concentration and deposition in precipitation in MIDN parks.
4. Report on the annual status and trends in fine particulate matter ($PM_{2.5}$) and coarse particulate matter (PM_{10}) concentrations and composition in MIDN parks as they pertain to visibility impairment and human health.

Management applications include:

1. Evaluate the causes of ozone formation and its impact on natural resources.
2. Determine the impact of acid deposition on aquatic and terrestrial ecosystems.
3. Identify the effects of air contaminants on park biotic communities.
4. Evaluate the impacts of air pollution on visibility, and the consequent effects on visitor experience and biotic communities.

Protocol status: Protocols in place and data being collected at a national level.

Air quality can affect not only human health but also the health of natural resources in parks.

Shenandoah National Park is the only Class I area in the Mid-Atlantic Network

5.3.2 Weather and Climate Monitoring

Parks: All MIDN parks.

Vital signs: Weather and Climate.

Justification: Climate is a dominant factor driving the physical and ecological processes affecting the MIDN (Davey et al. 2006). Climate variations are responsible for short- and long-term changes in ecosystem fluxes of energy and matter, and have profound effects on underlying geomorphic and biogeochemical processes. Individual storm events occasionally alter the structure of plant and animal communities in the MIDN. Future climate changes will likely cause migrations of plant and animal communities both northward and to higher elevations. Superimposed on these trends is a long history of human use in the region, with accompanying land use patterns that have fragmented the original landscape of wetlands and upland forests and that will influence the ability of the plant and animal communities of the MIDN parks to adapt to climate changes. Because of its influence on the ecology of MIDN park units and the surrounding areas, climate was identified as a high-priority vital sign for the network.

Climate is a dominant factor driving the physical and ecological processes affecting the Mid-Atlantic Network.

Monitoring objectives addressed by this protocol include:

1. Document long-term trends in weather and climate through seasonal and annual summaries of selected parameters (e.g., multiple forms of precipitation, temperature).
2. Identify and document extremes and averages of climatic conditions for common parameters (e.g., precipitation, air temperature), and other parameters where sufficient data are available (e.g., wind speed and direction, solar radiation).
3. Provide information on near real-time weather parameters, historical climate patterns, and climate station metadata from a single, easy to use Internet portal.

Management applications include:

1. Understand the effects of local climate change.

Protocol status: In development.

Fredericksburg and Spotsylvania National Military Park

5.3.3 Water Quality and Quantity Monitoring

Parks: All MIDN parks.

Vital signs: Water Chemistry, Stream and River Water Dynamics, Stream/River Channel Characteristics.

Justification: Water chemistry has ecological significance because the chemical composition (including nutrient content) of surface water is a critical attribute of aquatic habitats and an integrator of hydro-biogeochemical conditions and processes occurring throughout associated watersheds (Karr et al. 1985). Water quality is affected by a number of pollutants related to municipal and industrial discharges (point sources) and agricultural and airborne pollution (non-point sources) (Carpenter et al. 1996). The data obtained through water chemistry monitoring thus indicate current and changing ecological conditions in both surface waters and watersheds.

Water quantity has ecological significance as a basic property of aquatic habitat. Changes in water availability that occur on both long and short time scales (e.g., multi-year, seasonal, and episodic changes) can directly affect aquatic communities. In addition, water chemistry varies with discharge due to differences in surface runoff, soil contact, and other factors that affect biogeochemical processes and material transport (Jones et al. 2001, Wickham et al. 2000). The data obtained through water quantity monitoring thus provide a direct measure of habitat condition and support interpretation of data obtained through water chemistry monitoring.

Water chemistry and water quantity have management and policy significance because the National Park Service is legally required to protect pristine water quality and improve impaired water quality (Rosenlieb and Long 2006), and because the streams and rivers that it manages must meet state and federal water quality criteria as defined by the Clean Water Act (CWA). In addition, the Government Performance and Reporting Act (GPRA) requires the National Park Service to establish and evaluate attainment of goals for meeting water quality criteria.

Monitoring Objectives addressed by this protocol include:

1. Document the status and trends in water quality as influenced by point source and non-point source pollution (including atmospheric deposition).
2. Determine the natural range of variability in water chemistry (including bacterial composition).
3. Detect water quality measures that exceed threshold values and determine their compliance with state and federal water quality standards.
4. Document the status and long-term trends in water flow.
5. Document changes in stream channel characteristics at sampling sites.

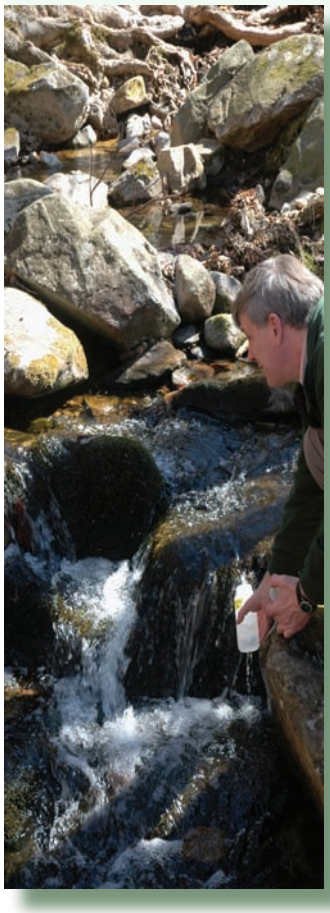
Management applications include:

1. Identify threats to maintaining stream flow and determine where restoration efforts are needed.
2. Identify and improve water quality of impaired waters.
3. Maintain high water quality where it exists.

Protocol status: Synoptic surveys and pilot testing in 2008. Draft protocol to be released during fiscal year 2009.

Water chemistry and water quantity have management and policy significance because the National Park Service is legally required to protect pristine water quality.

Water quality monitoring at Shenandoah National Park



5.3.4 Aquatic Macroinvertebrate Monitoring

Parks: All MIDN parks.

Vital signs: Aquatic Macroinvertebrates.

Justification: Aquatic macroinvertebrates are a vital component of all healthy stream ecosystems. They are instrumental in nutrient and carbon flows and are themselves an important link in stream food webs (Webster 1983). Moreover, unlike fish and periphyton (i.e., benthic algae) assemblages, aquatic macroinvertebrate assemblages are both productive and diverse in virtually all undisturbed streams with permanent flow (Lenat et al. 1980). This is an important consideration in the MIDN because many of the smaller tributary streams in MIDN parks (particularly Shenandoah NP) have gradients and natural barriers that impede the movement of fish, as well as canopies that restrict light and consequently limit algal productivity. As a result, fish and periphyton assemblages are often represented by very few species even in undisturbed streams. Other advantages of using benthic macroinvertebrate assemblages to monitor streams include: (1) they are good indicators of local conditions because most benthic species are either sessile or have limited migration patterns during their aquatic phases; (2) they exhibit wide variation in tolerance to environmental stresses among both species and life stages; (3) many species have long life cycles relative to other groups, which allows conclusions to be drawn regarding temporal trends; and (4) sampling aquatic macroinvertebrate assemblages is relatively easy and inexpensive, and has minimal effects on other biotic elements (Barbour et al. 1999 and Selected References therein; Rosenberg and Resh 1993). In addition, because aquatic macroinvertebrates have been by far the most commonly used group for biological monitoring of aquatic habitats in North America, natural variations and responses to numerous sources of degradation have been established for a large suite of aquatic macroinvertebrate summary metrics.

Aquatic macroinvertebrates are good indicators of local conditions. Because they have been commonly used for monitoring aquatic habitats, their natural variation and responses to sources of degradation are well known.

Monitoring objectives addressed by this protocol include:

1. Document the status and trends in the structure and composition of aquatic macroinvertebrates.
2. Determine trends in macroinvertebrate communities in relation to changes in water quality and quantity.

Management applications include:

1. Identify changes in macroinvertebrate communities in relation to changing land use and pollution.

Protocol status: In development.

Aquatic macroinvertebrate sampling at Petersburg National Battlefield

5.3.5 Forest Vegetation Monitoring

Parks: All MIDN parks.

Vital signs: Forest Plant Communities, Invasive Exotic Plants, Exotic Diseases/Pathogens of Plants, Native Forest Pests, White-Tailed Deer Herbivory, Soil Structure and Composition.

Justification: The Mid-Atlantic region is primarily a forested ecoregion and all MIDN parks have forests that form an essential part of the landscape and provide habitat for a diversity of wildlife. The Forest Vegetation Monitoring protocol will assess the status and trends in forest plant communities, and the impacts of stressors such as white-tailed deer, invasive exotic plants, exotic plant diseases and pathogens, and native forest pests, as well as the effect of acid deposition in forest soils. Evaluation of snags and downed woody debris will provide information on additional important habitat.

Forest structure, composition, and dynamics are important measures of forest condition and health (Yahner 2000). Changes in these metrics can be indicative of stressors that may result in alterations in the future ecological integrity of the forest communities and the species that depend on them (Keddy and Drummond 1996, Rutters et al. 1992). For example, high mortality rates among canopy trees may signal a change in the dominant forest species (Abrams and Black 2000, Orwig and Abrams 1994); declines in seedling and sapling densities could indicate a reduced capacity of the forest to regenerate (McWilliams et al. 2005); or increases in invasive exotic plant cover could result in the competitive exclusion of other herbaceous plants in the forest understory (Simberloff et al. 2005). Other anthropogenic stressors may have a long-term effect on forest communities–for example, acid deposition can alter soil chemistry, disrupting nutrient cycles (Fowler et al. 1999). Habitat fragmentation in the area surrounding parks can weaken the ecological integrity of the forests inside parks, increasing their susceptibility to exotic plant and pest invasions (Collinge 1996).

Monitoring objectives addressed by this protocol include:

1. Determine the status and trends in forest structure, composition, and dynamics of canopy and understory woody species.
2. Determine the status and trends in the density and composition of tree seedlings and selected herbaceous species that are indicators of deer browse.
3. Detect and monitor the presence of invasive exotic plants, exotic plant diseases and pathogens, and forest pests.
4. Determine the status and trends in forest coarse woody debris and the availability of snags.
5. Determine the status and trends in soil Ca:Al and C:N ratios to asses the extent of base cation depletion, increased aluminum availability, and/or nitrogen saturation impacting MIDN forest soils.

Management applications include:

1. Assess changes in forest communities and determine the need for management and restoration efforts.
2. Determine the need for deer management to reduce the impact of this species on vegetation communities.
3. Identify the need and location for exotic plant and animal management efforts.

Protocol status: Pilot testing completed 2007. Final protocol to be completed 2009.

Forests form an essential part of the landscape and provide habitat for a diversity of wildlife.

Vegetation monitoring at Richmond National Battlefield Park

Chapter 6: Data Management

6.1 Introduction

One of the most important goals of the Inventory and Monitoring (I&M) Program is to integrate natural resource inventory and monitoring information into National Park Service planning, management, and decision-making. Collecting data on specific natural resource parameters such as vital signs is a first step toward improving our understanding of park ecosystems. Sound data management practices enable us to analyze, synthesize, and model these data, transforming them into useful information (Chapter 7). In turn, with this information in hand, we can make decisions about the parks' vital natural resources and how to manage them in accordance with the National Park Service mission. This process requires a modern information management infrastructure (e.g., staffing, hardware, software) and procedures to ensure that relevant natural resource data collected by National Park Service staff, cooperators, researchers, and others are entered, quality-checked, analyzed, reported, archived, documented, cataloged, and made available to others for management decision-making, research, and education.

This chapter gives an overview of the MIDN Data Management Plan (DMP, Callahan and Wakamiya 2009). The full network plan, in conjunction with the national-level plan, Data Management Guidelines for Inventory and Monitoring Networks (NPS 2008), describes strategies that have been and will be adopted by the MIDN. Appendices to the network plan provide support and instruction on policies, specifications, and manuals. In addition to these general concepts and approaches, data management standard operating procedures (SOPs) associated with each vital sign's monitoring protocol will provide detailed, step-by-step instructions on specific data management procedures and methods for long-term monitoring projects. The MIDN DMP, its appendices, and the SOPs work in tandem to present and document the evolving MIDN data management program.

6.2 Mid-Atlantic Network Data Management Program Goals

The goals of the MIDN data management program are to make data and information:

- Available - Data are discoverable, accessible, and easily located.
- Usable - Data are stored in a stable, reliable, and interpretable data retrieval system.
- Shareable - Data products are complete, certified for quality assurance, screened for sensitive information, formatted for use, and documented for interpretation by others.
- Integrated - Data products are consistent with data exchange standards, interoperable with related natural resource data sets, and collected and stored in a way that optimizes the tradeoff between meeting local needs and achieving compatibility with other agencies and partners.
- Interpreted - Data have been reviewed, summarized, and transformed into useful information.

The MIDN data management strategy depends on all data and derived information generated or otherwise used by the program meeting high quality standards. Further, all data and information the MIDN I&M Program deems necessary to meet its objectives, and that are not otherwise maintained, will be archived, documented, and made easily available and accessible as part of the network's program. Data and information

Collecting data on specific natural resource parameters such as vital signs is a first step toward improving our understanding of park ecosystems. Sound data management practices enable us to analyze, synthesize, and model these data, transforming them into useful information.

Table 6.1. Categories of data products.

Category	Examples
Raw data	GPS files, field forms and notebooks, photographs and sound/video recordings, telemetry or remote-sensed data files, biological voucher specimens, etc.
Compiled/derived data	Relational databases, tabular data files, GIS layers, maps, species checklists, analyzed data
Documentation	Data collection protocols, data processing/analysis protocols, record of protocol changes, data dictionaries, FGDC/NBII metadata, data design documentation, quality assurance reports, catalogs of specimens/photographs etc.
Reports	Annual progress report, final report (technical or general audience), periodic trend analysis report, publications etc.
Administrative records	Contracts and agreements, study plans, research permit/applications, other critical administrative correspondences, etc.

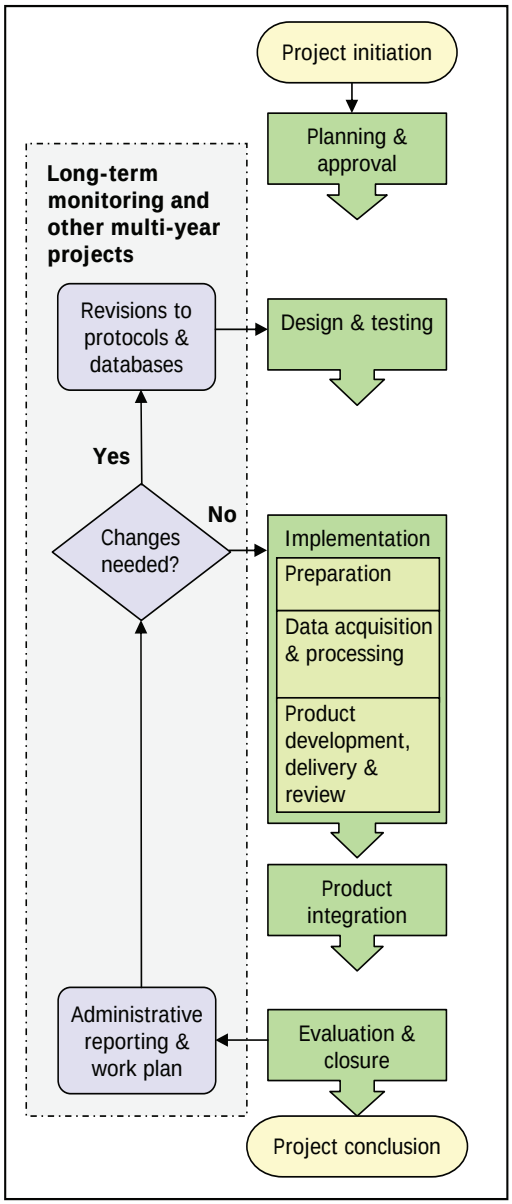


Figure 6.1. Project and data work flow.

will be accompanied by supporting documentation (metadata) that provides context, value, utility, and longevity, thereby facilitating a broad understanding of MIDN program products for current and future end-users.

6.3 Data Defined

Natural resource data are the building blocks out of which our evolving ecological understanding of park resources is built. The term "data" refers not only to tabular and spatial data, but also to other information recorded and stored alongside these data such as documentation. Data products fall into five general categories: raw data, derived data, documentation, reports, and administrative records (Table 6.1).

The MIDN makes use of data from a variety of sources in addition to those that originate from the network's I&M Program. Our highest priority is to produce and curate high-quality, well-documented data originating from the I&M Program. As time and resources permit, the MIDN will also work toward raising the level of data management for current projects, legacy data, and data originating outside the I&M Program.

6.4 Roles and Responsibilities

Data management cannot be successful unless everyone takes it seriously; it is therefore *everyone's* responsibility. Data management is sometimes more about managing people than it is about managing data. A data manager by profession can provide the tools, education, and encouragement to facilitate good data management, but it is primarily the actions of others that will dictate the quality of data management. Table 6.2 shows primary data management responsibilities by position in the MIDN.

Table 6.2. MIDN staff data management roles and responsibilities.

Role	Primary responsibilities related to data management
Project Crew Member (Biotech GS-5/7)	Record and verify measurements and observations based on project objectives and protocols Document methods, procedures, and anomalies
Network Data Manager	Provide overall network planning, training, and operational support for the awareness, coordination, and integration of data and information management activities
Park Resource Specialist	Make decisions about data with regard to validity, utility, sensitivity, and availability
Park or Other Curator	Oversee all aspects of the acquisition, documentation, preservation, and use of park collections
Statistician/Biometrician	Analyze data and present information, make suggestions on systematic data anomalies
Network Coordinator	Ensure programmatic data and information management requirements are met as part of overall network business

6.5 Data Life Cycle and Work Flow

The I&M Program involves both short-term and long-term projects. In the case of long-term projects, the importance of adhering to established, detailed data management and collection standards is of paramount importance, in order to ensure internal consistency and comparability of data through time. For short-term projects, standards are still important, but sometimes the cost of compliance will outweigh the benefits due to the scope, budget, and level of NPS influence over the project. Nevertheless, both short-term and long-term projects share many work flow characteristics,

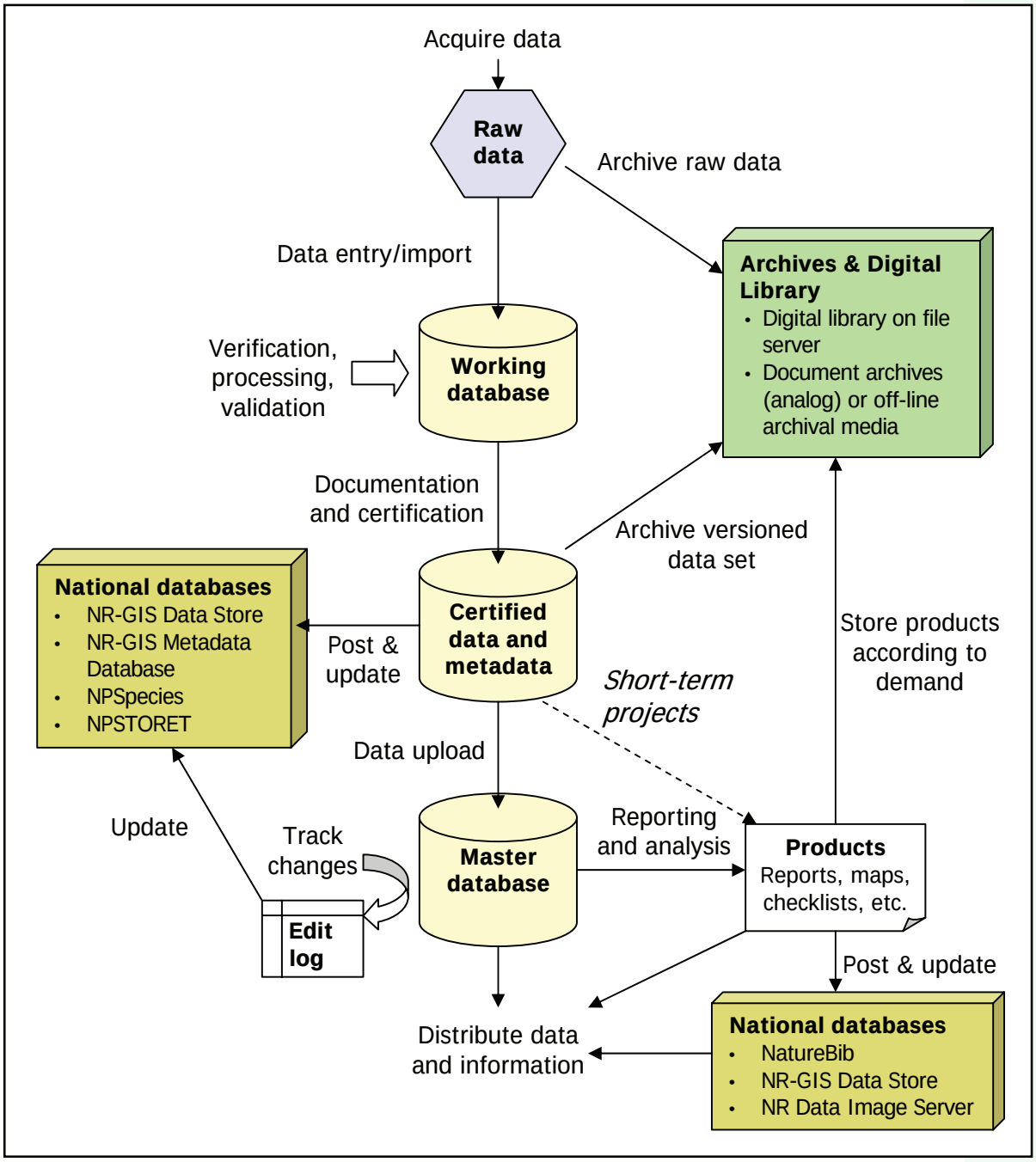


Figure 6.2. Diagram of typical data life cycle.

and both generate data products that must be managed and made available.

Projects can be divided into five primary stages: planning and approval, design and testing, implementation, product integration, evaluation, and closure (Figure 6.1). Each stage is characterized by a set of activities, including data management activities, carried out by staff involved in the project. Primary responsibility for these activities rests with different individuals depending on the phase of the project. Further details on these activities and responsibilities can be found in the MIDN and national DMPs.

During various phases of a project, data take different forms and are maintained in different places as they are acquired, processed, documented, and archived. This data life cycle is characterized by a sequence of events that we can model conceptually. Figure 6.2 models a typical life cycle for data in the MIDN, including relationships to national data servers and repositories.

6.6 Infrastructure and System Architecture

A complex system architecture and reliable computer infrastructure are necessary in order

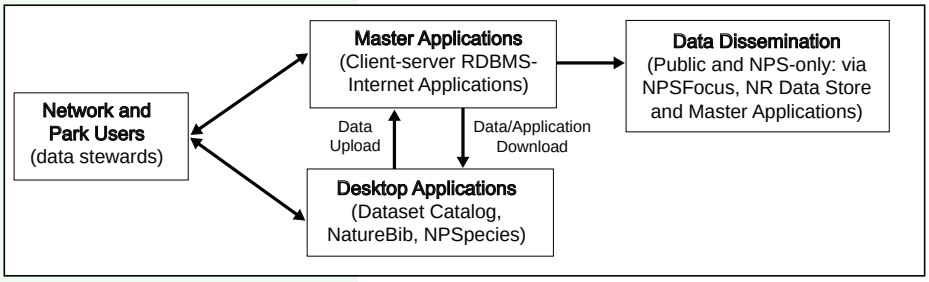


Figure 6.3. Sample conceptual model of I&M Program system architecture.

to support the data management program and its goals. The MIDN is duty-stationed at Fredericksburg and Spotsylvania NMP and relies on the park infrastructure on a daily basis to accomplish its mission. At the same time, MIDN staff also rely on data management system architecture developed and maintained by the national I&M Program for a variety of cataloging and data services. Data are generated, managed, and maintained at the local network level (Desktop Applications), and sometimes uploaded to the national level (Master Applications). Some aspects of the local MIDN system architecture are still under development, but Figure 6.3 shows generically how these two architectures will integrate with one another.

High-quality data and information are mandated by national NPS directives and orders and are vital to the credibility and success of the I&M Program. Quality can be defined as incorporating three key components—objectivity, utility, and integrity.

An additional, integral component of the national I&M Program data management infrastructure is the NPSTORET application for managing all data acquired during network water quality monitoring. Water quality data collected as part of the network's monitoring program have distinct data management requirements. Data must be managed according to guidelines from the NPS Water Resources Division (NPS-WRD). These guidelines include using the NPSTORET desktop database application to help manage data entry, documentation, and transfer to the WRD. The MIDN will integrate the use of NPSTORET into its overall water quality monitoring protocol. Figure 6.4 illustrates the flow of information and data between the network, national program offices, and EPA's main STORET repository.

6.7 Data Acquisition and Processing

Steps for acquiring and processing natural resource data will vary depending on the data source, which can be placed into three general categories:

- Mid-Atlantic Network data: Data resulting from projects that are initiated, sponsored, or funded by the MIDN
- Other National Park Service (NPS) data: Data resulting from projects that are initiated, sponsored, or funded by park units, or by regional or national NPS programs
- External data: Data produced or managed by agencies, organizations, or individuals other than the National Park Service

The MIDN staff has the most control over data produced by and for the network. They will, therefore, ensure that such data meet all specifications laid out by the network, the I&M Program, the National Park Service, the Department of the Interior, and the federal government. These standards can include those for documentation, cataloging, and dissemination. Data falling into the second category of "Other NPS data" are often managed by the NPS entity most closely associated with the data set. However, these entities sometimes lack the resources or expertise to manage the data properly. In such cases the MIDN will evaluate the data set's utility to the program or to natural resource management at an MIDN park, and manage the data set as needed. For data falling into the third category of "External data," MIDN staff will take the following actions where appropriate:

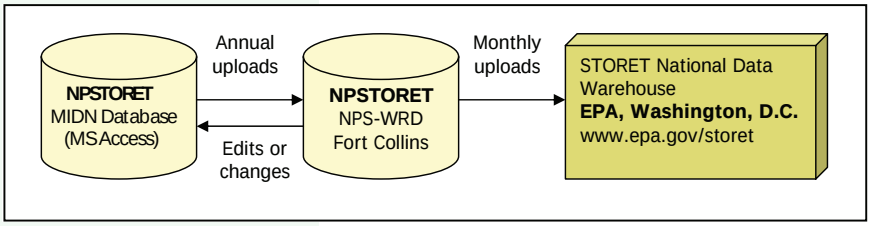
Acquire data → Evaluate → Transform → Catalog → Make Available

6.8 Quality Assurance and Quality Control (QA/QC)

High-quality data and information are mandated by national NPS directives and orders and are vital to the credibility and success of the I&M Program. Quality can be defined as incorporating three key components—objectivity, utility, and integrity.

Objectivity consists of (1) presentation, meaning whether disseminated information is being presented in an accurate, clear, complete, and unbiased manner within a proper context; and (2) substance, meaning whether the information is accurate, usable, and reliable.

Figure 6.4. Sample conceptual model of NPSTORET system architecture.



Utility refers to the usefulness of the information to its intended users, from the perspectives of both the network (perhaps most importantly, its natural resource managers) and the general public.

Integrity refers to the security of information, such as protection from unauthorized access or revision to ensure that the information is not compromised through corruption or falsification.

Data quality is planned for at each step of the data life cycle, from training to data collection, entry and input, verification and validation, documentation, communication, and review, and is incorporated into all aspects of general operations. A variety of methods can be employed at each step along the way. As the data moves further along in the cycle, with more quality assurance methods applied, confidence in the quality of the data increases (Figure 6.5).

Through constant review of the quality of data collected, the effectiveness of quality assurance and quality control (QA/QC) procedures will become evident. Nevertheless, a formal and coordinated review and revision of QA/QC procedures should take place every several years to ensure the quality of data generated in the future.

6.9 Data Documentation

Documenting data is the most important step toward ensuring that data sets are usable well into the future. Data longevity is directly related to the comprehensiveness of this documentation. A number of NPS and MIDN standards exist for documentation of spatial and tabular data, as well as for projects, administrative records, vital signs protocols, and Standard Operating Procedures (SOPs).

Overarching NPS standards include:

- Executive Order 12906, which mandates each federal agency to "...document all new geospatial data it collects or produces, either directly or indirectly..." using the Federal Geographic Data Committee (FGDC) Content Standard for Digital Geospatial Metadata (CSDGM)

- FGDC CSDGM extensions, such as the Biological Data Profile, Remote Sensing Extension, and Shoreline Data Profile, which are not required, but are recommended where appropriate

- The NPS Geographic Information System (GIS) Committee requires that all GIS data layers be described with FGDC standards and the NPS Metadata Profile

MIDN standards include:

- Projects will be documented and organized in their appropriate folder using standard folder organization as described in the Data Management Plan

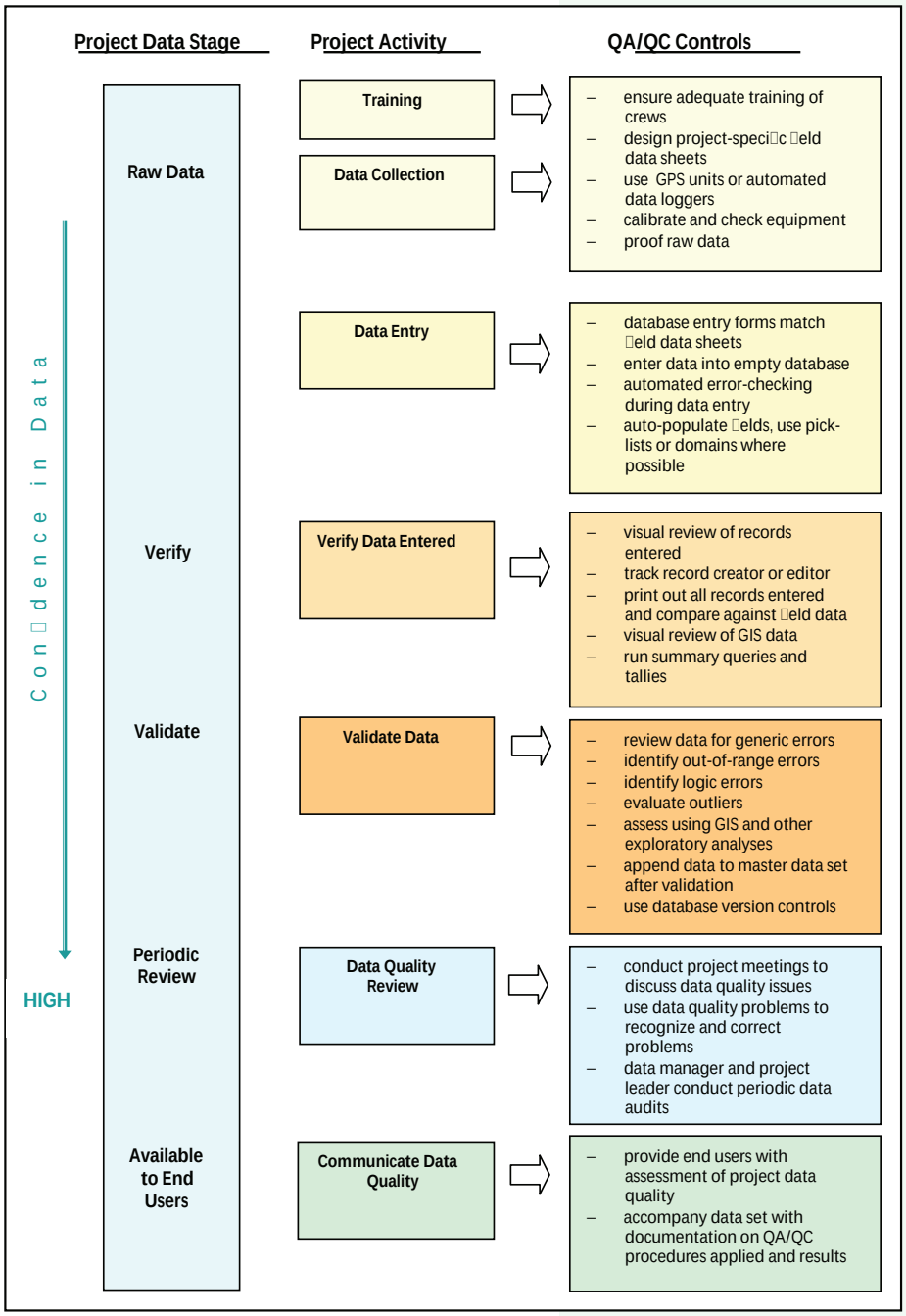


Figure 6.5. QA/QC controls and project work flow.

- Spatial data files will be documented in compliance with FGDC standards using the CSDGM
- Biological databases will be documented in compliance with FGDC standards using the National Biological Information Infrastructure (NBII) biological metadata profile

Data documentation is perhaps the most undervalued data management activity. As such, the network data manager must communicate, educate, and champion the importance of documentation, as well as sometimes just make sure it gets done!

6.10 Data Dissemination

To meet the goals of the I&M Program, procedures must be developed to ensure that relevant natural resource data collected by NPS staff, cooperators, researchers, and the public are entered, quality-checked, analyzed, documented, cataloged, archived, and made available for management decision-making, research, and education. Providing well-documented data in a timely manner to park managers is especially important to the success of the program. The MIDN I&M Program will make certain that:

- Data are easily discoverable and obtainable
- Data are subjected to full quality control or are NOT released
- Distributed data are accompanied by complete metadata that clearly establishes the data as a product of the NPS I&M Program
- Sensitive data are identified and protected from unauthorized access and inappropriate use
- A complete record of data distribution/dissemination is maintained

Data dissemination can be a complex task involving considerations of data ownership, sensitivity, and access. All data and information generated by the I&M Program should be property of the NPS and managed as such. This will require MIDN staff to work closely with cooperators, contractors, experts, and park staff to assess the sensitivity of data to public release and the potential for misuse. Data should be made accessible to the widest possible audience whenever prudent, keeping in mind federal requirements to both protect sensitive data and release (according to the Freedom of Information Act) data.

Table 6.3. Principal repositories for project products.

Project Products	Repository
Tabular Data and Documentation	
Final products	NCSU Digital Archive
	MIDN Physical Archive (on media)
	NPS Data Store
	NPSpecies
Draft products	MIDN Physical Archive (Projects Folder on media)
Spatial Data	
Final products	NCSU Digital Archive
	MIDN Physical Archive (on media)
	NPS Data Store
Draft products	MIDN Physical Archive (Projects Folder on media)
Technical Reports	
Digital	NPS Data Store, NPS Focus, NERO Science Website, E-TIC
Hard copy	MIDN library
	Park library
	MIDN physical archive
	TIC
Bibliography	NatureBib
Photographs	
Aerial hard copy	NCSU physical archive
Aerial digital	NCSU digital archive
Project related	NCSU digital archive
	MIDN physical archive (on media)

6.11 Data Maintenance, Storage, and Archiving

Long-term maintenance and management of digital information are vital to the I&M Program. This includes procedures for maintaining and managing digital data, documents, and objects that result from network projects and activities. These procedures will help ensure the continued availability of crucial project information and permit a broad range of users to obtain, share, and properly interpret that information.

The MIDN has entered into a long-term agreement with North Carolina State University to serve as our primary digital archive. This archive, along with a variety of MIDN and national I&M Program resources, make up the various repositories that store and safeguard

MIDN products for the future. Table 6.3 shows the various repositories and the MIDN products that can be found therein.

6.12 Feedback and Revisions

Revisions to this chapter and its associated MIDN Data Management Plan will be made as needed, or at least every several years. The network data manager is responsible for initiating and coordinating revisions. Questions and comments about this chapter and the Data Management Plan are welcome, as are suggestions on how to make it better, clearer, or more readable. Feedback should be directed to the network data manager.

Efficient and effective data management methods, strategies, and procedures are vital to meeting I&M Program goals and maintaining the program's support and relevance well into the future.

Chapter 7: Data Analysis and Reporting

7.1 Introduction

An essential role of the Mid-Atlantic Network is the analysis, interpretation, and dissemination of its Inventory and Monitoring (I&M) Program data to a wide audience, including park managers, superintendents, scientists, and the general public. Information on the status and trends in park resources is a crucial element of adaptive management, a systematic process for improving resource management based on operational results (Henderson et al. 2007, Williams et al. 2007; Figure 7.1). Conveying information to the public will enhance awareness of and support for park resources. The general strategy for effectively analyzing and reporting on MIDN monitoring results is outlined in the following pages. More specific details are provided in each vital signs monitoring protocol.

7.2 Data Analysis

Data analysis is essential in relating data to the established goals and objectives of a monitoring program. The MIDN defines data analysis as the processes by which monitoring data and other observations are turned into meaningful information. We have defined "data analysis" broadly to include all evaluations after data are collected and entered into an electronic file. Thus, data analysis includes everything from quality control checks that occur during summarization and exploratory analysis, to analytical procedures leading to conclusions and interpretations of the data. We present here some general considerations about analysis of monitoring data and outline the general strategy that the MIDN will take for all vital signs monitoring protocols.

As a general rule, data analysis should (1) ensure that the monitoring objectives are effectively addressed, (2) emphasize the importance of early detection of critical changes, (3) recognize that results from the analysis are meant to contribute to knowledge about the biodiversity component being monitored, and (4) emphasize that the results are intended to provide biodiversity managers with a scientific rationale for setting appropriate standards (Henderson et al. 2007). However, monitoring data pose challenges to analysis because of their inherent temporal associations—repeated measurements of the same variables at different times. It is essential that we use statistical approaches that accommodate these associations. These approaches can include time-series analyses, longitudinal data analysis (including repeated measures), trend estimation (for which there are many methods), direct estimation of change, and cumulative summary (CUSUM) techniques. Application of these analytical methods will require working closely with statisticians throughout the initial design process and during subsequent analyses of monitoring program data.

Many of the difficulties typically encountered in analysis of monitoring data can be avoided with proper planning, including the use of probabilistic sampling designs. The methods appropriate for analysis of monitoring depend on the monitoring objectives, the spatial and temporal aspects of the sampling design used, and management uses of the data. Analysis methods need to be considered from the beginning of the design process—when monitoring objectives are identified and the sampling design is selected, rather than after the data are collected. Failure to adequately consider analysis methods during program development could result in selection of a sampling design that is either inadequate or too complex to meet the monitoring objectives. The purpose of this portion of the MIDN monitoring plan, and of the specific standard operating procedures (SOPs) concerning data analysis for each vital signs protocol, is to ensure that the sampling designs and analysis methods we plan to use will allow us to meet our monitoring objectives.

A central tenet of the MIDN I&M Program is that data will be analyzed and reported promptly. Parks need to be alerted to changes in park ecosystems as soon as the changes can be detected—not several years after the fact. Mechanisms to support prompt analysis and reporting have been built into the Data Management Plan (e.g., data must be entered into the database within one month of returning from the field). Additional mechanisms to help reach this goal will be established in the Data Analysis SOP for each vital signs monitoring protocol.

One of the primary problems leading to long delays in analysis and reporting is a lack of explicit funding for these activities (Caughlan and Oakley 2001). Thus, the MIDN strategy includes allocating one-third of the MIDN I&M Program budget to support staff and/or principal investigators (PIs) for data analysis.

The first step in data analysis is summarization (Noon et al. 1999). This step is a critical ele-

Interpretation and dissemination of information to a wide audience is an essential task of the Mid-Atlantic Network.

Northern fence lizards (*Sceloporus undulatus*)

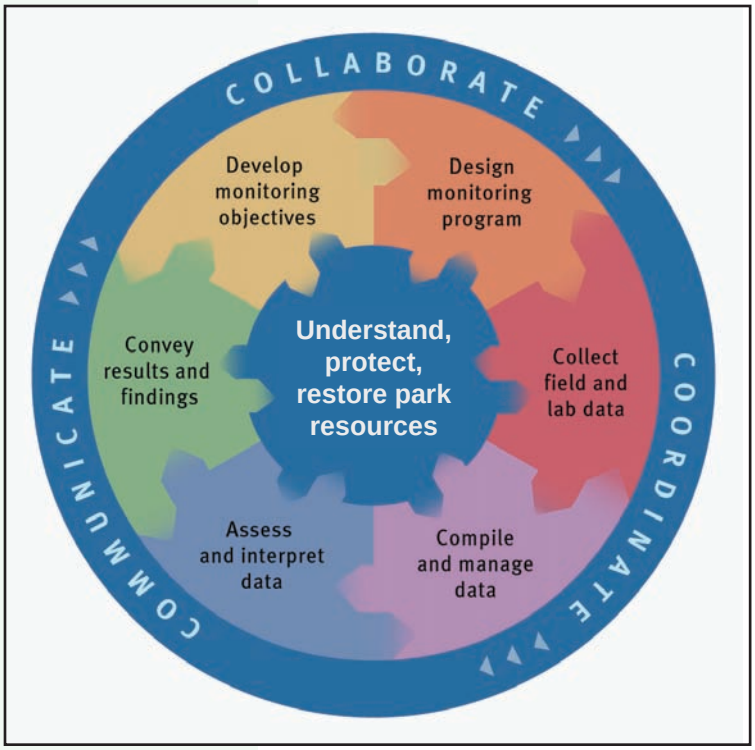


Figure 7.1. Monitoring as an integrated information management system. The various interconnected pieces of the information management system must be designed and implemented together to ensure that scientifically sound information obtained through monitoring is available for management decision-making, research, education, and promoting public understanding of park resources. Figure adapted from the National Water Quality Monitoring Council.

ment of overall quality control. The data need to be summarized promptly to identify missing values, outliers, and other problems related to data collection procedures and the data entry process (Jeffers 1994, Reid 2001). Routines for summarization will be prepared and codified in the SOPs for each monitoring protocol. The exact form of the summaries will vary depending on the vital sign. In general, however, the summaries will include graphical techniques to show the data in space and time, using measures of central tendency and variation.

The second step in analysis of MIDN datasets will be a rapid, top-level analysis to determine immediately if something has occurred that is out of the bounds of expected variation (i.e., is everything going about as expected or not?). Two methods under consideration for this step are the conformance metric and the cumulative summary (CUSUM) method described by Manly and Mackenzie (2003). The conformance metric separates out sampling variation from total variation to provide a measure of the natural variation in an attribute due to ecological processes. Once we establish a baseline to characterize "normal" variability, we can view new observations of the attribute and determine how well they conform to the documented history of the attribute. The conformance metric is the probability that a new observation comes from the same underlying process as the baseline. Hence, a small conformance indicates a change. Using conformance as a metric of change allows information from each vital sign to be translated to a common reporting system and to be pooled hierarchically to any desired level. The CUSUM approach is similar, but also includes the creation of charts that allow systematic deviations to be easily seen. Both approaches are relatively easy to carry out and can complement other approaches to analysis of changes and trends.

The third step in analysis of MIDN data sets will be in-depth analyses of change over time. Specific methods of detecting changes, trends, or temporal patterns detection will be selected for each monitoring protocol, and reported on at predetermined intervals. When appropriate, other analyses such as species-habitat relationships or community ordinations may also occur.

We expect the analysis methods used in the program to change over time. During the first five to ten years of the program, the focus will be on summarizing findings for a given year across the spatial scale of the network. Comparisons to previous years will be made if data are available. Once three measurements have been made over time, conformance can be calculated and trend analyses can begin. After measurements have been made for longer periods, modeling of relationships among monitoring protocols can begin, and time-series or other analyses can be approached.

7.3 Communications and Reporting

For monitoring information to be used effectively, it must be delivered to its target audience in a timely fashion and in an appropriate format. The main audience for MIDN monitoring data is the resource managers of the network parks and other managers in the National Park System, who will use the information to inform their management decisions as part of an adaptive management process. Other target audiences include scientists from other agencies and universities, as well as the general public.

7.3.1 General Considerations

Although the ultimate goal of monitoring programs is to make findings available to resource managers and other audiences, failure or long delays in reporting are common problems. Sometimes the reasons for not reporting do not lie in reporting mechanisms *per se*, but are the result of problems earlier in the monitoring process (e.g., problems with setting measurable objectives, sampling design, feasibility of carrying out the work, data management, or data

analysis). Thus, for the reporting end of the monitoring program to work well, all previous steps in the monitoring program must also be functioning properly as part of an integrated information management system (Figure 7.1). Like data analysis, reporting is an activity that needs to be adequately funded so that reports are produced on schedule (Caughlan and Oakley 2001). Too often, reports are delayed while the next cycle of data collection takes place.

Producing reports that effectively communicate findings from the monitoring program is also critical. Monitoring reports are frequently lengthy, with key results often buried in text and difficult for a busy manager to find. Thus, an important component of producing effective monitoring reports is to improve presentation of results. A concise yet informative executive summary is essential, as is increasing the use of visual methods for communicating results (i.e., graphical techniques). The network will work toward improving data presentation using some of the graphical techniques suggested by Thomas et al. (2006) and others.

The MIDN will strive to: (1) prepare monitoring reports that are understandable and useful to our primary audience of park resource managers, (2) prepare reports promptly, and (3) ensure that reports are readily available.

7.3.2 Initial Reporting Approaches

The list of reports to be produced by the MIDN (Table 7.1) is based on national guidance, modified to reflect MIDN reporting goals. For administrative reporting, the network will rely on the Annual Administrative Report and Work Plan required to be prepared in the fall of each year. The network will report monitoring results through a variety of annual and periodic written reports, a proposed network-wide conference every four to five years, and participation in other scientific forums (e.g., scientific meetings, symposia, etc.). The network will also conduct periodic program and protocol reviews.

As discussed in previous chapters, the MIDN has structured its vital signs monitoring program around a holistic ecosystem model and has focused on creating an integrated program (Figure 7.1). The vision of an integrated program will be carried through in the reporting stage by the annual production of a State of the Parks report for the network. Initially, this report will be constructed from the summaries provided in the annual reports produced for each monitoring protocol. The report will be short and will emphasize graphical summaries of the data. We will work toward incorporating conformance measures for each protocol as an initial method of integrating monitoring findings. It is anticipated that the first State of the Parks report will be produced in March 2010, following the first full year of program implementation.

Parasol mushroom (*Macrolepiota procera*)

Table 7.1. Reports to be produced by the Mid-Atlantic Network.

Type of Report (primary author)	Purpose of Report	Primary Audience	How Often?	Peer Review Process
Annual Administrative Report and Work Plan (Coordinator)	• Account for funds and FTEs expended • Describe objectives, tasks, accomplishments, products of the monitoring effort • Improve communication within park, network, and region	Superintendents, MIDN staff, regional coordinators, and Servicewide program managers, SAC; used for annual report to Congress	Annual	Review and approval by NER Regional Coordinator and Servicewide Program manager
Annual Reports for each Protocol or Project (Project Leader)	• Document annual monitoring activities and archive data • Describe current condition of the resource and provide alert if data are outside bounds of known variation • Document changes in monitoring protocols • Communication within the park or network	Park resource managers, network staff, external scientists	Annual	Peer reviewed at network level
Annual Report on the "State of the Parks" for the MIDN Vital Signs Program (Project Leaders and Coordinator)	• Describe current conditions of park resources • Report interesting trends and highlights of monitoring activities • Identify situations of concern • Explore future issues and directions	Superintendents; park resource managers, network staff; external scientists; public	Annual	Peer reviewed at network level
Analysis and Synthesis reports - Trends (Project Leaders and Coordinator; Statistician)	• Determine patterns/trends in condition of resources being monitored • Discover new characteristics of resources and correlations among resources being monitored • Analyze data to determine amount of change that can be detected by this type and level of sampling • Context - interpret data for the park within a multi-park, regional or national context • Recommend changes to management of resources (feedback for adaptive management)	Superintendents, park resource managers, network staff, external scientists	3–5 year intervals for resources sampled annually	Peer reviewed at network level
Program and Protocol Review reports (Project Lead)	• Periodic formal reviews of operations and results (5 year intervals) • Review protocol design and products to determine if changes needed • Part of quality assurance - peer review process	Superintendents, park resource managers, network staff, servicewide program managers, external scientists	5 year intervals	Peer reviewed at regional or national level
Newsletter, Fact Sheets and Brochures (Project Leaders and Coordinator)	• Review and summarize network activities and findings of general interest • Provide summaries of Annual Reports and Analysis and Synthesis Reports • Describe the role and purpose of the network to non-technical audiences	Superintendents, park resource managers, network staff, Servicewide Program managers, external scientists, public	Biannual	Peer reviewed at network level
Scientific journal articles and book chapters (various)	• Document and communicate advances in knowledge • Part of quality assurance - peer review process	External scientists, students, park resource managers, network staff	Varies	Peer reviewed by journal or book editor

Table 7.1 (cont.). Reports to be produced by the Mid-Atlantic Network.

Type of Report (primary author)	Purpose of Report	Primary Audience	How Often?	Peer Review Process
MIDN Vital Signs Monitoring Conference (Project Leads and Coordinator)	• Review and summarize information on MIDN vital signs • Help identify emerging issues and generate new ideas	Park resource managers, network staff, external scientists, students	5-year interval	Peer reviewed at network level
Other symposia, conferences, and workshops (Project Leads and Coordinator)	• Review and summarize information on a specific topic or subject area • Communication of latest findings with peers • Help identify emerging issues and generate new ideas	Park resource managers, network staff, external scientists	Varies	May be peer reviewed by editor if written papers are published
MIDN contributes to the national "State of the Parks" Report (Project Leads and Coordinator)	• Describe current conditions of park resources • Report interesting trends and highlights of monitoring activities • Identify situations of concern • Explore future issues and directions	Congress, budget office, NPS Leadership, superintendents, general public	Annual	Peer reviewed at national level
MIDN website and web-based media (Project Leads and Coordinator)	• Centralized repository of all final reports to ensure products are easily accessible in commonly-used electronic formats	Superintendents, park resource managers, network staff, Servicewide Program managers, external scientists	Variable: posted after reports are completed	Peer reviewed at network level

Chapter 8: Administration and Implementation

8.1 Administration

The Mid-Atlantic Network's Inventory and Monitoring (I&M) Program receives guidance from the network's charter and from individuals and groups at both the network and national levels (Figure 8.1).

8.1.1 Network Charter

The MIDN charter was established in April 2003 and outlines the basic practices to be used to plan, organize, manage, evaluate, and modify the Mid-Atlantic Network's vital signs monitoring program.

8.1.2 National Guidance

At the national level, several officials and governing bodies provide guidance and direction for the MIDN I&M Program. The National Park Service associate director of natural resources (ADNR) is directed to implement the national I&M Program. The Inventory and Monitoring Advisory Council (IMAC) meets twice a year to make recommendations to the ADNR and resolve issues affecting all networks. The IMAC has two representatives from each region of the National Park Service, including the regional I&M Program coordinator and one other person selected by the region. In addition, the IMAC is regularly attended by staff from the Natural Resources Program Center (NRPC), which is charged with providing guidance, vision, and technical support to implement the networks' I&M Programs. The NRPC Office of Inventory, Monitoring, and Evaluation also provides day-to-day guidance, policy interpretation, and technical assistance to the MIDN program.

8.1.3 Board of Directors

At the network level, the MIDN Board of Directors (BOD) provides administrative and budgetary guidance and approval for the network's I&M Program. The BOD is composed of the superintendent (or the designee thereof) from each park in the MIDN (Table 8.1), the NPS Northeast Region (NER) chief scientist, and the NER regional I&M Program coordinator. The BOD meets at least annually and approves the Annual Administrative Report and Work Plan (AARWP), and also approves decisions regarding budget, staffing, and project implementation. Their work is guided by a charter, a key feature of which prescribes that all BOD decisions be made by consensus. The board's membership periodically changes as staff changes occur in the parks; current membership is reported in the most recent AARWP. The BOD's most critical function is to ensure that the monitoring program becomes integrated into the day-to-day activities of park planning and management including maintenance, interpretation, resource protection, and resource management.

8.1.4 Science Advisory Committee

The second component of I&M Program guidance at the network level comes from the Science Advisory Committee (SAC), which was established by the MIDN coordinator and approved by the BOD in order to provide technical guidance throughout the development and implementation of the monitoring plan. The SAC meets at least annually (and additionally when their input is needed from the I&M Program staff) and, to comply with the Federal Advisory Committee Act, is composed only of federal employees. Participants include representatives from the resource management

Upland chorus frog (*Pseudacris feriarum feriarum*)

Figure 8.1. Relationship between different components of the I&M Program and the Mid-Atlantic Network.

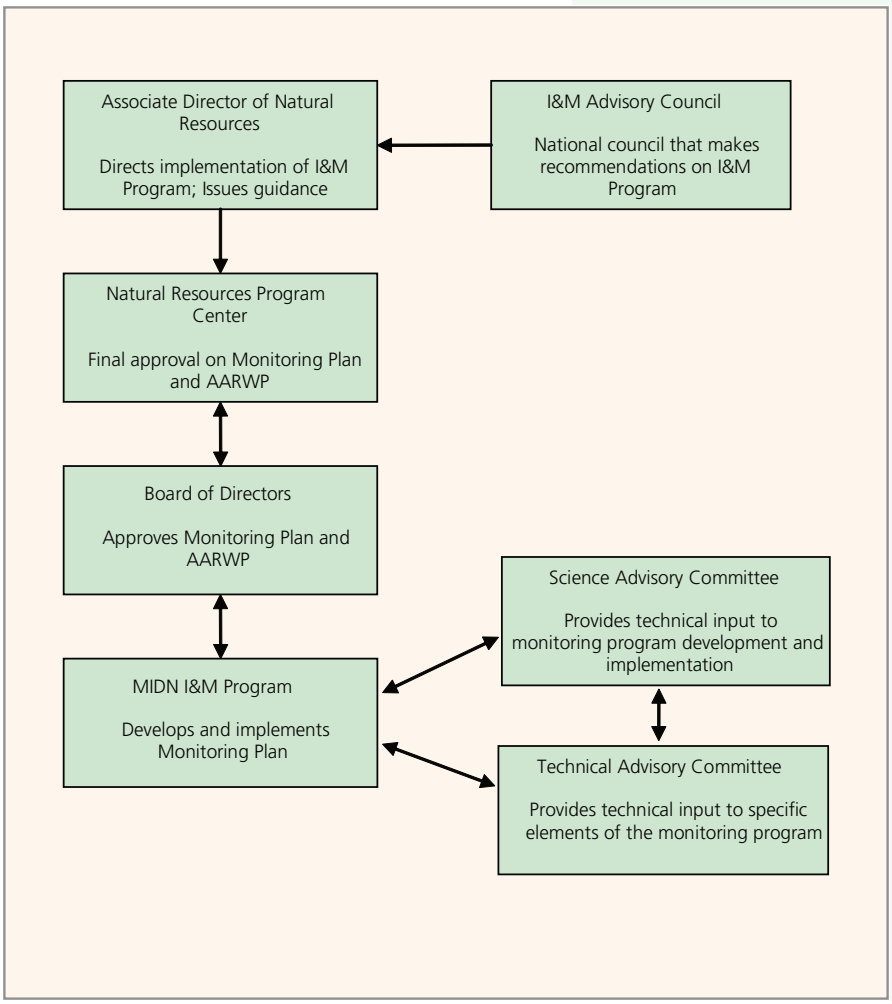


Table 8.1. Members of the Mid-Atlantic Network Board of Director Directors.

Board Member	Title	Park(s)
Steven Ambrose	Resource Manager	Hopewell Furnace NHS
Mike Caldwell	Superintendent	Valley Forge NHP
James Comiskey	MIDN Coordinator	I&M Program
Rebecca Harriett	Superintendent	Booker T. Washington NM
Jim Johnson	Chief of Resources	Gettysburg NMP
Reed Johnson	Superintendent	Appomattox Court House NHP
Bob Kirby	Superintendent	Petersburg NB
Dave Ruth	Superintendent	Richmond NBP
Gordon Olson	Chief of Resources	Shenandoah NP
Russ Smith	Superintendent	Fredericksburg and Spotsylvania NMP
John Karish	Chief Scientist	Northeast Region
Elizabeth Johnson	I&M Regional Coordinator	I&M Program

Table 8.2. Members of the Mid-Atlantic Network Science Advisory Committee.

Committee Member	Title/Specialty	Institution
Alan Ellsworth	Hydrologist	NPS, Northeast Region (NER)
Craig Snyder	Aquatic Ecologist	USGS, Leetown Science Center
Elizabeth Johnson	I&M Regional Coordinator	NPS, I&M Program
Gordon Olson	Chief of Resources	NPS, Shenandoah NP
James Comiskey	Network Coordinator	NPS, I&M Program, Mid-Atlantic Network
John Karish	Chief Scientist	NPS, NER
John Young	Landscape Ecologist	USGS, Leetown Science Center
Julie Thomas	Air Resources	NPS, Washington Support Office (WASO)
Kristen Allen	Natural Resources	NPS, Richmond NBP
Sarah Wakamiya	Data Manager	NPS, I&M Program, Mid-Atlantic Network
Paul Geissler	Statistical Ecologist	USGS, Patuxent Wildlife Research Center
Zachary Bolitho	Natural Resources	NPS, Gettysburg NMP

Table 8.3. Subject matter experts who provide technical assistance to the Mid-Atlantic Network Science Advisory Committee and Board of Directors.

Committee Member	Title/specialty	Institution
Carolyn Mahan	Community Ecologist	Penn State University
Rick Webb	Aquatic Ecologist	University of Virginia
Gary Fleming	Vegetation Ecologist	VA Natural Heritage Program
Karen Patterson	Vegetation Ecologist	VA Natural Heritage Program

divisions of MIDN parks; the hydrologist, chief scientist, and regional I&M Program coordinator from the NPS Northeast Region; and employees from partner agencies (Table 8.2) including the U.S. Geological Survey (USGS). Subject matter experts (Table 8.3) are regularly brought in to share their knowledge on specific topics, and typically represent local universities, partnering agencies, and state or local government agencies. The current composition of the SAC is listed in the most recent AARWP.

8.1.5 Technical Advisory Committee

The Technical Advisory Committee (TAC) is a short-term, ad hoc committee established to provide credible scientific review of I&M Program products and research. The TAC is composed of a small group of scientists who are well versed in the science of monitoring and represent various universities and agencies. The members are reimbursed for their time and effort. The committee's current composition is listed in the most recent AARWP.

8.2 Staffing

8.2.1 MIDN Staff

The MIDN I&M Program is one of four networks under the Natural Resources Directorate of the Northeast Region. The network is directed and supervised by the MIDN coordinator with oversight by the NER regional I&M Program coordinator (Figure 8.2). Program staff currently consists of two permanent positions, the MIDN coordinator and the data manager, whose duties are described in further detail below. In addition, a botanist/database support person at Penn State University provides support to both the MIDN and the Eastern Rivers & Mountains Network (ERMN). A part-time science communicator in the NER Science Office provides communications support. Additional staff are hired seasonally for the forest vegetation monitoring program, and park staff provide assistance when their time permits.

Coordinator/Ecologist (GS-12) - The network coordinator provides the overall direction and guidance for the MIDN I&M Program and also develops and oversees the implementation of the Monitoring Plan. The coordinator acts as the liaison between MIDN staff and network parks, as well as the SAC, BOD, TAC, and the NER regional I&M Program coordinator. The coordinator supervises the MIDN professional staff and provides general oversight and accountability for the network program.

The coordinator also operates as the network ecologist and is responsible for the overseeing the design, implementation, data analysis, and reporting of the monitoring protocols.

Data Manager/Biologist (GS-11) - The data manager is responsible for the development, management, coordination, and implementation of natural resource information systems, including databases, data archives, and Geographic Information System (GIS) resources. This position's responsibilities include creating new databases consistent with NPS standards, performing quality assurance/quality control (QA/QC) for new data, and generating metadata that comply with Federal Geographic Data Committee (FGDC) standards. The data manager assists the coordinator in making data accessible to parks by summarizing the data, generating standard reports as identified by protocols, and sharing data through the Internet or other media. The data manager also operates as the network biologist, providing additional support for MIDN monitoring protocols.

Seasonal Biotechnicians (GS-5 and GS-7) - These are seasonal positions, typically lasting four months, with data collection as their primary duty. It is anticipated that two seasonal biotechnicians will be needed each year for the vegetation monitoring program. The biotechnicians will be directed by the network coordinator and will follow existing protocols to gather data; record, verify, and correct data values; and perform regular data transfer and backup. The biotechnicians also assist with documentation of data sets and procedures, and are responsible for documenting any deviations from protocols or study plans.

8.2.2 Park Staff

Given staffing constraints, the potential for direct support of the I&M Program from park staff is extremely limited, and it is not expected or anticipated that park staff will be involved with routine data collection, management, analyses, or reporting. However, park staff including resource managers will play a critical role in implementing the I&M Program and we anticipate that each park will be responsible for the following tasks:

- Issuing park permits—Along with issuing permits, parks will be responsible for handling compliance issues.
- Review and approval of Investigator Annual Reports (IARs) — Parks will be responsible for reviewing IARs submitted by the I&M Program or by cooperators working for the I&M Program.
- Park access—Parks will be responsible for ensuring, to the best of their ability, that sampling sites can be accessed.
- Park housing—For parks that have housing available, parks will do their best to make housing available to field crews as needed.
- Field assistance—Parks that are interested and have staff available are encouraged to participate in field work.

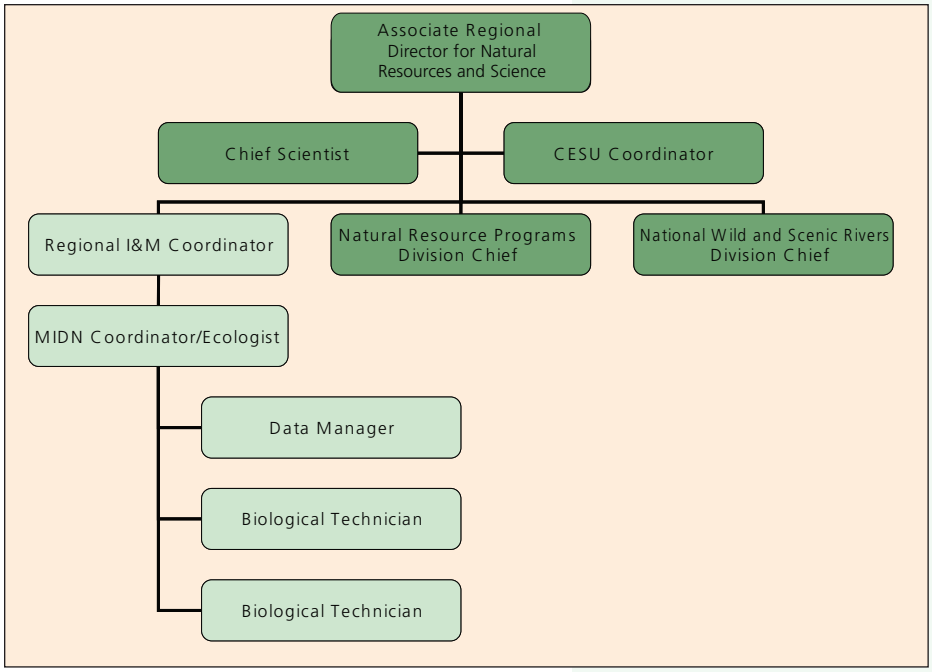


Figure 8.2. Proposed organizational chart for the Mid-Atlantic Network. Positions in light green are funded by the Inventory and Monitoring Program.

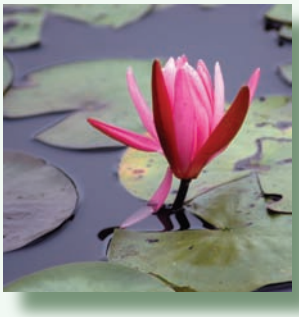
8.3 Network Office

The MIDN I&M Program is based at the Natural Resources Office in Fredericksburg and Spotsylvania National Military Park. The MIDN covers the cost of utilities for the building, phones, and a T1 line. The duty station for additional MIDN seasonal staff will also be Fredericksburg and Spotsylvania NMP. The MIDN office is conveniently located within a four-hour drive of the network's most distant parks, Valley Forge National Historical Park to the north and Booker T. Washington National Monument to the southwest.

8.3.1 Program Implementation

Each project associated with the MIDN I&M Program has an assigned lead. In most situations the network coordinator is the lead. For any contracts, cooperative agreements, or interagency agreements, the official lead is the key official. Some projects may also have a

Flowering dogwood (Cornus florida)



Water lily (*Nymphaea spp.*)

Several partnerships are already in place to accomplish some components of the MIDN I&M Program.

project manager who oversees the day-to-day project oversight but works under the guidance of the key official.

8.3.2 Key Official

The key official (network coordinator) is the contracting officer's technical representative (COTR), and is the person who signs all agreements and is ultimately responsible for the execution and administration of projects that fall under the scope of an agreement. Such agreements may include contracts, cooperative agreements, or interagency agreements.

8.3.3 Project Manager

The project manager provides day-to-day oversight on a given I&M Program project. Project managers can be network, park, or regional staff, but will typically be network staff. For most projects, the key official and project manager may be the same person. If a specific technical background is needed to manage a project, the key official may name a project manager who has that necessary background. It is, however, still the key official's responsibility to ensure that the project is appropriately implemented.

The project manager coordinates and supervises all phases of the data life cycle, including data collection, entry, verification and validation, summary, analysis, and reporting. The project manager also creates the documentation and criteria needed to properly use and interpret the data. As such, this person is the primary point of contact for information about the project. His or her active involvement determines the quality of the project and the overall success of the MIDN I&M Program.

Specifically, a project manager's role is to:

- Complete project documentation describing the "who, what, where, when, why, and how" of a project
- Coordinate field data collection with parks and principal investigators, including training of any field help and biotechnicians
- Maintain concise explanatory documentation of all deviations from standard procedures
- Ensure documentation of important details from each field data collection period
- Ensure proper records management, including archiving
- Ensure adherence to protocol procedures and timelines, including data collection periods, data processing target dates, and reporting deadlines
- Produce or collect annual reports and final reports
- Provide summary reports for outreach communications
- Coordinate data management and archiving with the data manager
- Oversee periodic trend analysis of data, store the resulting reports, and make them available to users
- Increase the interpretability and accessibility of existing natural resource information
- Act as the main point of contact concerning the project
- Keep the key official (if different from the project manager) informed of progress and potential issues that may result in delays or changes to the project scope

8.4 Partnerships

Several partnerships are already in place to accomplish some components of the MIDN I&M Program. Protocols, for example, are being developed through partnerships with the University of Virginia, The Pennsylvania State University (School for Forest Resources and Department of Meteorology/State Climatologist's Office), and the USGS Leetown Science Center. Support for data management and archiving is being provided by North Carolina State University. Data that will be used for monitoring the air quality vital signs are already being collected by various agencies, including the National Oceanic and Atmospheric Administration (NOAA) and the U.S. Environmental Protection Agency (EPA) through their Clean Air Status and Trends Network (CASTNet) and National Atmospheric Deposition Program (NADP). As protocol development continues, the MIDN will continue to enlist more partners in the program.

8.4.1 Periodic Program and Protocol Review

We have developed an all-encompassing, three-level review process (Table 8.4) to evaluate the myriad facets of the I&M Program. The first level of review is the Annual Administrative Re-

port and Work Plan (AARWP), which provides the MIDN parks and BOD with an opportunity every year to review what has taken place and what is planned, and to evaluate the overall program. However, we must ensure that rigorous evaluation takes place at this level, and that we do not adopt a mindset of "business as usual." This will be particularly important during the next two to four years as the actual operation of the program and monitoring of vital signs are established.

Our second level of review will take place during our biennial update to the SAC. This will be a day-long symposium at which all I&M Program staff and cooperators conducting any portion of the program will give a technical presentation on the results and status of their work. These presentations will be followed by a discussion to evaluate the work's scientific and operational merits. The decisions resulting from this review will then be presented to the BOD for their endorsement.

Finally, our third level of review will be the five-year program review. After an initial start-up review of each network's I&M Program within three years after its monitoring plan is accepted and implemented, subsequent reviews will be on a five-year cycle. The five-year review will focus on the operational and administrative aspects of the network's monitoring program (that is, it will not be a technical review), asking the basic question, "Is the network set up to succeed?" The review will allow network and park staff to step back and evaluate their progress against the objectives and schedule set forth in the network's monitoring plan, to develop a road map for completing and implementing the first set of protocols, and to make adjustments if needed.

Peer Review—Each protocol will be reviewed after five years of data are available. This technical review will be performed by subject matter experts not involved in the data collection, who will analyze the data and make recommendations to improve the protocols, including all aspects of the standard operating procedures. Recommendations will be presented to the network I&M Program staff, SAC, and BOD for review.

Program Review—Every five years, the SAC will meet to hear a series of technical presentations from the I&M Program staff and discuss what has been learned from the data collected and its relevance to park management. The list of vital signs will be reviewed to make sure that these indicators are still priorities for monitoring. Data management will be reviewed to ensure that standards continue to be met and are adequate. The annual budgets and staffing plan will be revised if needed. All recommendations will be presented to the regional coordinator and the BOD for review.

8.5 Integration of the I&M Program with Park Operations

The MIDN I&M Program has made a commitment to implement long-term monitoring, ana-

Integrating science into park management will require providing technical assistance, coordination, communication, and data sharing.

Table 8.4. Periodic program reports and reviews.

Review	Timing	Who is Involved	Intent of Review
Annual Administrative Report and Work Plan	Annual	Regional Coordinator, I&M Staff, Park Staff, BOD, NRPC	Provide yearly accountability for program. Report on accomplishments and explain goals and projects for next fiscal year.
Report to Science Advisory Committee	Biennial	Regional Coordinator, I&M Staff, BOD, SAC, Park Staff	Provide technical details on results and status of all data collection within program. Evaluate if goals are being met appropriately and if focus of program is consistent with goals. Also evaluate if operations of program are working in concert with other aspects of program.
Five Year Program Review	Quinquennial	National Monitoring Program Leader, Regional Coordinator, I&M Staff, Anonymous Reviewers	The first review will take place three years after this monitoring plan is accepted. The review will focus on the operational and administrative aspects of the network's monitoring program (this is not a technical review), and will ask the basic question "Is the network set up to succeed?"

The Mid-Atlantic Network will work diligently to ensure that all science products, including those from the long-term monitoring program, are fully integrated and used by park management.

lyze data, and report findings to various audiences in the parks, including resource management, park administration, and interpretation staff. Integrating science into park management, however, is more complex than simply reporting results. The MIDN I&M Program will work diligently to ensure that all science products, including those from the long-term monitoring program, are fully integrated and used by park management. This integration strategy consists of a four-pronged approach that emphasizes (1) technical assistance, (2) coordination, (3) communication, and (4) data sharing. As part of the five-year review, the SAC will analyze how well the integration strategy has worked to meet park needs and how well I&M Program products have been used by park management.

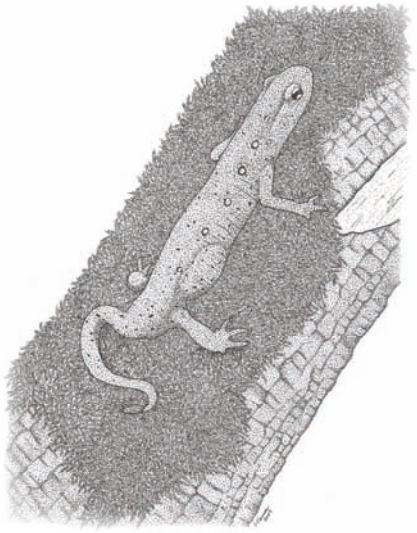
Technical Assistance: Given the current and anticipated scientific and technical expertise within the I&M Program, there are many opportunities to provide technical assistance to the parks. Technical assistance will be offered to parks in order to help:

- Identify clear objectives for research, monitoring, or management
- Prioritize projects, solicit funding, and implement park projects
- Support park planning efforts, including development of Resource Stewardship Strategies (RSS), General Management Plans (GMP), Fire Management Plans (FMP), Natural Resource Condition Assessments (NRCA), and compliance needs
- Review data collected in parks and provide support for analysis and reporting results

Coordination: The MIDN will closely coordinate implementation of the monitoring program with parks. Emphasis will be placed on coordinating fieldwork with resource managers and coordinating and reviewing I&M Program research permits.

Communication: Results from the monitoring program must be communicated in a timely manner and must meet rigorous scientific standards. In order to enhance communication, the I&M Program will provide both oral and written communications to a variety of audiences. The I&M Program will be generating a variety of reports, including the AARWP and State of the Parks report cards every year. Chapters 6 and 7 provide more details on data reporting and analysis. In addition, the I&M Program has made it a priority to develop outreach and education products such as fact sheets, brochures, or other products in order to promote the results and findings of long-term monitoring.

Data Sharing: The I&M Program will promote and coordinate data sharing of monitoring program results through regionally accessible online databases.



Chapter 9: Schedule

9.1 Introduction

The Mid-Atlantic Network (MIDN) currently plans to implement five monitoring protocols that will cover 15 high-priority vital signs (Table 9.1). Two protocols (Air Quality, Weather and Climate) are planned for 2009, Water Quality and Quantity will be implemented in 2010, and Aquatic Macroinvertebrates, is scheduled for implementation in 2011. Pilot testing and implementation of the Forest Vegetation monitoring protocol began in 2007 and will be completed by 2010. An anticipated annual schedule for the frequency and timing of sampling for the five protocols is shown in Table 9.2.

9.2 Vital Signs Monitoring Protocols

9.2.1 Air Quality

The MIDN's Air Quality monitoring protocol will primarily consist of reporting on data collected through existing national monitoring programs. The NPS Air Resources Division (NPS-ARD) has developed protocols for monitoring ozone, wet deposition, and dry deposition, and reports are produced annually as data summaries (for example, Ray 2007, 2008) and trend reports (NPS-ARD 2007). The MIDN will implement the reporting protocols in 2009. Data will be available from continuous monitoring.

9.2.2 Weather and Climate

A detailed inventory of weather stations in proximity to MIDN parks has been completed (Davey et al. 2006). Under a cooperative agreement with The Pennsylvania State University, a protocol is being developed for compilation, analysis, reporting, and management of weather and climate data that will be used by both the MIDN and the Eastern Rivers and Mountains Network (ERMN). Data from individual stations will be accessible via a Web-based interface by 2009 along with annual reports. Data will be available from continuous monitoring.

Pink lady's slipper (*Cypripedium acule*)

Table 9.1. Schedule for development and implementation of five Mid-Atlantic Network monitoring protocols.

Protocol	MIDN Vital Sign	Draft	Final	Implemented	Lead Institution
Air Quality	Ozone Wet and dry deposition Visibility and particulate matter Air contaminants (mercury)	Protocols complete Reporting protocols 2008		MIDN reporting 2009	NPS Air Resources Division
Weather and Climate	Weather and climate	Reporting protocols 2008		2009	Penn State University
Water Quality and Quantity	Stream / river channel characteristics Stream and river water dynamics Water chemistry	2008	2009	2010	University of Virginia
Aquatic Macroinvertebrates	Aquatic macroinvertebrates	2009	2010	2011	Appalachian Aquatic Consultants and USGS
Forest Vegetation	Forest plant communities Invasive exotic plants Native forest pests Exotic diseases / Pathogens – plants White tailed deer (herbivory) Soil structure and composition	2008	2009	2010	MIDN

Red-spotted newt (*Notophthalmus viridescens viridescens*)

9.2.3 Water Quality and Quantity

A monitoring protocol is currently being developed by the University of Virginia. A series of synoptic surveys were initiated in 2008 to obtain data from unassessed reaches in MIDN parks. These results will inform the site selection process during sampling design. The monitoring protocol will be available in 2009, and implementation is anticipated for 2010. Data will be collected, at minimum, on a quarterly basis.

9.2.4 Aquatic Macroinvertebrates

Work commenced on an Aquatic Macroinvertebrates monitoring protocol in 2008. Synoptic surveys will be conducted in spring and fall to determine the optimum sampling methods and timing. An additional project is also underway to identify ecological thresholds for aquatic macroinvertebrates in MIDN and ERMN parks, led by the USGS with funding from the Status and Trends Program. Results from this project will inform development of specific monitoring protocols for aquatic macroinvertebrates. The final protocol will be available in 2010, with protocol implementation in 2011. Data will likely be collected in spring of each year.

9.2.5 Forest Vegetation

The Forest Vegetation monitoring protocol has been developed and adapted through a collaborative partnership between seven I&M Program networks and three prototype parks. MIDN staff conducted pilot testing in 2007, and will evaluate the results to ensure that sampling objectives are met. A final protocol will be available in 2009. Data collected during 2008 represent the second year of implementation for this protocol. Data will be collected during the summer months.

Table 9.2. Proposed annual schedule for Mid-Atlantic Network vital signs monitoring protocols.

Protocol	Sampling interval	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Air Quality	Continuous												
Weather and Climate	Continuous												
Water Quality and Quantity	Quarterly												
Aquatic Macroinvertebrates	Spring or Fall												
Forest Vegetation	Summer												

Chapter 10: Budget

Mole salamander (*Ambystoma talpoideum*)

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Chapter 11: Literature Cited

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Glossary

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

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

Attributes: any living or nonliving feature or process of the environment that can be measured or estimated and that provide insights into the state of the ecosystem. The term **Indicator** is reserved for a subset of attributes that is particularly information-rich (see Indicator).

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

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

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

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, a recognition that ecosystems are spatially and temporally dynamic, and acceptance of the dictum that ecosystem function depends on ecosystem structure and diversity. The whole-system focus of ecosystem management implies coordinated land-use decisions.

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.

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

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

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

Metadata: data about data. Metadata describes the content, quality, condition, and other characteristics of data. It's purpose is to help organize and maintain a organization's internal investment in spatial data, provide information

about an organization's data holdings to data catalogues, clearinghouses, and brokerages, and provide information to process and interpret data received through a transfer from an external source.

Monitoring: 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.

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

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). 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.

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

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

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

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