National Park Service
U.S. Department of the Interior

Cumberland Piedmont Network and Mammoth Cave National Park Prototype

Vital Signs Monitoring Plan

The Cumberland Piedmont Network

Abraham Lincoln Birthplace National Historic Site
Carl Sandburg Home National Historc Site
Chickamauga and Chattanooga National Military Park
Cowpens National Battlefield
Cumberland Gap National Historical Park
Fort Donelson National Battlefield
Guilford Courthouse National Military Park
Kings Mountain National Military Park
Little River Canyon National Preserve
Mammoth Cave National Park
Ninety Six National Historic Site
Russell Cave National Monument
Shiloh National Military Park
Stones River National Battlefield

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Executive Summary

The Cumberland Piedmont Network (CUPN) Inventory and Monitoring Program was initiated in January 2001 to conduct biological inventories and examine the status and trends of ecosystem health for its cohort of 14 national parks, battlefields, and historic sites. Within the CUPN, Mammoth Cave National Park (MACA) is the prototype for monitoring the cave-and-karst biome and provides technical expertise and protocol assistance to the other parks in the Network.

Cave Cricket – a denizen of Mammoth Cave National Park's cave-and-karst biome.

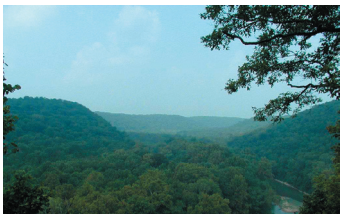
The CUPN, and every network of parks that received funding from the Natural Resource Program Center to develop an Inventory and Monitoring Program, is required to prepare a monitoring plan that describes the design and implementation of their monitoring program as well as the process that led to the final selection of the Vital Signs to be monitored. Successful completion of the monitoring plan was accomplished in three-phases:

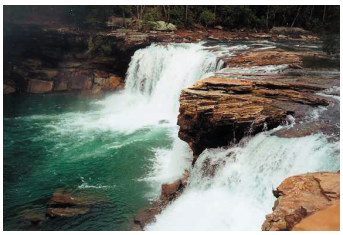
Phase I – Identification of Significant Natural Resources, Management Issues, Background Information, and Development of Conceptual Models (2001-2002): The general purpose of the CUPN-MACA Monitoring Program is to provide information to detect, predict, and understand changes in major ecosystem resources of primary interest to the park(s) that contain them. Central to achieving this purpose was the identification of natural resources that are significant both to the ecosystem and to park managers. This was accomplished in Phase I by conducting a series of Network-wide workshops to develop a comprehensive list of significant natural resources that met one or more of four criteria: (1) natural resources significant to enabling legislation; (2) natural resources significant because of specific legal mandates or policies; (3) natural resources significant because of performance management goals; and (4) natural resources significant for other reasons, such as those identified as important by other agencies. The workshops also summarized park management issues using categories defined in existing Resource Management Plans. An overview of these significant natural resources and management issues is presented in Chapter 1 of this document.

In addition to the parks' perspectives on resource significance, the Network involved external scientists to develop a series of theoretical, or conceptual, ecosystem models. Ecologists from the University of Tennessee and United States Geological Survey-Biological Resource Discipline (USGS-BRD) took the lead in this effort, following a multi-agency science meeting held jointly with the Appalachian Highlands Network. The conceptual models were developed around the framework of three major ecosystems: aquatic, caves, and terrestrial. While using general models to illustrate the overall ecosystem, detailed sub-models were designed to focus on resources of park-specific management priority. Chapter 2 provides a description of the ecosystem modeling process.

Phase I also began the process of identifying, evaluating, and synthesizing existing data, including a comprehensive evaluation of water resources. To accomplish this, an on-site hydrologic assessment of each Network park was conducted that included a brief description of park hydrology, documented and potential threats to water quality, general water uses, and general aquatic resources. Potential sampling locations, including past sites, were assessed and described (including factors of site relevance, sampling logistics, and safety). Appendix E contains the complete Water Quality Monitoring Program that was subsequently developed. Other monitoring efforts both within and outside of the NPS are summarized in Chapter 1 and Appendix I of this document. Having in hand a listing of its significant natural resources and management issues, completed development of conceptual ecosystem models and submodels, and an evaluation of its water resources, the CUPN was ready to proceed to the Phase II Vital Signs selection process.

Landscape Change


Air Quality


Water Quality

Ozone Damage

Invasive Species

Cave Biota

Phase II – Prioritization and Selection Process (2002-2003): The selection and prioritization of Vital Signs to be monitored was accomplished through a series of park-by-park workshops. USGS-BRD Ecologist, Dr. Robert Woodman, took the lead in simplifying the conceptual ecosystem models by extracting component sub-models for discussion and focus during the workshops. Working with other staff and scientists from MACA, the prototype ranked its Vital Signs first, then Dr. Woodman helped to apply these procedures to the other Network units. Dr. Jack Ranney, Ecologist with University of Tennessee, became the workshop leader for the thirteen smaller parks, and each potential vital sign was ranked using a group consensus on three weighted factors: Ecological Significance (40%), Management Significance (40%), and Monitoring Efficacy (20%).

The resulting scores were tallied and weighted according to the majority of parks (separate from MACA Prototype ranking). This resulted in a short-list of high-priority Vital Signs for the CUPN which was later combined with the list from MACA, to produce a combined total of seventeen high-priority Vital Signs (see chart below). A full description of the ranking process and resulting lists of Vital Signs are the subjects of Chapter 3.

Phase III – Sampling Design, Protocol Development, and Data Management (2003-2004): Phase III (and beyond) of the monitoring plan involves developing strategic sampling designs which are appropriate for both Network-wide and park-level components. The overall sampling strategy is to promote the integration of various monitoring components and to allow inferences to be made beyond the areas actually sampled. The terrestrial component of Network-wide vegetation sampling will be based upon grid-and-plot arrays developed during the course of biological inventories. For some community types that are not represented by established plots, additional sampling locations will be added. For other monitoring efforts, the sampling design will be based upon factors specific to the spatial distribution of resources. Ozone monitors must consider topography, openness of

Seventeen High-Priority Vital Signs for the Cumblerand Piedmont Network

Park / Vital Sign Name	Ozone and Ozone Impact	Atmospheric Deposition	Cave Air Quality	Water Quality and Quantity	Benthic Macro-Invertebrates	Invasive Plants	Forest Pests	Cave Aquatic Fauna	Cave Beetles	Cave Crickets	Vegetation Communities	Mussel Diversity	Fish Diversity	Cave Bats	Allegheny Woodrats	Plant Species of Concern	Adjacent Land Use
ABLI	■			■		■	■				■						■
CARL	■			■		■	■				■					■	■
CHCH	■			■		■	■				■					■	■
COWP	■			■		■	■				■					■	■
CUGA	■		■	■		■	■				■						■
FODO	■			■		■	■				■					■	■
GUCO	■			■		■	■				■						■
KIMO	■			■		■	■				■					■	■
LIRI	■			■		■	■				■		■			■	■
MACA	■	■	■	■	■		■	■	■	■		■	■	■	■		■
NISI	■			■		■	■				■					■	■
RUCA	■		■	■		■	■				■						■
SHIL	■			■		■	■				■		■				■
STRI	■			■		■	■				■					■	■

forest canopy, and nearby ozone sources; while cave sampling is driven by distribution of caves, accessibility, and management status. Sampling designs are discussed in Chapter 4 of this plan.

Protocol development was another major task of Phase III. The complexity of a long-term monitoring program with multiple parks and sampling designs requires a standard for review of how data are to be collected, managed, analyzed, and presented. Following IM guidance, the Network adopted use of protocol guidelines (Oakley, et al. 2003) and protocol development summaries (PDS). These include a brief justification narrative and specific monitoring objectives, as well as the list of parks involved. The Network currently has three draft protocols under review and has included a PDS for each of the remaining 14 in Appendix R of this document.

In addition to protocol-specific data management procedures, an overall data management strategy is required to address the needs of a multi-park monitoring program; therefore, in 2004, the CUPN-MACA data management team developed a comprehensive draft Data Management Plan (DMP) in collaboration with other networks, and with initial coordination and guidance provided by the IM Program. The DMP will serve to guide program managers and other staff in the management of data documentation, data quality, and data distribution. An overall summary of data management is discussed in Chapter 6 and the draft DMP can be found as Appendix T of this document. The remaining chapters of this plan cover topics on administration, schedule, and budget (Chapters 8, 9, 10).

Future Direction: The CUPN-MACA plans to implement its monitoring of three high-priority Vital Signs in 2005, pending approval of relevant protocols. These are the Allegheny Woodrat (MACA), Cave Cricket (MACA), and Water Quality (all 14 CUPN parks). Databases and sampling designs are already under development for these three. Also continuing in 2005, will be the development and testing of several additional protocols for ozone, cave beetles, cave air quality, and fish diversity. Vegetation classification and mapping baselines will also continue.

The Water Quality monitoring program has completed a two-year baseline inventory and park-by-park discussions began in January 2005 to determine which parameters will remain in the active monitoring program. Database training and implementation of NPStoret (Water Resource Division's Service-wide database) will also take place in 2005.

In the years following, biological inventory and monitoring data will be updated appropriately as projects approach their ending dates. These new datasets of information will be compiled and summarized to fill any gaps that may have occurred during the prioritization of Vital Signs.

The CUPN-MACA monitoring program will undergo programmatic reviews at approximately 5-year intervals. Periodic program reviews are an essential component of quality assurance for any long-term monitoring program, and are conducted specifically to evaluate and improve the program. This CUPN-MACA Vital Signs Monitoring Plan will be updated as needed to reflect changes to the ongoing monitoring program.

Chapter One
Introduction and Background

The Cumberland Piedmont Network (CUPN) is one of 32 National Park Service (NPS) inventory and monitoring networks nationwide that are creating a Vital Signs Monitoring Plan for assessing the condition of park ecosystems. The network approach facilitates collaboration, information sharing, and economies of scale in natural resource monitoring, and will provide parks with a minimum infrastructure for initiating natural resource monitoring that can be built upon in the future. This plan defines the process used by CUPN to accomplish Vital Signs monitoring integrated with the prototype long-term ecological monitoring efforts underway at Mammoth Cave National Park (MACA). Both CUPN and MACA Prototype are funded through the Natural Resource Challenge and are working together toward a mutual goal to provide critical information to park managers regarding the status and trends of selected resources designated as Vital Signs.

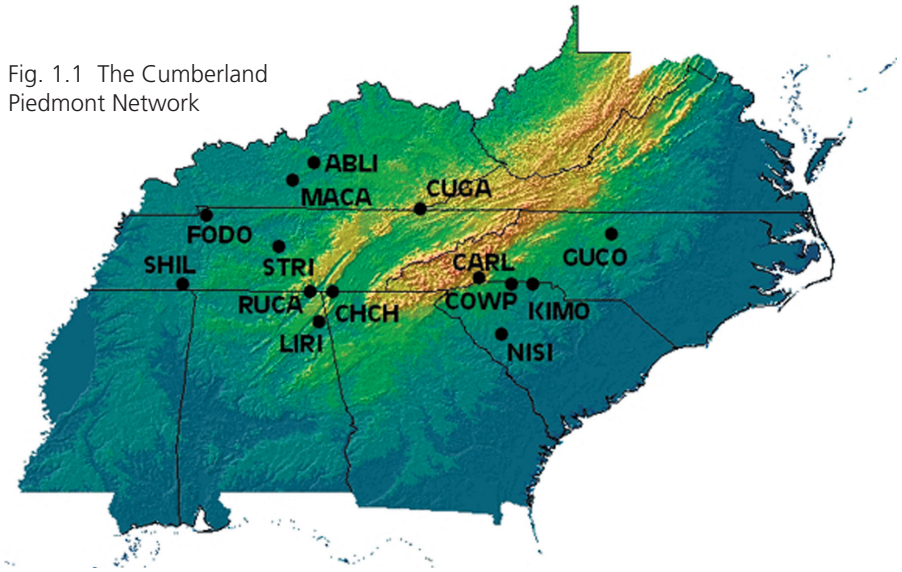


Fig. 1.1 The Cumberland Piedmont Network

1.1 Overview of Network Parks

The CUPN consists of 14 parks with diverse cultural and natural resources distributed across seven states and six different physiographic regions (Figure 1.1). Ecosystems encompassed

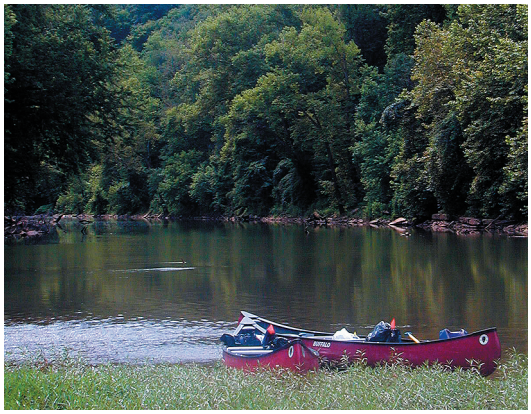
Table 1.1 Cumberland Piedmont Network Parks

Park Name	Code	Size (acre)	Size (ha)	State
Abraham Lincoln Birthplace National Historic Site	ABLI	341	138	KY
Carl Sandburg Home National Historic Site	CARL	264	107	NC
Chickamauga & Chattanooga National Military Park	CHCH	8,178	3,318	GA/TN
Cowpens National Battlefield	COWP	842	341	SC
Cumberland Gap National Historical Park	CUGA	20,437	8,274	KY/TN/VA
Fort Donelson National Battlefield	FODO	558	226	TN
Guilford Courthouse National Military Park	GUCO	220	89	NC
Kings Mountain National Military Park	KIMO	3,945	1,597	SC
Little River Canyon National Preserve	LIRI	13,691	5,543	AL
Mammoth Cave National Park	MACA	52,809	21,380	KY
Ninety Six National Historic Site	NISI	988	400	SC
Russell Cave National Monument	RUCA	309	125	AL
Shiloh National Military Park	SHIL	3,969	1,607	TN
Stones River National Battlefield	STRI	709	287	TN

The Mission of the National Park Service (National Park Service Organic Act, 1916) is: "…to promote and regulate the use of the Federal areas known as national parks, monuments, and reservations hereinafter specified by such means and measures as conform to the fundamental purposes of the said parks, monuments, and reservations, which purpose is to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations".

Terrestrial

Cave



Aquatic

by the CUPN parks include three major components: aquatic systems, terrestrial systems, and sub-terrestrial cave systems. Parks in the Network range in size from 220 acres to almost 53,000 acres, and include four Revolutionary War parks, four Civil War parks, four national historic sites, one national preserve, and one national park (Table 1.1). The Network's largest park is Mammoth Cave National Park, a World Heritage Site that constitutes the core area of an International Biosphere Reserve. Mammoth Cave National Park is the long-term ecological monitoring prototype for the NPS cave and karst biome category. The CUPN and MACA are working together to prepare a monitoring program that will provide the information needed to assess changes within critical elements of the Network parks' ecosystems.

Although most were established for the preservation of cultural resources, all CUPN parks contain significant natural resources. Examples include the limestone glades found at Chickamauga and Stones River National Battlefields; a pristine bog at Cumberland Gap National Historical Park; caves at Russell Cave National Monument, Lookout Mountain (Chattanooga), and MACA; prairie remnants at Cowpens National Battlefield; and nationally significant waters found at Little River Canyon National Preserve and MACA. General descriptions of natural resources for each park are presented in Appendix A. Natural resources at MACA are further described in Appendix B. An overview of special habitats and Threatened and Endangered species that occur in each park is included in Appendix C.

1.2 Integrated Natural Resource Monitoring

1.2.1 Justification for Integrated Natural Resource Monitoring

Knowing the condition of natural resources in national parks is fundamental to the Service's ability to manage park resources "unimpaired for the enjoyment of future generations". National Park managers across the country are confronted with increasingly complex and challenging issues that require a broad-based understanding of the status and trends of park resources as a basis for making decisions and working with other agencies and the public. The challenge of protecting and managing a park's natural resources requires a multi-agency, ecosystem-based approach because most parks are open systems, with threats such as air and water pollution, or invasive species, originating outside of the park's boundaries. An ecosystem-based approach is further needed because no single spatial or temporal scale is appropriate for all system components and processes; the appropriate scale for understanding and effectively managing a resource might be at

the population, species, community, or landscape level, and in some cases may require a regional, national or international effort to understand and manage the resource. National parks are part of larger ecosystems and must be managed in that context.

The intent of the NPS long-term ecological monitoring program is to track a subset of park resources and processes, known as "Vital Signs", that are determined to be the most significant indicators of ecosystem conditions. Vital Signs are defined by the NPS monitoring program as a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values. The elements and processes that are monitored are a subset of the total suite of natural resources that park managers are directed to preserve "unimpaired for future generations," including water, air, geological resources, plants and animals, and the various ecological, biological, and physical processes acting on those resources. Vital Signs may be designated 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). 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 long-term 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. Congress strengthened the National Park Service's protective function, and provided language important to recent decisions about resource impairment, when it amended the Organic Act in 1978 to state that "the protection, management, and administration of these areas shall be conducted in light of the high public value and integrity of the National Park System and shall not be exercised in derogation of the values and purposes for which these various areas have been established…".

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

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

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

The 2001 NPS Management Policies updated previous policy and specifically directed the Service to inventory and monitor natural systems:

"Natural systems in the national park system, and the human influences upon them, will be

monitored to detect change. The Service will use the results of monitoring and research to understand the detected change and to develop appropriate management actions".

Further, "The Service will:

- Identify, acquire, and interpret needed inventory, monitoring, and research, including applicable traditional knowledge, to obtain information and data that will help park managers accomplish park management objectives provided for in law and planning documents.
- Define, assemble, and synthesize comprehensive baseline inventory data describing the natural resources under its stewardship, and identify the processes that influence those resources.
- Use qualitative and quantitative techniques to monitor key aspects of resources and processes at regular intervals.
- Analyze the resulting information to detect or predict changes, including interrelationships with visitor carrying capacities, that may require management intervention, and to provide reference points for comparison with other environments and time frames.
- Use the resulting information to maintain-and, where necessary, restore-the integrity of natural systems" (2001 NPS Management Policies).

Additional statutes that provide legal direction for expending funds to determine the condition of natural resources in parks and specifically guide the natural resource management of Network parks can be found in "Summary of Laws, Policy and Guidance" (http://science.nature.nps.gov/im/monitor/LawsPolicy.htm).

1.2.3 National Park Service Framework

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 managerial decision-making and resource protection (Figure 1.2). The NPS strategy to institutionalize inventory and monitoring throughout the agency consists of a framework [see "Framework for

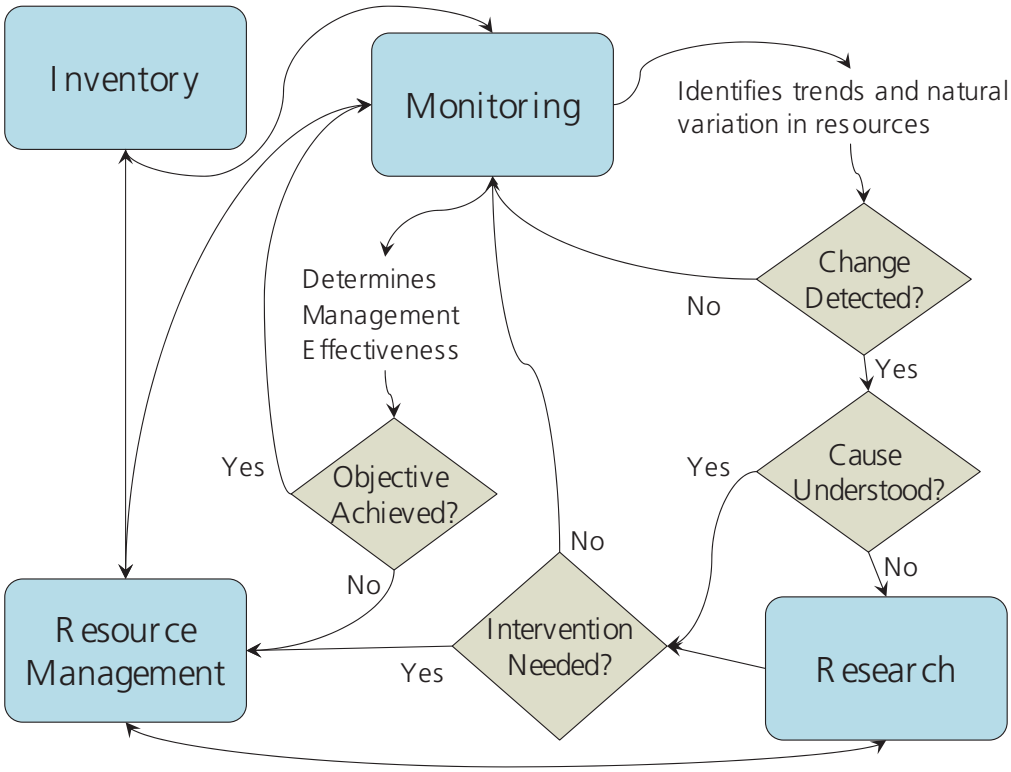


Fig. 1.2 Relationships between monitoring, inventories, research, and natural resource management activities in national parks (modified from Jenkins et al., 2002).

National Park Service Inventory and Monitoring" (http://science.nature.nps.gov/im/monitor/NationalFramework.htm)] having three major components: (1) completion of 12 basic resource inventories upon which monitoring efforts can be based; (2) a network of 11 experimental or "prototype" long-term ecological monitoring programs begun in 1992 to evaluate alternative monitoring designs and strategies; and (3) implementation of operational monitoring of critical parameters (i.e., "Vital Signs") in approximately 270 parks with significant natural resources.

To implement natural resource monitoring in approximately 270 parks with significant natural resources, the NPS has organized parks into 32 "Vital Signs monitoring networks" linked by geography and shared natural resource characteristics. Ten of the 32 networks include one or two prototype programs. These prototypes, which also may receive funding and scientific expertise from USGS, are expected to develop and test sampling protocols and provide technical assistance and mentoring to other parks within their network and nationwide. By nature of these enhanced funding and staffing levels and USGS involvement, most prototypes are able to conduct a level of monitoring that is more comprehensive and intensive than what other parks can undertake. In addition to the initial emphasis on protocol development, there is a long-term role for the prototypes in developing and testing new approaches to data analysis and synthesis, and reporting of monitoring results, and in providing mentoring and training to others. The following section describes the CUPN and MACA Prototype relationship.

1.2.4 Developmental History of the CUPN-MACA Monitoring Program.

The CUPN-MACA Monitoring Program exists today as a synthesis of two formerly separate and independent programs: the Mammoth Cave National Park Prototype Monitoring Program and the Cumberland Piedmont Vital Signs Network Monitoring Program. This unified program addresses a composite list of monitoring tasks, shares resources originating from its component programs, and focuses efforts onto combined tasks such as data management, yet still operates under two separate budgets. This functional articulation with budgetary separateness is the product of a complex, yet important, evolution. It reveals a documentary record potentially useful to the development of other programs, including the changes in naming, approach, terminology, and focus that occurred. The attached evolutionary history (Appendix D) presents a brief synopsis highlighting some "phases" in our evolution. This synopsis will, we hope, help reduce the potential for confusion as the reader of this plan attempts to reconcile current approaches, stated focus, terminology and usage with that found in the diverse materials appended to this Vital Signs Monitoring Plan. At present, (July 2005), the CUPN-MACA Program exists as one program encompassing and addressing the needs of one large Prototype Park (MACA), and 13 smaller park units spread across seven states in the southeastern USA.

1.2.5 Goals and Objectives for Vital Signs Monitoring

The general purpose of the CUPN-MACA Monitoring Program is to provide information to detect, predict, and understand changes in major ecosystem resources of primary interest to the park(s) that contain them. Central to achieving this purpose, is the identification of sets of resources or system attributes for monitoring. Our challenge is to build a size-limited, practical, "do fewer things better" monitoring program that emphasize addressing park management needs in an ecosystem-relevant context. The degree of emphasis differs between the two (formerly separate) programs in that MACA is able to focus more intensively on resources of one park, whereas CUPN is distributing its effort across many parks.

1.2.5.1 Monitoring Goals

The goals of the CUPN-MACA program follow those developed as Servicewide Goals for Vital Signs Monitoring for the National Park Service. These are:

- Determine status and trends in selected indicators of the condition of park ecosystems to allow managers to make better-informed decisions and to work more effectively with other agencies and individuals for the benefit of park resources.
- Provide early warning of abnormal conditions and impairment of selected resources to help develop effective mitigation measures and reduce costs of management.

Table 1.2 General Ecosystem Monitoring Objectives

Ecosystem	Component	Preliminary Monitoring Objective	Program Element
Aquatic Ecosystem	Key aquatic communities (Fauna)	Establish the current status and determine trends of key aquatic biotic communities (e.g., fish diversity, mussel diversity)	MACA and CUPN
	Species-at-Risk (Fauna)	Monitor impacts on threatened aquatic fauna (e.g., muskrat predation on mussel community, beaver impact on federally listed fish species)	MACA and CUPN
	Species-at-Risk (Flora)	Establish current baseline and assess changes in populations of threatened aquatic flora (e.g., Kral's water plantain (LIRI))	CUPN
	Key aquatic communities (Flora)	Determine extent, function, and trends of wetlands communities	CUPN
	Water Quality and Quantity	Establish current baseline and assess changes in surface water quality (silt, chemistry, nutrients, pesticides, metals) and quantity (flow rates, water level changes, cycles of rate changes)	MACA and CUPN
	Water Quality	Track status of indicators of Water Quality (Benthic MacroInvertebrate assemblages)	MACA and CUPN
Cave Ecosystem	Cave Air Quality	Establish current status and determine trends of air flux, temperature, relative humidity, and chemistry	MACA and CUPN
	Cave Biotic Organisms	Determine status and trends of selected cave organisms (crickets, beetles, woodrats, bats)	MACA (CUPN needs inventory)
	Cave Biotic Communities	Determine status and trends of selected cave biotic communities (aquatic invertebrates and fish)	MACA (CUPN needs inventory)
	Cave Nutrient Import	Establish current rates and determine trends of nutrient input (quantity and quality)	MACA
	Cave Nutrient Import	Establish current routes and determine trends of nutrient input (rats, bats, crickets)	MACA
	Cave Water Quality and Quantity	Determine current status and trends of cave water quality (silt, chemistry, nutrients, pesticides, metals) and quantity (flow rates, water level changes, cycles of rate changes)	MACA and CUPN
Terrestrial Ecosystem	Adjacent Land Use	Determine rate and extent of adjacent land use change within a park's watershed or other significant buffer zone	MACA and CUPN
	Air Quality	Determine current air quality baseline and how it is changing over time (air chemistry, ozone, atmospheric deposition)	MACA and CUPN
	Invasive Plants	Determine current status, distribution, impacts and trends of invasive plant species	MACA and CUPN
	Forest Pests	Assess impacts to forest community from selected animal species (deer, hemlock wooly adelgid, and other forest pests)	MACA and CUPN
	Species-at-Risk (Fauna)	Establish current status, distribution, and determine trends of selected animal species (birds of concern)	MACA-SRM and CUPN
	Species-at-Risk (Flora)	Determine current status, distribution, and trends of selected plant species (ph-sensitive, ozone sensitive, poached, rare or declining)	MACA and CUPN
	Vegetation Community	Determine current structure, composition, distribution of vegetation communities and monitor changes (grasslands, glades)	CUPN
	Visitor Use Impacts	Assess visitor use impacts to significant natural resources (clifflines and plant communities from rock climbing activities)	CUPN

- 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.

These broad goals capture the dual role of the program to respond to park management needs and to make progress toward understanding park ecosystems. In Chapter 3, the "Selection of Vital Signs" more fully describes how these needs are captured within the ranking process. Ideally, the Vital Signs chosen for monitoring are ones which provide good insight into the status of resources of management interest, and which serve as effective Vital Signs or indicators of the functional condition of park ecosystems.

1.2.5.2 Monitoring Objectives

The preliminary monitoring objectives for CUPN-MACA (Table 1.2) are centered upon the framework of three major ecosystems: aquatic, caves, and terrestrial. Each set of objectives was derived from an analysis of park management issues, discussions of significant natural resources, and was reviewed by members of the CUPN Science and Technical Committee. The specific measures, precision, and confidence for each objective will be further defined during the protocol development stage (Phase III and beyond). Specific questions related to these objectives can be found in the CUPN workshop summary (Appendix M) and MACA Prototype report (Appendix B).

1.2.6 Strategic Approaches to Monitoring

1.2.6.1 Scope and Process for Developing an Integrated Monitoring Program

While developing the strategy for Vital Signs monitoring, it became clear that a "one size fits all" approach to monitoring design would not be effective in the NPS considering the tremendous variability of ecological conditions, sizes, and management capabilities among parks. To develop an effective, cost-efficient monitoring program that addresses the most critical information needs of each park and integrates with other park operations, parks need considerable flexibility to combine existing programs, funding and staffing with new funding and staffing available through the Natural Resource Challenge and the various divisions of the Natural Resource Program Center. 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 system.

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

Table 1.3 Timeline for Phase III Planning and Design

	FY01 Oct-Mar	FY01 Apr-Sep	FY02 Oct-Mar	FY02 Apr-Sep	FY03 Oct-Mar	FY03 Apr-Sep	FY04 Oct-Mar	FY04 Apr-Sep	FY05 Oct-Mar	FY05 Apr-Sep
Data gathering, Internal scoping	■	■	■	■	■	■	■	■	■	■
Inventories to support monitoring	■	■	■	■	■	■	■	■	■	■
Scoping Workshops			■	■						
Conceptual Modeling				■	■	■	■	■		
Indicator Prioritization and Selection					■	■	■			
Protocol development, Monitoring design								■	■	■
Monitoring Plan Due Dates Phase 1, 2, 3					■		■			■

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 to address the monitoring goals listed above; one that is tailored to the high-priority monitoring needs and partnership opportunities for the parks in that network. Although there will be considerable variability among networks in the final design, the basic approach to designing a monitoring program should follow five basic steps, which are further discussed in the "Recommended Approach for Developing a Network Monitoring Program" (http://science.nature.nps.gov/im/monitor/Approach.htm):

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. Select Vital Signs and specific monitoring objectives for each; and
5. Determine the appropriate sampling design and sampling protocols.

These steps are incorporated into a 3-phase planning and design process that has been established for the network monitoring program. 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 that will be included in the network's initial integrated monitoring program. 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 websites. The schedule for completing the 3-phase planning and design process is shown below in Table 1.3.

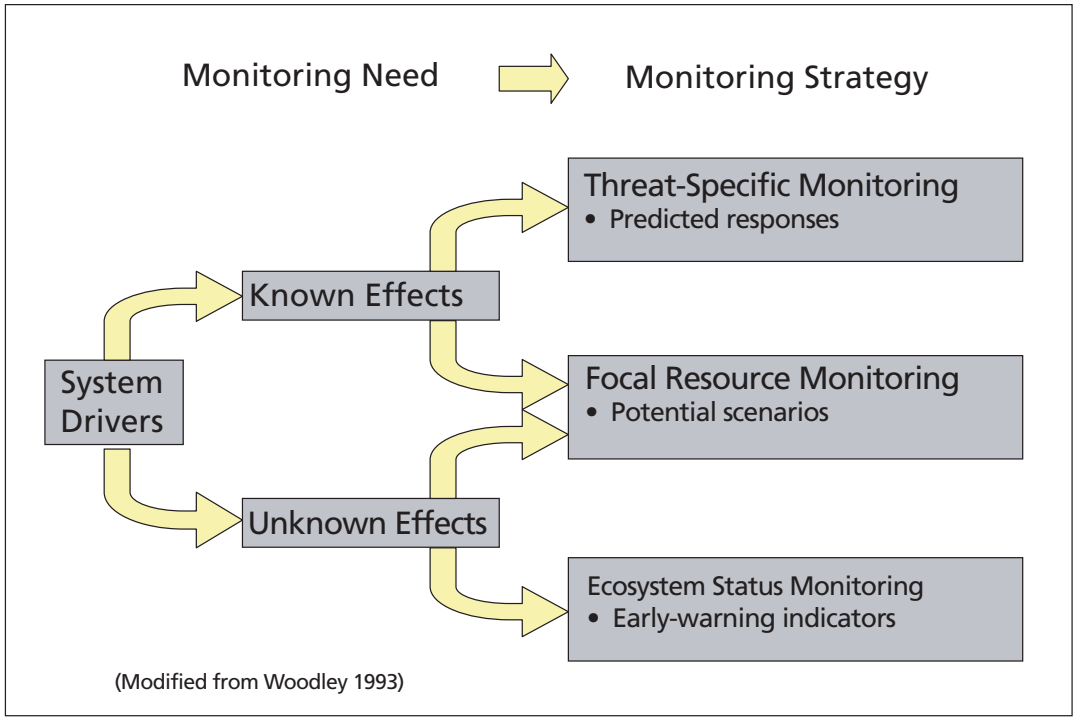


Figure 1.3 Conceptual approach for selecting Vital Signs

The implementation plan for water quality monitoring, funded by the NPS Water Resources Division (WRD), is keyed to the concept of becoming fully integrated with the network-based Vital Signs monitoring program. Networks incorporate the 3-phase approach and follow the same implementation schedule for their water quality monitoring planning. Networks have the option of producing a single, integrated monitoring plan that incorporates the "core Vital Signs" and water quality monitoring components, or they can produce a separate document for the water quality monitoring component that follows the guidance for water quality monitoring (http://science.nature.nps.gov/im/monitor). The CUPN has prepared a separate study plan for Water Quality Monitoring (Appendix E).

1.2.6.2 Strategies for Determining What to Monitor

Monitoring is an on-going 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 measures that are thought to be important to long-term understanding of park ecosystems. However, 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 threat/response relationships and current issues 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 a useful ecological indicator must 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 et al., (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, or alternate taxonomic, integrative, reductionist, or hypothesis-testing monitoring designs (Woodley et al., 1993, Woodward et al., 1999). The approach adopted by our Network agrees with the assertion that the best way to meet the challenges of monitoring in national parks and other protected areas is to achieve a balance among different monitoring approaches, while recognizing that the program will not succeed without also considering political issues.

We have adopted a multi-faceted approach for monitoring park resources, based on both integrated and threat-specific monitoring approaches and building upon concepts presented originally for the Canadian national parks (See Figure 1.3; Woodley 1993). Specifically, we recommend choosing indicators in each of the following broad categories:

(1) ecosystem drivers that fundamentally affect park ecosystems,

(2) stressors and their ecological effects,

(3) focal resources of parks, and

(4) key properties and processes of ecosystem integrity.

Ecosystem drivers are major natural 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 sig-

nificance, 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** will provide 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). Ecological integrity is the summation of physical, chemical, and biological integrity, and it implies that ecosystem structures and functions are unimpaired by human-caused stresses. Indicators of ecosystem integrity are aimed at early-warning detection of presently unforeseeable detriments to the sustainability or resilience of ecosystems.

Collectively, these basic strategies for choosing Vital Signs achieve the diverse monitoring goals of the National Park Service.

1.2.6.3 Integration: Ecological, Spatial, Temporal and Programmatic

One of the more difficult aspects of designing a comprehensive monitoring program is integration of monitoring projects so that the interpretation of the whole monitoring program yields information more useful than that of individual parts. Integration involves ecological, spatial, temporal and programmatic aspects:

- Ecological Integration involves considering the ecological linkages among system drivers and the components, structures, and functions of ecosystems when selecting Vital Signs. An effective ecosystem monitoring strategy will employ a suite of individual measurements that collectively monitor the integrity of the entire ecosystem. One approach for effective ecological integration is to select Vital Signs at various hierarchical levels of ecological organization (e.g., landscape, community, population, genetic; see Noss 1990).

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

- Temporal Integration involves establishing linkages between measurements made at various temporal scales. It will be necessary to determine a meaningful timeline for sampling different indicators while considering characteristics of temporal variation in these indicators. For example, sampling changes in the structure of a forest overstory (e.g., size class distribution) may require much less frequent sampling than that required to detect changes in the composition or density of herbaceous groundcover. Temporal integration requires nesting the more frequent and, often, more intensive sampling within the context of less frequent sampling.

- Programmatic Integration involves the coordination and communication of monitoring activities within and among parks, among divisions of the NPS Natural Resource Program Center, and among the NPS and other agencies, to promote broad participation in monitoring and use of the resulting data. At the park or network level, for example, the involvement of a park's law enforcement, maintenance, and interpretative staff in routine monitoring activities and reporting results in a well-informed park staff, wider support for monitoring, improved potential for informing the public, and greater acceptance of monitoring results in the decision-making process. The systems approach to monitoring planning and design requires a coordinated effort by the NPS Natural Resource Program Center divisions of Air Resources (ARD), Biological Resource Management, Geologic Resources, Natural Resource Information, and Water Resources to provide guidance, technical support and funding to the networks. Finally, there is a need for the NPS to coordinate monitoring planning, design and implementation with other agencies to promote sharing of data among neighboring land management agencies, while also providing context for interpreting the data.

1.2.6.4 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 on a range of scales of time, space, and organization complexity (De Leo and Levin 1997) (Note: the NPS I&M Program uses an alternative definition for "ecosystem", as given in our Glossary). Natural systems as well as human activities change over time, and it is extremely challenging to separate the natural variability inherent to ecosystems from the undesirable changes in park resources and ecosystems that may result from anthropogenic causes. The monitoring program simply cannot address all resource management interests because of limitations of funding, staffing, and logistical constraints (Appendix B, pp. 24-25). Rather, the intent of Vital Signs monitoring is to monitor a select set of ecosystem components and processes that reflect the condition of the park ecosystem and are relevant to 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 sets are interpreted, as our understanding of ecological processes is enhanced, and as trends are detected, future issues will emerge (Roman and Barrett 1999). The monitoring plan should therefore be viewed as a working document, subject to periodic review and adjustments over time as our understanding improves and new issues and technological advances arise (see Chapter 8.6).

1.3 The CUPN-MACA Approach

The overall approach used to develop a Vital Signs Monitoring Plan for CUPN-MACA is shown in Figure 1.4. We began with a series of brainstorming sessions, questionnaires, meetings and workshops to scope out (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 basic key properties and processes of ecosystem condition (e.g., weather, soil nutrients) (Chapter 1).

Conceptual models were then developed, to help organize and communicate the information compiled during scoping. From these general models, specialized sub-ecosystem models (sub-models) 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 group of potential Vital Signs for each ecosystem, which were then prioritized through a series of park workshops to identify the subset of Vital Signs to be included in our initial integrated monitoring program (Chapter 3).

One of the more important steps in developing a monitoring strategy is identifying, summarizing, and evaluating the existing information on park ecosystems. To accomplish this step: 1) literature and management plans for each park were reviewed, 2) existing datasets and current monitoring were summarized, and 3) resource management issues were ranked (Appendix G). Due to the inactive status of many Resource Management Plans, park managers were asked (by electronic survey) to prioritize management issues. The gathered data were then presented at a series of three workshops by park staff and subject-matter experts. Mammoth Cave National Park hosted a fourth workshop specific to their Long-term Ecological Monitoring Program. The fifth and final workshop was held jointly with the Appalachian Highlands Network to develop conceptual models (Table 1.4).

The purpose of the first three workshops was to give an overview of the Inventory and Monitoring (IM) Network strategy, to identify significant natural resources, to prioritize park management issues, and to identify monitoring needs. The three CUPN workshops were attended by a variety of park staff including: Historians, Curators, Resource Managers, Chief Rangers, Chief of Operations, Chief of Visitor Use, and Superintendents. Each park presented their significant natural resources on the first day and discussed management issues on the second.

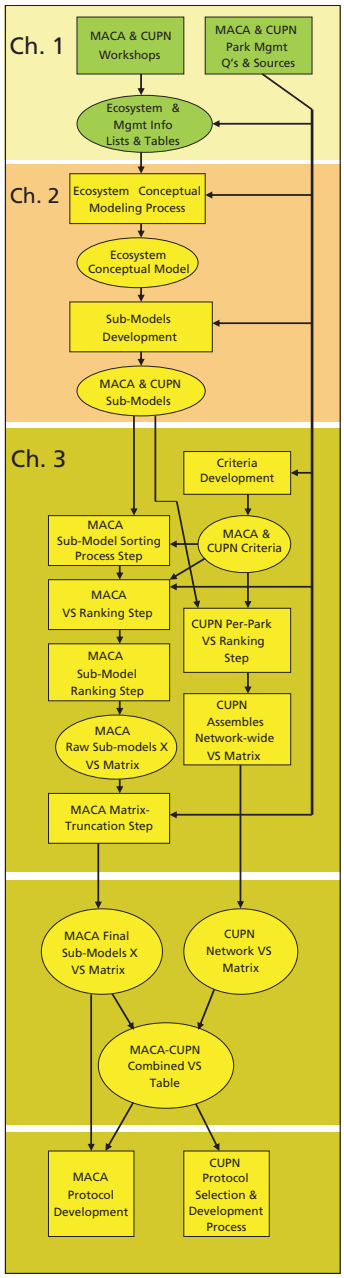


Fig. 1.4 Vital Signs Process Model

1.4 Ecological Context

1.4.1 Significant Natural Resources

One of the primary tasks in Phase I was to develop a comprehensive list of significant natural resources for Network parks. We used four criteria to identify the significant natural resources of Network parks: (1) natural

Table 1.4 Workshops held in FY 2002 to identify significant resources, management and scientific issues, and monitoring needs for parks in the Cumberland Piedmont Network.

Date/Place	Parks	Participants	Purpose
January 30-31, 2002 at Kings Mountain, NC	Carl Sandburg Home NHS Cowpens NB Guilford Courthouse NMP Kings Mountain NMP Ninety Six NHS	Park Staff, Subject Matter Experts: Air, Water, Fire, Invasives, CESU, NatureServe, SER-IM Coordinators, Appalachian Highlands Network Coordinators	Identify Significant Resources, Prioritize Management Issues, Identify Monitoring Needs
March 26-27, 2002 at DeSoto State Park, AL	Chickamauga and Chattanooga NMP Little River Canyon Russell Cave NM Shiloh NMP	Park Staff, Subject Matter Experts: Air, Water, Fire, Invasives, CESU, NatureServe, FWS, SER-IM, Appalachian Highlands Network Coordinators	Identify Significant Resources, Prioritize Management Issues, Identify Monitoring Needs
May 1-2, 2002 at Mammoth Cave National Park, KY	Abraham Lincoln Birthplace NHS Cumberland Gap NHP Fort Donelson NB Stones River NB	Park Staff, Subject Matter Experts: Air, Water, Fire, Invasives, CESU, NatureServe, SER-IM, CUPN, Appalachian Highlands Network Coordinators, MACA Prototype Staff	Identify Significant Resources, Prioritize Management Issues, Identify Monitoring Needs
May 15, 2002 at Mammoth Cave National Park, KY	Mammoth Cave NP-Prototype Long-Term Ecological Monitoring Program	Park Staff, USGS-BRD, University of Tenn, CUPN Coordinator	Identify Significant Resources, Prioritize Management Issues, Identify Monitoring Needs
July 17-18, 2002 at Great Smoky Mtns Learning Center, NC	Big South Fork NRRA Blue Ridge Parkway Great Smoky Mtns NP Mammoth Cave NP Obed River	Park Staff, University Staff, FWS, SAMAB, NRCS, USGS-BRD, CESU, Gulf Coast/ Appalachian Highlands/ CUPN Coordinators, MACA Prototype Staff	Brainstorm session on general Aquatic and Terrestrial Ecosystem Conceptual Models

Table 1.5 Significant Natural Resources for Parks in the Cumberland Piedmont Network

Park	*Natural Resources Significant to Enabling Legislation*	*Natural Resources Significant to Legal Mandates/Policy*	*Natural Resources Significant to Performance Managment Goals*	*Natural Resoucres Significant for Other Reasons*
ABLI	Sinking Spring, Knob Creek. Cultural landscape of 1808-1816	Sinking Spring Cave, Wetlands, State listed species, Invasive species	Invasives, Vital Signs	Old growth forest, rock shelters, cave species, glades, biodiversity at Knob Creek, Birds
CARL	Cultural landscape of 1945-1967 "wildness"	Wetlands, State listed species, Invasive species	Invasives, Vital Signs, Cultural landscape	G2 Appalachian Low Elevation Granitic domes, Birds, Beaver
CHCH	Battlefield landscape of 1863	Federally listed species: Mountain Skullcap and Gray Bat. State listed species, Caves, 303d waterbody.	Invasives, Vital Signs, T&E species, Water Quality	Cedar Glades, Deer, Birds, Southern Pine Beetle
COWP	Battlefield landscape of 1781	Federally listed species: dwarf-flowered heartleaf, State listed species, Wetlands, Invasive species	Invasives, Vital Signs, T&E species, Air Quality, Cultural landscape	Deer, Birds, nonvascular plants
CUGA	Cultural Landscape pre-history through Civil War. Geologic formations	Federally listed species: Black side dace, Indiana bat, proposed wilderness, caves, State listed species, wetlands, Invasives	Invasives, Vital Signs, Water quality, T&E species	Limestone cliffs, rock shelters, elk?, forest pests, G1 Forest Community, Birds
FODO	Battlefield landscape of 1862	Federally listed species: Price's Potato Bean, State listed species, Wetlands, Invasive species	Invasives, Vital Signs, T&E species	Earth works vegetation, Birds
GUCO	Battlefield landscape of 1781	Wetlands, Invasive species (No known state/ federally listed species)	Invasives, Vital Signs, Cultural landscape	G3 Piedmont Small Stream Sweetgum Forest, G3G4 Acidic Piedmont Mesic Mixed Hardwood, Birds
KIMO	Battlefield landscape of 1780	Federally listed species: Georgia Aster, Wetlands, State listed species, Invasive species	Invasives, Vital Signs, Cultural landscape, T&E species	Macroinvertebrates? (inventory is needed), Birds
LIRI	River and Canyon	Outstanding National Resource Water (ONRW), Wetlands, Federally listed species (3 plants,1fish), State listed species, Invasive species	Water Quality, Vital Signs, Invasives, T&E species	Sandstone Glades, Green Pitcher bog, Terrace- Riparian communities, Riffles and Shoals, Birds

Table 1.5 Significant Natural Resources for Parks in the Cumberland Piedmont Network, continued

Park	*Natural Resources Significant to Enabling Legislation*	*Natural Resources Significant to Legal Mandates/Policy*	*Natural Resources Significant to Performance Managment Goals*	*Natural Resoucres Significant for Other Reasons*
MACA	Green and Nolin rivers specifically mentioned in park EL. Cave streams specifically mentioned in park EL. Forest old growth and diversity specifically mentioned in park EL. Caves (formations) specifically mentioned in park EL.	ESA listed species: 6 mussel species, Indiana and gray bats, bald eagle, Kentucky cave shrimp, crystal darter fish (historic), dragonfly, and Eggert's sunflower. Federal Cave Protection Act. Green River State listed as ONRW and Wild and Scenic River. Green River State designated use WQ limits and TMDL's (ONRW). Cave streams State listed as ONRW and State designated use WQ limits and TMDL's (cold water aquatic and ONR). 303d Water. Wetlands (as mapped and yet to be delineated). Clean Air Act (Class I Airshed). State listed species (NPS Policy). EO invasive species.	Water quality and aquatic ecosystem condition, invasive plant control, disturbed lands, Class I air quality, T&E species, and Vital Signs.	Biodiversity: surface/cave aquatic, surface terrestrial, soils, and cave terrestrial ecosystems. [Green River: 82 fish, 192 macroinvertebrates, 51 mussels. Species diversity of cave streams; 3 fish, shrimp, crayfish, inverts, and microbes. Undisturbed forest ecosystem: plant species diversity (over 1,300 species flowering plants including 84 species of trees). Significant habitats Big Woods (300 acres old growth), glades, bogs, river islands, sinkholes, hemlock hollows, barren remnants, cliff-lines, cave entrance ecotones.].
NISI	Battlefield landscape of 1781	State listed species, Wetlands, Invasive species	Invasives, Vital Signs, Cultural landscape	Swampy woods/ wetlands, Lake, Deer, Fire ants, Coyote, Birds
RUCA	Cave, Cultural Landscape 7000 BC to 1600 AD	Cave, State listed Species, Invasives	Vital Signs, Invasives	Biodiversity of cave ecosystem, Birds, Bryophytes.
SHIL	Battlefield Landscape of 1862	Federally listed species 1 bird, 2 bats, 2 inverts, State listed species, Invasives	Water Quality, Vital Signs, Invasives	Endemic Lichen, Birds, High Biodiversity in Aquatic Community, Deer, Beaver Hardwood Bottomland Forest, New Land Acquisition,
STRI	Battlefield landscape of 1862-1866	Federally listed species: Tennessee Coneflower, 303d Water, cave, State listed species, Invasive species	Invasives, Disturbed lands, Vital Signs, Water Quality	Earth work restoration, cedar glades, deer & groundhog problems, Birds

resources significant to enabling legislation; (2) natural resources significant because of specific legal mandates or policy; (3) natural resources significant because of performance management goals; and (4) natural resources significant for other reasons (e.g., identified as globally rare and important by The Nature Conservancy). An overview of these resources is presented in Table 1.5, with additional details given in Appendices A and B (pp. 5-21).

Category 1: Natural resources significant to enabling legislation

Natural resources are specifically mentioned in the enabling legislation of four parks in the Network: Abraham Lincoln Birthplace National Historical Site (sinking spring), Little River Canyon National Preserve (river, canyon), Mammoth Cave National Park (cave, water, forest), and Russell Cave National Monument (cave). The enabling legislation for twelve of the fourteen CUPN parks provides for the preservation of the cultural resources and commemoration of Civil War and Revolutionary War battles. Although natural resources are not specifically mentioned in the enabling legislation of many cultural parks, certain resources hold significance to the interpretation of the historic landscapes (e.g., battlefield, home, farm, caves). Some parks have Cultural Landscape Plans and Reports that provide details for restoration and maintenance that relate specifically to natural resources.

Category 2: Natural resources significant to legal mandates/policy

Mammoth Cave National Park has specific protection and responsibilities under the Clean Air Act because of its designation as a Class I air quality area. Mammoth Cave National Park is

Table 1.6 Performance management goals related to IM for Network parks

NPS Strategic Plan Mission Goals	Cumberland Piedmont Network
Ia1. Disturbed Lands / Invasive Species – By 2008, 10.1% of targeted disturbed park lands are restored and invasive vegetation on 6.3% of targeted acres are contained.	All CUPN parks have invasive invasives; only a few have disturbed lands.
Ia2. Threatened and Endangered Species – By 2008, 14.4% of the 1999 identified park populations of federally listed threatened and endangered species with critical habitat on park lands or requiring NPS recovery actions have improved status, and an additional 20.5% have stable populations.	Nine parks have federally listed species, but not all have critical habitat and not all species require NPS recovery actions.
Ia3. Air Quality – By 2008, air quality in 70% of reporting park areas has remained stable or improved.	MACA is a Class I air quality area. COWP and MACA are currently monitoring air quality.
Ia4. Water Quality – By 2008, 75% of 288 parks have unimpaired water quality.	All CUPN parks. MACA and LIRI have ONRW status and STRI has 303d status
Ia7. Cultural Landscapes – By 2008, 35% of the cultural landscapes on the Cultural Landscape Inventory with condition information are in good condition.	Only a few CUPN parks have Cultural Landscape Inventory completed
Ib1. National Resource Inventories – By 2008, acquire or develop 87% of the 2,527 outstanding data sets identified in 1999 of basic natural resource inventories for all parks.	All CUPN parks
Ib3A. Vital Signs Identified – By 2008, 100% of 270 parks with significant natural resources have identified their Vital Signs for natural resource monitoring.	All CUPN parks
Ib3B. Vital Signs Monitoring – By 2008, 80% of (216 of 270) parks with significant natural resources have implemented natural resource monitoring of key Vital Signs parameters.	All CUPN parks
Ib5. Aquatic Resources – By 2008, NPS will complete an assessment of aquatic resource conditions in 265 parks.	All CUPN parks

Table 1.7 Number of species in Cumberland Piedmont parks that are ranked as "Critically imperiled", "Imperiled" or "Vulnerable" by The Nature Conservancy.

TNC Global Rank	# CUPN Species	Status	Description
G1	5	Critically Imperiled	Critically imperiled globally because of extreme rarity or because of some factor(s) making it especially vulnerable to extinction. Typically 5 or fewer occurrences or very few remaining individuals (<1,000) or acres (<2,000) or linear miles (<10).
G2	43	Imperiled	Imperiled globally because of rarity or because of some factor(s) making it very vulnerable to extinction or elimination. Typically 6 to 20 occurrences or few remaining individuals (1,000 to 3,000) or acres (2,000 to 10,000) or linear miles (10 to 50).
G3	80	Vulnerable	Vulnerable globally either because very rare and local throughout its range, found only in a restricted range (even if abundant at some locations), or because of other factors making it vulnerable to extinction or elimination. Typically 21 to 100 occurrences or between 3,000 and 10,000 individuals.

designated as an International Biosphere Reserve and contains a "Wild and Scenic River". Mammoth Cave and Little River Canyon both have water resources designated as "Outstanding National Resource Waters" (ONRW). The CUPN has nine parks with federally-listed plants, five parks with federally-listed bats, two with federally-listed fish, and one with federally-listed mussels and cave shrimp. Additional federally-listed species may be discovered during the biological inventories that are underway during 2002-07. Five parks in the CUPN have caves, several of which need surveys and biological inventories. Wetlands mapping is currently underway in eleven parks.

Category 3: Natural resources significant to performance management goals

Performance goals that are relevant to natural resource monitoring are summarized in Table 1.6. All 14 CUPN parks have invasive plant species (Goal 1a1). Nine parks in the CUPN have federally listed species (see Appendix C). Mammoth Cave National Park is a Class I air quality area, and along with Cowpens, is monitoring Air Quality (see Appendix F: Air Quality Monitoring Considerations). Some parks with Fire Management Plans and active prescribed burning have weather stations (CUGA, LIRI). Mammoth Cave National Park and Little River Canyon National Preserve include waters that have been designated as "Outstanding National Resource Waters", whereas state 303d lists (impaired waters designations) include three water bodies in the Network: Lookout Creek in Chickamauga and Chattanooga NMP, the Green River in Mammoth Cave National Park, and the West Fork of the Stones River in Stones River National Preserve (see Appendix E: Water Quality Monitoring Considerations).

Category 4: Natural resources significant for other reasons

Several parks have globally significant species and communities according to ranks designated by The Nature Conservancy (NatureServe 2002-04). As the vegetation mapping and biological inventories progress, we can fully document these occurrences. New discoveries already include: G1 forest type at Cumberland Gap, a G2 granitic dome at Carl Sandburg, a G2/G3 glade at Chickamauga, and a G3 forest type found at Guilford Courthouse. The current count of Globally Significant species for the Network: five G1s, forty-three G2s, eighty G3s, and three G4s (NPSpecies database). These are summarized in Table 1.7. Some natural resources were considered significant for various other reasons, such as public appeal or management significance.

1.4.2 Management and Scientific Issues for Network Parks

Scientific and management issues relevant to natural resource stewardship in the 14 CUPN

Table 1.8 Summary of priority natural resource issues for parks in the Cumberland Piedmont Network.

Management Issue	# of Parks per Rank	Management/ Monitoring Question	Preliminary CUPN Actions	Partners
Adjacent Land Use Impacts	12-HIGH 2-MED	How is adjacent land use changing?	Evaluate existing GIS, data and standards for evaluation of landuse change.	State Agencies, EPA, USGS
Invasive Plant Management	11-HIGH 3-MED	Are invasive plants spreading to new areas of park? Are new invasives approaching?	Coordinate with EPMT to map existing invasives and document encroachment in NPSpecies	Invasive Plant Management Team, State Invasive Pest Councils
Threatened and Endangered Species Management	10-HIGH 2-MED 1-LOW 1-UNK	Is current monitoring adequate and are data being managed to detect trends?	Evaluate current monitoring of T&E species to document protocols and incorporate dataflow into NRDTemplate	FWS, NatureServe, State Heritage Programs
Fire Management	9-HIGH 3-MED 1-LOW 1-UNK	Are fuels building up enough to pose a serious threat to resources?	Coordinate with Fire Program to incorporate fuels data into current or planned field activities	Fire Program, SERO, Univ of GA, NatureServe
Water Resources Management	8-HIGH 4-MED 2-UNK	Is water quality impaired per designated use standards?	Implement the CUPN-Water Quality Monitoring Plan. Coordinate with MACA hydrologists to begin sampling.	MACA, WRD
Native Terrestrial Plant Management	7-HIGH 4-MED 1-LOW 2-UNK	What are the major vegetation types, their distribution, and condition?	Continue vegetation and wetlands mapping projects and documentation of significant communities.	NatureServe, Univ of GA, Tenn. Tech.
Air Resources Management	7-HIGH 3-MED 2-LOW 1-UNK	Are high levels of ozone impacting park resources?	Coordinate with ARD to determine which parks need additional ozone monitoring and foliar injury surveys	ARD, MACA
Cultural Landscape Management	6-HIGH 6-MED 2-LOW	What natural resources need manipulation significant to cultural landscape?	Work with SERO-Cultural Resources Division to evaluate restoration efforts involving natural resources	SERO-Cultural Resources Division

Table 1.8 Summary of priority natural resource issues for parks in the Cumberland Piedmont Network, continued.

Management Issue	# of Parks per Rank	Management/ Monitoring Question	Preliminary CUPN Actions	Partners
Forest Insects and Diseases	4-HIGH 8-MED	Are forest pests spreading into the park?	Work with USFS to determine which parks are currently covered by FHM or FIA plots	USFS
Visitor Use Impacts	4-HIGH 6-MED 2-LOW 2-UNK	Is trail use (horse, bike) impacting natural resources? Are rock climbing activities (CHCH, LIRI) impacting natural resources (esp. rare species)?	Conduct a literature review to determine which units in NPS have active trail/rock climbing monitoring, what research studies have been done, and what management actions have been taken.	Other NPS units with active trail/ rock climbing monitoring
Poaching and Theft of Natural Resources	4-HIGH 5-MED 2-LOW 3-UNK	What resources are at threat from poaching? Is poaching occurring?	Evaluate data from plant surveys and field plots to determine presence, location, and extent of populations known to be at risk	NatureServe, State Heritage Programs, MACA

parks are summarized in Table 1.8. These issues were identified and ranked (high, medium, low) by park managers and were discussed during the Phase I workshops. For a complete list of park management issues see Appendix G.

These issues are also described in the following documents:

Appendix A: Summary of parks in the Cumberland Piedmont Network

Appendix B: Conceptual Framework for the Development of Long-term Monitoring Protocols at Mammoth Cave National Park, Kentucky

Appendix C: Overview of special habitats and Threatened and Endangered species

Appendix E: Water Quality Monitoring Program for the CUPN

Appendix F: Air Quality Monitoring Program for the CUPN

1.5 Summary of Existing Monitoring and Partnership Opportunities for Network Parks

We conducted a survey of current and historical monitoring efforts within the Network parks to identify opportunities to continue, modify, or expand existing programs. In-park monitoring efforts (prior to 2003) are summarized in Table 1.9, and additional details for historical and current monitoring efforts are presented in Appendix H.

To help us develop partnerships with monitoring efforts being conducted by other federal and state agencies, we reviewed national, regional, and other park monitoring efforts that may be relevant to natural resource monitoring in our Network. These 'outside the parks' monitoring efforts are summarized in Appendix I.

Table 1.9 Summary of Monitoring Prior to Vital Signs Program (2002).
Current Monitoring (C, data collected within last 5 years) and Historical (H, data collected more than 5 years ago). Monitoring work funded by the NPS is indicated by shading the cell.

Current Monitoring	ABLI	CARL	CHCH	COWP	CUGA	FODO	GUCO	KIMO	LIRI	MACA	NISI	RUCA	SHIL	STRI	TOTAL
Adjacent Land Use	C									C					2
Air Quality:															
Ozone				C						C					2
Visibility										C					1
Particulates										C					1
Deposition				C						C					2
Toxics										C					1
Cave Atmospheric										C					1
Fire Effects								C	C	C					3
Geologic Resources															0
Soundscape															0
Visual landscape		C													1
Water Quality:															0
Ground Water	H	C	C	C	C			C		C		H	C	C	10
Surface Water		C		C	C	C	C	C	C	C			C	C	10
MacroInvertebrates										C			C		2
Wetlands					C			C							2
Stream Morphology										C			C		2
Aquatic Biology		H			C					C			C		4
Aquatic Biology Cave			H							C		H			3
Amphibians					C					C					2
Birds										C					1
Fish										C					1
Forest Health										C					1
Insects Cave										C					1
Mammals: Bats										C			C		2
Woodrat										C					1
Muskrat, Otter										C					1
Mussels										C					1
Pest Species (Gypsy Moth)						C									1
Vegetation:															0
Poached Plants										C					1
Rare Plants			C	C					C	C				C	5
Vegetation Communities			H					H		H				C	4
Non-vascular Plants		C													1
Invasive Plants		C				C				C				C	4

Chapter Two
Conceptual Ecological Models

2.1 Introduction and Approach

A conceptual model is a visual or narrative summary that describes or identifies the important components of a system, and the possible interactions among them. For ecosystems, such models may include biotic and abiotic components, such as organismal populations and physical properties of the environment, plus an array of interactions that can include how agents of change influence the structure and function of the natural system. Conceptual models can illustrate the interconnectedness of ecological processes, both as they occur in nature and as they respond to anthropogenic influences. Conceptual models further help identify how major drivers and stressors will impact ecosystem components (Barber 1994) and provide a framework for communication among scientists and park managers from diverse disciplines.

2.1.1 What will NPS Ecological Monitoring Programs Learn From Conceptual Modeling?

Conceptual models can provide several key benefits to ecological monitoring programs:

- Understanding ecosystem structure, function, and interconnectedness at varying temporal and spatial scales enables identification of appropriate vital sign indicators for assessing overall ecosystem condition and associated trends (Plumb 2002).
- Conceptual ecosystem models assist us in thinking about the scope and context of the processes that may affect ecological integrity (Karr, 1991).
- Perhaps most essential to effective monitoring program design and development, models serve as robust, cross-disciplinary heuristic devices during the program-development process (Allen and Hoekstra 1992).

2.1.2 Preparation and Selection of Conceptual Models

Conceptual models designed for monitoring programs must present useful system information in formats that are acceptable and accessible to the personnel involved. Good models provide sufficient amounts of appropriate information to support effective decision-making, while avoiding surplus and overly-detailed information that can impede and delay the development process the models are created to support. A conceptual model is a purposefully overly-simplified and distorted depiction of a complex system. Models present very limited and, often, focused information and should always be clearly understood as very imperfect (and potentially misleading) representations of real systems. There are three general types of conceptual models typically in use in monitoring programs:

- Narrative models portray an ecosystem through word description, mathematical or representational formula.
- Tabular models generally describe an ecosystem by presenting a two-dimensional array of related system components in the familiar row-and-column format.
- Schematic models appear in three forms: (1) Picture models that depict ecosystem function, vary from simple XY plots to complex diagrams and drawings; (2) Box-and-arrow schematic models that provide simplified ecosystem representations focused on the key system components and a limited set of the interrelationships among those components; and (3) Input/output matrix models, a subset of box-and-arrow models, that explicitly indicate mass-cycling and/or energy-flow among ecosystem components.

In the development of the CUPN-MACA ecological monitoring program the "Box-and-arrow" schematic format was chosen for our conceptual

The basic purposes of conceptual models are to:

- *Conceptualize ecosystem structure, function, and interconnectedness (cumulative, holistic, multi-scale)*
- *Identify major drivers, stressors, attributes affected, impacts, and indicators at a broad level*
- *Help select "Vital Signs" to detect ecological condition changes*

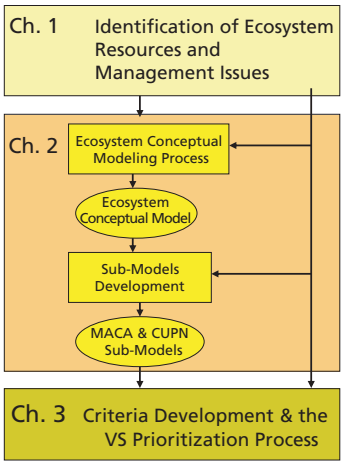


Figure 2.1 Process Model depicting the Chapter 2-related elements of the CUPN-MACA overall Vital Signs Selection and Prioritization Processes. The highlighted elements are discussed in this chapter.

models. The program quickly recognized that the ease-of-use and accessibility of box-and-arrow schematic models offered compelling reasons for using this simpler and more intuitive format. Box-and-arrow models are easily discussed in meetings where participants represent diverse disciplines, levels of technical sophistication and perspectives. A salient additional advantage to the box-and-arrow format is the relative ease with which a larger model may be usefully divided into smaller sub-models. This adaptability was key to the CUPN-MACA Vital Signs Prioritization Processes, as it allowed us to efficiently and effectively partition complex ecosystems into small, coherent, portions for team consideration. This partitioning supports a discussion-based, hierarchical and step-wise approach to the complex decision-making that underlies prioritizing among many resources or potential monitoring subjects, where all candidates are "important", yet only a few can be effectively considered at any one time within a limited program.

2.2 Development of Conceptual Models and Sub-Models

Integral to the CUPN-MACA processes for prioritization of Vital Signs was the use of diagrammatic conceptual models. These models were developed in hierarchical order by assembling the resource and management information for the Network parks, followed by development of general ecosystem models, followed by development of sub-models. This modeling process is summarized in Figure 2.1, and elements should be considered in relation to the other components of the overall Vital Signs Prioritization Process introduced in Chapter 1 and completed, with prioritization of the selected Vital Signs, in Chapter 3.

2.2.1 Selection of Major Ecosystems

The CUPN-MACA Monitoring program employed two major sets of models: 1) general ecosystem models that present park resources in a broadly ecologically-functional arrangement within a few major ecosystem types, and 2) sub-models that focus on sub-sets of functionally linked resources selected from the general ecosystem models.

Early in 2002, program teams recognized that the natural resources and management issues identified in the Phase I scoping workshops could be effectively grouped into three general intuitive levels of ecological organization (sensu GRYN 2003), an "aquatic ecosystem" type, a vegetation-based "terrestrial ecosystem" type, and a third, more narrowly defined ecosystem type focused on caves. Both the MACA Prototype and the rest of the CUPN recognized that park resources could be reasonably divided among any number of ecosystems within these three general levels, depending upon the relative breadth or narrowness of the definitions employed. It also was realized that a smaller number of more general, "lumped" ecosystem models would be more useful in the early phases of our process than would be a larger set of more narrowly and precisely defined ones.

The next step was to hold an "ecosystem modeling" workshop at Great Smoky Mountains National Park (GRSM) in July of 2002. This workshop brought program staff from CUPN, MACA, and the Appalachian Highlands Network (APHN), together with professional ecologists from diverse government agencies and academe for the purpose of detailing general "aquatic ecosystem" and "terrestrial ecosystem" models. The outcomes of this workshop included detailed lists of ecosystem attributes, drivers, stressors, potential indicators, and potential measures for system components, and draft models depicting subsets of the general systems. Development of the cave ecosystem model was initiated afterwards at a workshop hosted by MACA in April 2003.

Based upon the detailed outcomes of the GRSM modeling workshop, work began to develop conceptual models for general aquatic, terrestrial, and cave "ecosystems". Primary development of the these models was undertaken by Dr. R. Woodman (USGS-BRD Ecologist at MACA) with assistance from the MACA Prototype work team and professional ecologists from other agencies and academe. Additional modeling was performed by Dr. J. Ranney, an ecologist from the University of Tennessee, who was working with CUPN under a cooperative agreement. It was agreed that each conceptual model would present a set of ecological attributes, major system-level drivers, anthropogenic stressors, and major processes important within the system.

2.2.2 Selection of the Major Ecosystem Sub-Models

Large sets of ecosystem sub-models were developed for the CUPN-MACA Monitoring program. These became the key support tools used in the Vital Signs Prioritization Process performed by program teams during several workshops, as described in Chapter 3. Each sub-model was a reduced and focused depiction of a subset of system attributes drawn from one of the three general ecosystem models. The MACA Prototype developed an initial set of 18 sub-models, which then were sorted and ranked (Chapter 3). The rest of the CUPN selected and developed a separate set of eleven sub-models. The selection process to determine which sub-models would ultimately be developed differed between the MACA Prototype and the rest of the CUPN.

Selection of the original 18 MACA sub-models was performed by the MACA Prototype work team through discussion of park management issues, historical research, and ecological resource information developed in the Phase I scoping workshops (Table 2.1). Several attributes and associated sub-models were identified for development from each of the three general ecosystem models.

Table 2.1 MACA Ecological Sub-Models

Sub-Model
1 Cave River
2 Cave Air
3 Cricket Guano + Nutrients
4 Woodrat Guano/Litter
5 Bat Guano + Nutrients
6 Other Visitors Guano +
7 Benthic Macroinvertebrates
8 GR Fish Community
9 Mussel Community
10 Muskrats
11 Aquatic Birds
12 Aquatic Reptiles/Amphibians
13 Specific Vegetation
14 Soil & Mycorrhizae
15 Land Birds
16 Vernal Pools
17 Grazer – Deer
18 Grazer – Turkey

As an example of this identification process, ecological function of the cave ecosystem is of interest to MACA park management and one key issue is the continued import of organic nutrients into the cave system from the surface ecosystem. Imported organic matter is the source of virtually all nutrients available to the cave system. The cave cricket, *Hadenoecus subterraneus,* is widely understood to be a key importer of organic matter in the cave system, as it forages on surface plant matter, and defecates in caves (Helf 2003).

This information led to the selection and development of a cave-cricket-based, nutrient-import, sub-model. This sub-model centers on cave crickets, and includes a variety of ecosystem attributes, drivers, and stressors which putatively affect or functionally relate to the crickets.

Selection of sub-models by the rest of the CUPN was based upon identification and prioritization of specific park monitoring questions posed by individual park managers. In parallel processes, managers at MACA and the several other CUPN parks were asked to develop prioritized short-lists of their most important or salient monitoring questions. MACA management was asked to develop a "Top Ten" list, while each of the other Network parks was asked for a park-specific "Top Five" list. The complete list of MACA's top monitoring questions is presented in Appendix B (p.29) and for the remaining CUPN parks in Appendix J. A summary of park monitoring interests addressed in those questions are presented below in Table 2.2.

The "top ten" monitoring questions for MACA were used as tools in the park's Vital Signs Prioritization Process (Chapter 3, Section 3.2), but were not used to guide selection of the 18 original MACA sub-models. Using a slightly different approach to streamline the process across multiple parks, the rest of the CUPN focused on the "top five" monitoring questions to develop sub-models. The sub-models and monitoring questions were then used during each Network park's prioritization workshop (Chapter 3, Section 3.2). See Table 2.3 for a complete listing of CUPN sub-models (without MACA) and Appendix K for sub-model diagrams.

Table 2.2 Summary of Priority Monitoring Interests Identified by Individual Parks.

Top Monitoring Issues for Sub-Model Development	Number of Parks	Program Element
Adjacent land-use impacts on park resources	14	CUPN & MACA
Air quality and its effect on park resources	14	CUPN & MACA
Invasive species and diseases in forests	14	CUPN & MACA
Forest community changes	13	CUPN
Water quality changes in park	11	CUPN & MACA
Species of Concern changes in populations	9	CUPN & MACA
Deer impacts on forests	7	CUPN & MACA
Prescribed Fire Impacts	6	CUPN & MACA
Changes in grasslands, open forest, cedar glades	5	CUPN
Invertebrate populations (aquatic and terrestrial)	5	CUPN & MACA
Cave Air and Cave Biota	4	CUPN & MACA
Cliff habitats affected by recreational use	3	CUPN
Impacts to plants from poaching	2	CUPN & MACA
Changes in bird populations	2	CUPN
Changes in lichen and moss communities	2	CUPN
Changes in soil affecting plant communities	2	CUPN
Changes in wetland/bog qualities & biology	2	CUPN
Nutrient inputs in cave ecosystems	1	MACA

Table 2.3 Cumberland Piedmont Network Ecosystem Sub-Models *(MACA not included).*

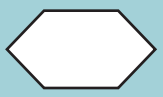
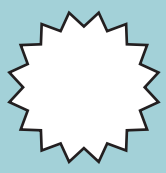
Park / CUPN Sub-Model	Aquatic	Forest	Deer	Bird	Special Vegetation	Glades/Domes	Grasslands	Caves	Wetlands	Clifflines	Terrestrial Vertebrates
ABLI	■	■				■					
CARL	■	■			■	■	■				
CHCH		■	■		■	■		■		■	
COWP		■	■		■		■				
CUGA	■	■						■	■	■	
FODO	■	■			■						
GUCO	■	■									
KIMO	■	■	■		■						
LIRI	■	■	■		■	■				■	
NISI		■	■		■		■				
RUCA	■	■						■			
SHIL	■	■	■	■			■				
STRI	■	■		■	■	■	■				■

2.2.3 How Do We Model It?

The CUPN-MACA Vital Signs Prioritization Processes used general ecosystem conceptual models and system sub-models in "box-and-arrow" formats which tied their components with non-specific "effects" arrows. To provide uniformity among the various ecosystem components, both program elements used a general modeling process and consistent format. A model's content and arrangement were developed following review of the information derived from the Phase I scoping workshops and a review of scientific literature. Major foci in the information and literature reviews included:

- Identification of specific resources vulnerable to natural and anthropogenic disturbances.
- Identification of principal ecosystem drivers and stressors, their presumed effects, and the probable ecosystem responses to them.
- Identification of specific actions that lead to understanding the present status and trends within an ecosystem and its components.
- Identification of significant concerns and questions that may be addressed through short- and long-term monitoring.

Table 2.4 Conceptual Model Components and Definitions

Symbol	Model Component
	Drivers are major, naturally occurring, forces of change such as climate, fire cycles, biological invasions, hydrologic cycles, and natural disturbance events (e.g., droughts, floods, lightening-caused fires) that have large-scale influences on the **Attributes** of natural systems.
	**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 air pollution, water pollution, water withdrawal, pesticide use, timber harvesting, traffic emissions, stream acidification, trampling, poaching, and land-use change. They act together with **Drivers** on ecosystem **Attributes**.
	Monitoring **Attributes** are any living or nonliving feature or process of the environment that can be measured or estimated and that provide insights into the state of the ecosystem. The term **Indicator** is reserved for a subset of **Attributes** that is particularly information-rich in the sense that their values are somehow indicative of the quality, health, or integrity of the larger ecological system to which they belong (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, known or hypothesized effects of **Stressors**, or elements that have important human values.
	Major Ecological Processes that occur within ecosystems. **Processes** may include succession, extirpation and extinction, organismal population growth and reproduction, emigration and immigration (migration), nutrient cycling, etc.
	**Grouping Nodes** are modeling symbols that do not represent a particular feature of an ecosystem, but serve as a tool for bundling multiple relational arrows in order to reduce visual clutter in ecosystem models.
	Ecological effects (not illustrated in the conceptual model but included in the description of stressors and attributes) are the physical, chemical, biological, or functional responses of ecosystem **Attributes** to **Drivers** and **Stressors**.

Outcomes of the information and literature reviews included narrative summary descriptions of the three general ecosystems (aquatic, cave, and terrestrial) and their major resources, system drivers, anthropogenic stressors, and a list of literature cited. Moreover, staff developed "box-and-arrow" conceptual models for each major ecosystem, along with a large number of derived sub-models using standardized symbols and definitions (Table 2.4).

Two other useful components; potential indicators, and specific measures, are not presented in the MACA-CUPN models, in contrast to the practice seen in some other programs (e.g., GRYN 2003). We do not present these components in our general ecosystem models, or in our sub-models, as these components require, in most cases, considerable additional and specific development, and inclusion of most such elements would not substantially contribute to effective Vital Signs prioritization within our process. Further consideration of potential measures and indicators will be a key element of the ongoing process to select and/or develop protocols. Development of measures and indicators is currently underway in the process of developing monitoring protocols for some ecosystem attributes already prioritized by the program (see Appendix B, p.47 for list of protocols selected for initial development by MACA in FY2004-2006).

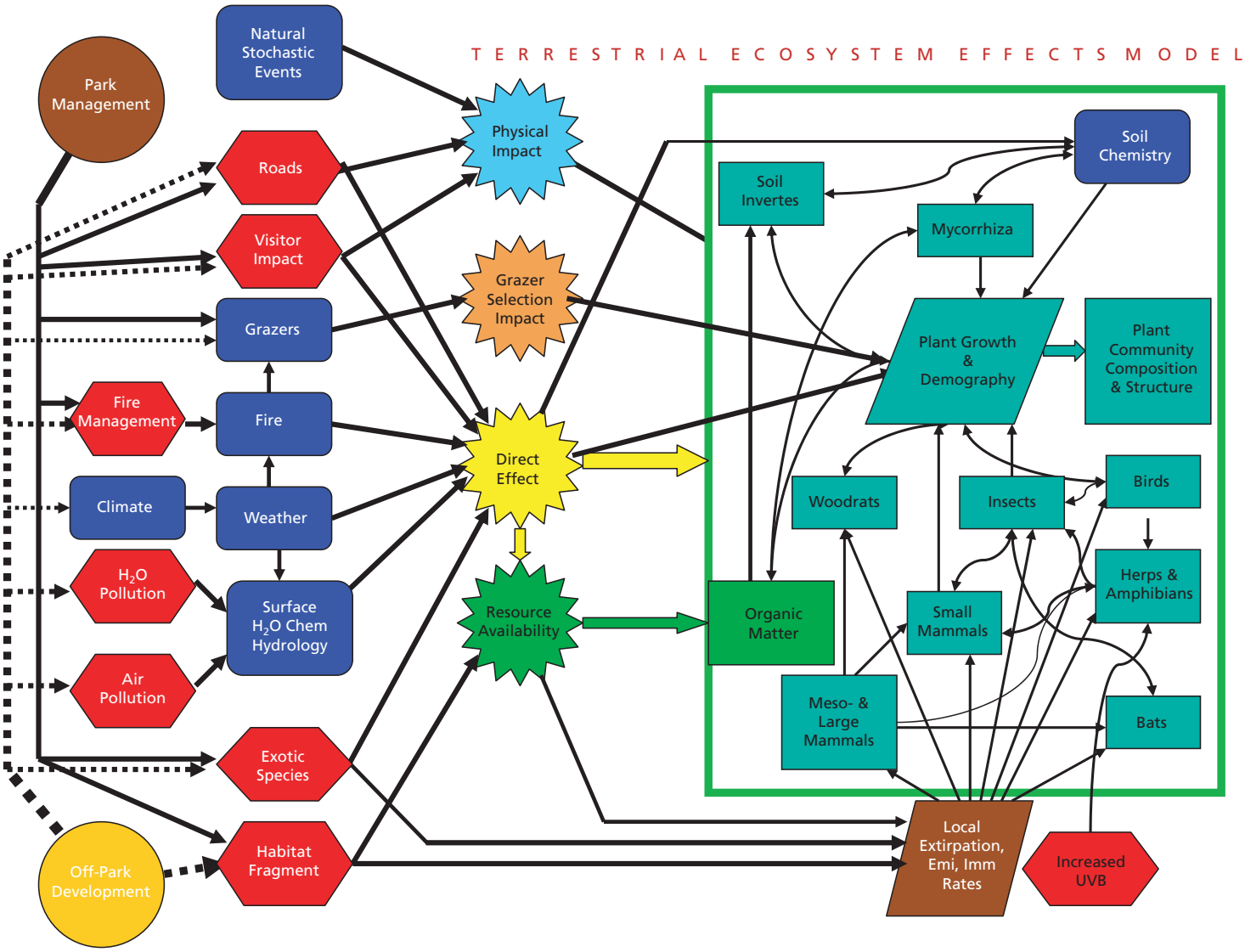


Figure 2.2 The generalized "Vegetation-based Terrestrial Ecosystem" model used as a program tool for selection of system sub-models. This model presents several major drivers, anthropogenic stressors, biotic and abiotic system attributes, and some putative connections among these, in a generalized, hierarchical format. Note that "park management" and "off-park development" are identified as elements that may have diverse influences on many aspects of the general system. Symbols and definitions are given in Table 2.4.

2.2.3.1 The General Ecosystem Models – an Example

Figure 2.2 provides an example of the general terrestrial ecosystem model used by both the MACA Prototype and the rest of the CUPN as a reference for developing system sub-models. This model depicts, in a hierarchical diagram, some of the major drivers, stressors, biotic and abiotic ecosystem attributes that are found within this ecosystem. These are depicted with labeled boxes following the convention for symbols identified in Table 2.4. Arrows and lines depict existence of some putative or likely interactions between and among adjacent model components. The magnitude and specific type(s) of interactions are not indicated by the arrows on this model. In addition, any one connecting arrow may encompass a composite of several interactions, and does not distinguish amongst these. It also should be recognized that directionality of arrows does not accurately indicate a real ecological asymmetry of interaction. In general, ecological interactions can have reciprocal elements (e.g., predators can impact prey populations by direct mortality; prey can, in turn, affect their predators through many routes, not limited to basic supply and resource-availability effects). These specifics will be analyzed fully within the context of protocol development.

The hierarchy in this model decreases as one reads from left to right. Large-scale forces (system drivers and stressors) that act broadly across the system, such as weather, climate, air and water pollution, natural and altered fire regimes, are arrayed on the left side. A generalized set of (mostly) biotic and abiotic system attributes, together with some ecological process and possible interactions amongst these attributes are arrayed within a large box on the right of the model. Major biotic attributes are represented with broad taxonomic labels, such as “birds” or “insects”. The large box enclosing the set of system attributes is a simplifying structure—it groups together a large set of attributes that will collectively be impacted or affected (albeit in many different ways) by a common force. For example, stochastic weather events (storms) can diversely impact a forest ecosystem by damaging trees, killing or dislocating diverse fauna, creating understory impacts through flooding and mudslides, etc. In a different, but equally broad manner, airborne contaminants and pollution may impact several trophic levels within the system. This highly simplified model groups broad-scale impacts through a format that reduces the need for many arrows that could occlude model components. Ecological responses, such as changes in population dynamics or distributions are implicit in this model, and are fully developed within the context of the actual Vital Signs Prioritization Process. Potential system indicators are, likewise, implicit. Indicators may occur at almost any level within a system, up to and including measures of anthropogenic stressors. For example, an invasive species population is both a stressor and a potential indicator of ecosystem condition. Potential indicators, like ecological responses, are a useful focus for discussion within the context of prioritization workshops.

2.2.3.2 An Example of a System Sub-Model

Figure 2.3a presents one example of a system sub-model used by the MACA Prototype. In general, the sub-models are simplified, smaller-scale versions of the general ecosystem model. Sub-model format and symbol-usage follow that used for the general ecosystem models. Figure 2.3a shows the sub-model used in discussion of attributes associated with nutrient-import into cave ecosystems. Parks with cave ecosystems are concerned with the import of organic matter into caves as the primary system nutrient-source. This sub-model identifies several potential organic-matter importers (bats, woodrats, crickets, etc.), together with several system attributes that relate closely to one or more of these importer taxa, plus system attributes (dependent user taxa) that relate to the imported organic-matter. An important composite in-cave system driver (cave air quality) is included, as this component is both within the actual cave-system, and is a direct responder to both management actions and natural surface weather and climate conditions. Other system drivers and stressors, mostly directly associated with surface ecosystems and environmental conditions, and only indirectly impacting within caves, are grouped into the “surface-factors” box.

It was recognized that many sub-models would refer to the same set of system drivers and stressors such that their incorporation would become repetitive. Also, many of the drivers and stressors did not need to be ranked within our Vital Signs Prioritization Processes, because they were already being monitored by various parks and programs. To simplify and reduce redundancy among sub-models, most system drivers and anthropogenic stressors were grouped into a single

"surface factors model" (Figure 2.3b) that could be referenced as needed during the prioritization process. Within most sub-models, these collected drivers and stressors were identified in a box labeled "surface factors" and placed on the left side of the model. The left-side placement conforms to the general hierarchical relationship used for system drivers and stressors in the general ecosystem models. As noted above, the "surface-factors" were thus included in the sub-models as a separate, non-ranked, collective component.

2.3 Summaries of Ecosystem Drivers, Stressors, and Attributes

The list in Appendix L contains descriptions of major drivers, stressors, and attributes identified in the conceptual models developed by the CUPN-MACA Monitoring program. Most of the system elements listed below may be found in the example model presented in Figure 2.2. See additional ecosystem models in Appendix B for further usage.

Ecosystem Drivers are the major natural forces of change that determine the state and function of ecosystems. These are important because they define the baselines and natural ranges of ecological change and stability. They begin the process of defining how an ecosystem works. They act on the ecosystem elements (i.e., attributes) and processes in combination with major stressors to generate change or stability. The dominant drivers for the ecosystems considered for monitoring by the CUPN-MACA program are: air chemistry, climate and weather, grazers, landscape patterns, natural disturbance regimes, soil chemistry, and water quality and water quantity. Descriptions for each of these can be found in Appendix L.

Ecosystem Stressors are human-generated (anthropogenic) forces and system components (i.e., chemical pollutants or introduced invasive species), or anthropogenic alterations of natural forces and system components (i.e., modified fire regimes or stream-flow regimes), that act in combination with naturally occurring drivers to influence ecosystem function, stability and change. Stressors are important to identify because they are the likely agents of undesirable ecosystem changes, and may provide important insight into how the ecosystem is changing, and which conditions may be most important to monitor. Stressors considered in the models include air quality degradation, global climate change, invasive species, landuse change, resource extraction, water quality degradation, water quantity alteration, and visitor use impacts. Descriptions of these stressors are also included in Appendix L.

Attributes are elements or processes of the ecosystem, which can be affected by drivers and stressors. Understanding how attributes (potential indicators) are affected by stressors and drivers helps define monitoring priorities. For simplification, the major attributes are grouped within three broad types: abiotic, biotic, and processes. Specific examples of attributes considered for ranking as part of the program's Vital Sign Prioritization Process are described in Appendix L. Abiotic attributes include air quality, landscape patterns, soil chemistry, visibility and sound, water quality, water quantity, weather and climate. Biotic attributes are vegetation composition and structure, fauna and related biotic characteristics.

Significant processes considered were disturbance regimes caused by the stresses of climate change, land use change, invasive species introductions, declining air quality, and altered fire cycles. Synergies among these stressors (e.g., climate change and decreased air quality) can increase vulnerability to other stressors (e.g., invasive species and fire). Change in disturbance regimes can influence several ecosystem processes (productivity, nutrient dynamics, and interspecific interactions) as well as the viability of species at risk, the role of invasive species, population genetics, and biodiversity. Measures of changing disturbance regimes consequently offer some good indicators of ecosystem condition across several other attributes.

Significant **ecosystem processes** include productivity, nutrient dynamics, soil erosion/deposition, cave geologic processes, bioaccumulation (including trophic structure), succession, and interspecific interactions (e.g., predation). When these change, many other attributes will be changed. The stressors of climate change, air quality degradation, water quality degradation, landuse change, and changes in hydrology (water quantity) act on these processes. Specific ecological changes include loss of nutrients, altered rates and patterns of succession, changes in biotic composition (biodiversity), and altered habitat patterns. Ecosystem processes considered for ranking by the program include bioaccumulation, succession, encroachment, predation, nutrient cycling, and soil erosion/deposition.

Cricket Guano Nutrient Import Sub-Model

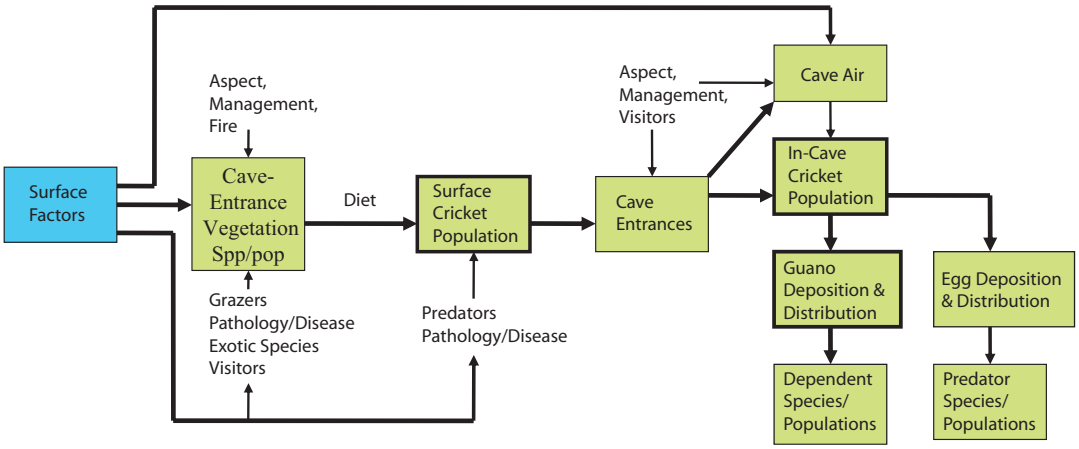


Figure 2.3a The cave-cricket-guano-based nutrient import sub-model. This model schematically depicts several ecosystem attributes that are functionally related to cave cricket populations and cricket guano deposition in caves. The model elements are arrayed in a hierarchical "path", with arrows denoting putative major influences between adjacent elements. Surface vegetation is a major (and thus possibly regulating) resource for crickets on the surface. Cave entrances (and park management of entrances) influence cricket movement in and out of caves. Cave air conditions may strongly affect crickets in caves. Cricket guano serves as the primary food source for many other species of cave fauna. Cricket eggs represent a second cricket-based food source for various cave organisms. Non-boxed elements (mgmt, visitors, etc.) are non-ranked potential sources of impact on the various components of the cricket-based guano-import nutrient route into the cave ecosystem.

General "Surface Factors Model" and Some Measures

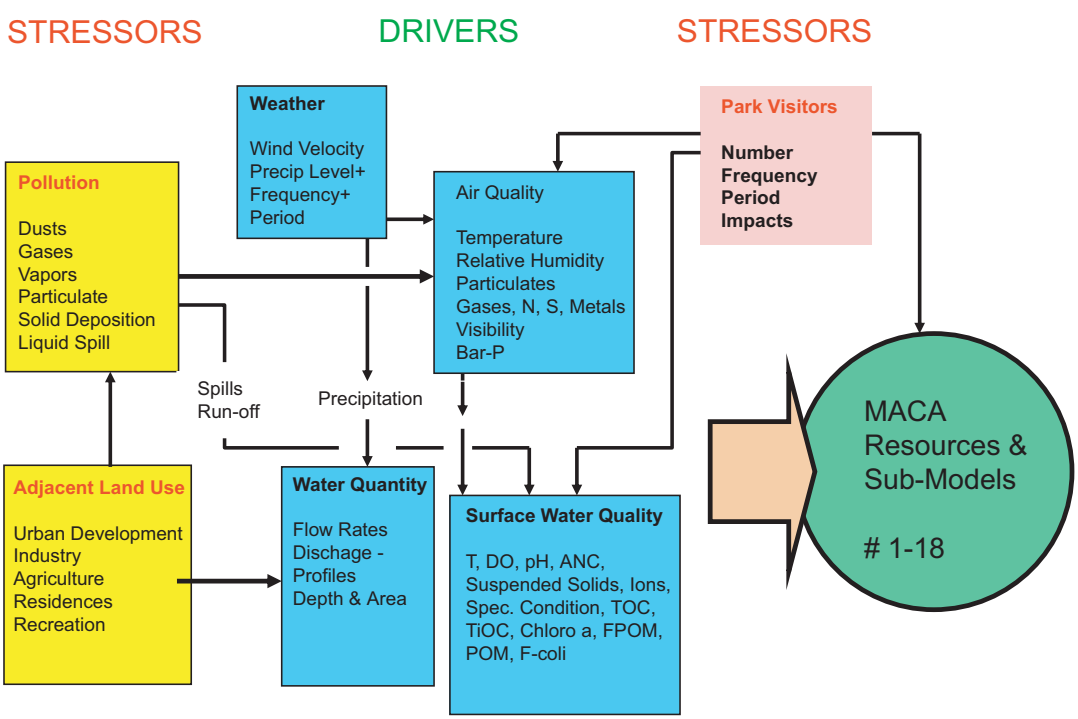


Figure 2.3b The general "Surface Factors Model". This model groups the major natural system drivers and anthropogenic stressors that are associated with many ecosystems into a "reference box" for use during discussion of system sub-models in the Vital Signs ranking process. The model lists drivers, stressors, some possible measures, and some putative major "effects" connections among them.

Chapter Three
Vital Signs

3.1 Development of Vital Signs Prioritization and Selection Processes

3.1.1 Guiding Principles

The guiding principles in developing our prioritization processes were that they had to take both park management needs and ecological validity into account, be reasonably objective, and be "user-friendly" to scientists and resource managers with diverse perspectives and levels of technical expertise. Both CUPN and MACA sought to develop short lists of good attributes, yet, many more attributes exist than can be effectively monitored under even the most ambitious and wide-reaching programs. The solution to this challenge was to develop and implement an effective "Vital Signs" prioritization and selection process, to create a focused, size-limited program.

A key step in achieving functional understanding of park ecosystems in this context was to identify the highest priority system "drivers" (i.e., surface water and air quality) and "stressors" (i.e., adjacent landuse, invasive plants) and set them aside as "givens" that did not need to be further ranked in the Vital Signs prioritization process. These components were already identified as "high priority Network-wide" in the Phase I Scoping workshops, and will be monitored on CUPN parks regardless of what other ecosystem attributes are selected. This simplification allows the program to focus on the attributes (resources) within the ecosystems as being potential respondents to the regional and national-scale (generally supra-park or off-park in origin) stressors and drivers.

3.1.2 General Description of Process

The Vital Signs Prioritization Process involved multiple-step, conceptual-models and formal criteria-based, team decisions (Figure 3.1). The primary purpose was to provide objective identification and ranking of ecosystem Vital Signs that would be the focus of long-term monitoring by the program. Explicitly, our process first identified Vital Signs as being suitable for monitoring, then ranked or prioritized them. The ranking process considered a Vital Sign's relative importance and whether it could be effectively monitored in the context of realistic resource-limitation. This included consideration of ecological relevance, park management needs, policies and legal mandates, and monitoring efficacy in the final determination of rank.

Our process was based on team discussion and analysis of conceptual models that summarize diverse abiotic and biotic components and functional aspects of ecosystems. One key feature was the use of simplified "sub-models" that focus on small sections of ecosystems. The sub-model approach served to focus team attention onto relatively compact portions of large (and less accessible for the non-expert) systems, and partitioned Vital Sign-ranking into smaller, discrete tasks for more efficient performance by diverse teams. The conceptual models were discussed in detail in Chapter 2. Another key feature of the ranking process was the use of defined selection criteria, together with a defined numerical scoring system, to quantify each Vital Sign ranking. This strategy permitted a high degree of objectivity in the selection process. Greater objectivity lends greater credence to the overall process, increases our confidence in the outcome, and enhances the validity of our program overall.

Another essential component in process implementation was the use of a team discussion format. This format emphasized open discussion of models, Vital Signs, issues and concerns, and application of criteria and scoring in a consen-

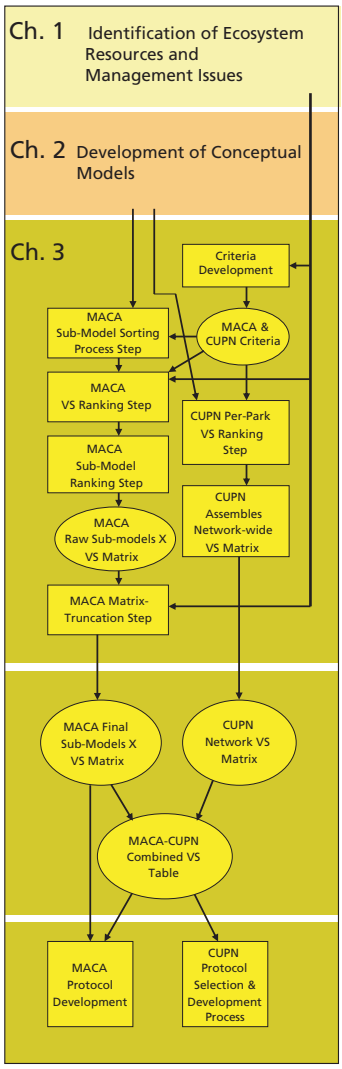


Figure 3.1 Model depicting the Chapter 3-related elements of the MACA and CUPN overall Vital Signs Prioritization and Selection Processes.

sus-based manner that sought active contribution from all team participants. Team discussion and consensus-building also enhanced objectivity while supporting real consideration of diverse perspectives, expertise, and interests of park managers and the contributing "outside experts".

3.1.3 Criteria, Scoring Systems and Weighting

The criteria for Vital Signs Prioritization, the associated sub-criterion questions, and a numerical scoring system were developed following review of similar processes used in development of other NPS ecological monitoring programs (Silsbee and Peterson 1991, Peterson, et al. 1995, and Thomas, et al. 2001) . MACA developed prioritization or selection criteria for two discrete ranking steps. Two criteria were developed for the first, sub-model ranking step. One addressed whether the sub-model was of major importance or interest to park management, the other addressed the central ecological relevance of the sub-model being considered to our understanding it's larger (parental) ecosystem. Four additional criteria, each incorporating one or more sub-criterion questions, were developed for the second, Vital Signs ranking step. These four criteria addressed the ecological importance or relevance of the vital sign to understanding its ecosystem, the vital sign's relative "robustness" and ability to help explain other sub-models and Vital Signs, the vital sign's significance or importance to park management, and the efficacy or anticipated feasibility of monitoring the considered vital sign. In the MACA process, all criteria and associated sub-criterion questions carried equal weight and were scored on a common numerical scale ranging from 0 to 3. For details of the MACA criteria and scoring, see Appendix B (pp. 35-39 and 93-94).

The CUPN Vital Signs Prioritization process derived from that developed by MACA, but the process varied from the original in several major ways: First, the CUPN process dropped the sub-model-ranking step used by MACA, and functionally replaced it with the park-specific sub-models identification procedure described in Chapter 2. Second, CUPN re-wrote and combined some of the criteria and associated sub-criterion questions to improve their clarity and applicability in the Network process, following comments received from users in early trials. Although CUPN's revisions retained the central focus of the criteria used by MACA, they were significantly re-structured. The CUPN criteria-categories addressed ecological significance of Vital Signs, significance of the Vital Signs to management (needs, issues and interests), and the relative efficacy of monitoring the vital sign being considered. And third, CUPN developed a weighting factor to apply in a summary analysis step following completion of Vital Sign Prioritization by the Network parks. This weighting factor increased the relative importance of the "relevance to park management" and "ecological significance" categories, as compared to that of the "efficacy of monitoring" category. CUPN retained the numerical scoring system used by MACA (i.e., scored on a scale of from 0 to 3, with score-interpretations being provided for each criterion). The CUPN criteria, scoring system, and weighting factor application are detailed in Table 3.1.

3.2 Implementation of Vital Signs Prioritization and Selection Processes

The implementation process emphasized teamwork, collaboration, and reaching informed consensus during decision-making steps. The MACA team, together with diverse "outside participants" (other park staff, NPS I & M Network staff, subject-matter experts and professional scientists), collaborated to perform the several steps of the process. The CUPN employed a workshop facilitator, Dr. Jack Ranney, via cooperative agreement with University of Tennessee.

There were five main steps employed by the CUPN-MACA program to rank Vital Signs. The prioritization processes differed between the CUPN and MACA elements in numbers of steps and in some of the actual tasks performed in each step. In the MACA process, four steps first sorted candidate sub-models, then ranked the Vital Signs contained within "higher-ranked" sub-models, then ranked the six higher-ranked sub-models, then finally reduced ("truncated") the ranked Sub-model X Vital Signs matrix. In the CUPN process, sub-models were not ranked. Two steps first ranked Vital Signs at each individual Network park, then assembled and ranked the Vital Signs selected by the several individual parks in a Network-wide matrix. The MACA process, as the original model, is fully described and diagrammed in Appendix B (pp. 35-40), and should be consulted for additional details on steps and rationale.

Table 3.1 Cumberland Piedmont Network Criteria for Ranking Vital Signs

Ecological Significance 40%	
1. How useful is the Vital Sign in explaining the condition of the ecosystem sub-model?	3=extremely useful 2=useful 1=of little use 0=not useful
2. How central is the Vital Sign in controlling or driving ecosystem sub-model function?	3=central to sub-model function 2=plays a moderate role in sub-model function 1=plays a minor role in sub-model function 0=on periphery of sub-model, almost no role in sub-model function
3. How closely linked is the Vital Sign with other Vital Signs in other sub-models in the park?	3=many major/strong links 2=few major/strong links 1=few minor/weak links 0=not linked at all
Management Significance 40%	
4. How important is the understanding of this Vital Sign to Park management?	3=extremely important (legally required monitoring) 2=important (e.g., GPRA) 1=lesser importance (no specific mandate except general policies and Organic Act) 0=no management goals related to Vital Sign
5. How well will monitoring of the Vital Sign provide data needed for making management decisions?	3=extremely well 2=moderately 1=poorly at best 0=not at all
6. How well will monitoring of this Vital Sign provide an accurate evaluation of the outcomes of one or more management decisions?	3=extremely well, 2=moderately 1=poorly at best 0=not at all
Monitoring Efficacy/Feasibility 20%	
7. How much is currently known about the Vital Sign?	3=much known 2=some known 1=little known 0=almost nothing known
8. How difficult will it be to monitor this Vital Sign?	3=easy and convenient 2=practical 1=impractical and inconvenient 0=impractical and extremely difficult
9. Will you be able to collect data for this Vital Sign at the same time as (and in the general vicinity of where) you are collecting data for one or more other Vital Signs?	3=many collateral datasets 2=maybe 2 or 3 collateral datasets 1=maybe 1 collateral dataset 0=no collateral datasets

3.2.1 Sub-Models Ranking Step (MACA process only)

In this step, the MACA team and outside ecologists used the appropriate criteria to sort the candidate sub-models into higher-ranked and lower-ranked classes. The higher-ranked sub-models went forward for consideration in the Vital Signs Ranking step. The CUPN did not employ this step at the park-level. The CUPN intention was to give priority to Vital Signs ranked by the most parks, across multiple sub-models, as the best approach for a multi-park program. Details of the MACA process are described in Appendix B (pp. 35-40).

The sub-models ranking step proceeded as a team-discussion process, with discussion involving the MACA Prototype and MACA's Division of Science and Resources Management (SRM) staff, together with two invited "outsider" professional ecologists. Sub-model ranking and vital sign-ranking occurred in a two-day workshop meeting held at MACA on 31 March and 1 April 2003.

3.2.2 Vital Signs Ranking Step (CUPN and MACA)

In this step, work-teams used formal criteria to prioritize the Vital Signs identified within the sub-models being considered. For MACA, the sub-models considered in this step were the six selected as "higher-ranked" in the previous step. For CUPN, the sub-models were based on the top-five monitoring questions selected by each park for discussion at that park's prioritization workshop as described in Chapter 2.

For MACA, this step considered the six sub-models that we had identified from the sub-models ranking step as being of greater importance and/or interest to MACA. The team prioritized among the Vital Signs within each sub-model to identify which would be the best focus for initial monitoring. The working assumption was that we probably could "paint" a reasonable functional picture by tracking a few linked "key components" within a sub-model (and portion of the parental ecosystem), rather than by having to monitor all of the components identified therein. Vital Signs ranking proceeded as a team-discussion process focused around the four Vital Sign Ranking criteria. This step involved the MACA Prototype and SRM staff, together with two invited "outsider" professional ecologists, who, along with the USGS-BRD Ecologist, provided technical advice and ecological subject-matter expertise from a non-MACA-centric perspective. These experts participated in the MACA team discussions to select the "better" Vital Signs for monitoring, and contributed to the actual numerical scoring done at this step.

The ranking process for the CUPN parks focused on the top five monitoring questions for each park, using sub-ecosystem conceptual models (sub-models) to illustrate the context of each question. Conceptual model posters along with handouts for nine criteria were prepared for each park meeting and a Vital Signs (VS) Team was assembled. This VS Team consisted of a core group of ecologists, hydrologists, data managers, and coordinators. Eleven workshops were held from May through September 2003 (see Table 3.2). The top five management questions and associated sub-models were presented at each workshop and used to apply nine criteria to each key attribute. No more than three-to-seven attributes were evaluated per sub-model and these were decided by consensus. The role of the VS Team was to present conceptual models and review their connection to park-specific management issues, define terms, and provide discussion for ecological concepts during the ranking process. The VS Team lead facilitator was Jack Ranney, University of Tennessee. The VS Team was also responsible for recording key points of the discussion and to document any park-specific considerations involved in the numerical evaluations. Fifty-eight attributes were ranked (by one or more parks) during the workshop series. See Appendix M for meeting notes and Appendix N for spreadsheet of park scores obtained from this step.

3.2.3 Sub-models Posteriori Subjective Ranking Step (MACA only)

Following the prioritization of the attributes within each of the six higher-priority sub-models, the MACA team completed the sub-models ranking by applying "Subjective scoring value" (scoring based upon their individual evaluations of each sub-model) in a recorded, individual poll. This scoring served to shuffle the heretofore random order of sub-models into a series ordered by rank-scoring into the revised, raw "Sub-models x Vital Signs" matrix.

Table 3.2 Park prioritization workshops based on top five management questions

Date	Parks	Participants
May 29, 2003	Abraham Lincoln Birthplace NHS	Superintendent, Chief of Operations, Park Ranger, USGS-BRD Ecologist, Univ of TN Ecologist, CUPN IM Coordinator
June 30, 2003	Shiloh NMP	Superintendent, Historian, Resource Management Technician, MACA-Hydrologist, Univ of TN Ecologist, CUPN IM Coordinator
July 1, 2003	Fort Donelson NB	Superintendent, Chief Ranger, MACA-Hydrologist, Univ of TN Ecologist, CUPN IM Coordinator
July 16, 2003	Guilford Courthouse NMP	Superintendent, Chief Ranger, Resource Specialist, Univ of TN Ecologist, CUPN Data Mgr/Ecologist, CUPN IM Coordinator
July 17, 2003	Carl Sandburg Home NHS	Superintendent, Chief of RM, Resource Specialist, Curator, Univ of TN Ecologist, CUPN Data Mgr/Ecologist, APHN Ecologist, APHN & CUPN IM Coordinators
July 22, 2003	Stones River NB	Superintendent, Chief of Operations, Ecologist, MACA Prototype Coordinator, Univ of TN Ecologist, CUPN IM Coordinator
August 5,2003	Cowpens NB & Ninety-Six NHS	Superintendent, Chief Rangers, Resource Specialist, USGS-BRD Ecologist, Univ of TN Ecologist, CUPN IM Coordinator, CUPN Data Mgr/Ecologist
August 26, 2003	Chickamauga Chattanooga NMP	Superintendent, Chief of Operations, Resource Specialist, Cultural Resource Specialist, MACA Prototype Coordinator, Univ of TN Ecologist, CUPN IM Coordinator and Data Mgr
August 27, 2003	Little River Canyon Natl Preserve & Russell Cave NM	Superintendent, Chief of Resource Mgmt, USGS-BRD Ecologist, MACA Prototype Coordinator, Univ of TN Ecologist, CUPN IM Coordinator and Data Mgr
September 4, 2003	Kings Mountain NMP	Superintendent, Chief Resource Mgmt, Univ of TN Ecologist, CUPN IM Coordinator, CUPN Data Mgr/Ecologist
September 11, 2003	Cumberland Gap NHP	Superintendent, Assist Supt, Chief RM, Resource Mgmt Specialist, USGS-BRD Ecologist, MACA-Hydrologist, Univ of TN Ecologist, CUPN IM Coordinator

3.2.4 Network-level Vital Signs Prioritization Step (CUPN only)

After rankings for each park were tallied using a weighting for Ecological Significance (40%), Management Significance (40%), and Monitoring Efficacy (20%), a second level of weighting was applied to identify Vital Signs that meet "Network-level" priorities. A "Network-level" priority is simply defined as a majority of the parks, at least seven out of thirteen, have selected a certain vital sign. The Network-level weighting factor was a fractional multiplier, determined by dividing the number of parks ranking the Vital Sign, by 13 total parks. For example, the "forest canopy" scores were averaged then multiplied by 13/13, indicating that 13 out of 13 parks ranked that Vital Sign in the Forest Community Sub-model. For full list of weighted mean scores, see Appendix O.

3.2.5 Matrix Truncation Step (MACA only)

This step consisted of a "matrix-truncation", or reduction, process that served to trim or reduce the ranked sub-models and Vital Signs matrix. It was based upon consideration of whether Vital Signs meet legal and policy mandates, whether a vital sign should be classified as a research project versus a monitoring subject, and a discussion of how the MACA Prototype may strategically allocate its available monitoring resources. The MACA lead team used these factors, together with discussion of what is currently known about the vital sign, to consider whether a vital sign should be dropped from the matrix. This selection process did not shift the ranked order established for sub-models and Vital Signs in the raw "Sub-models x Attributes Matrix", but did lead to deletion of some Vital Signs and

sub-models from the monitoring matrix table. Vital Signs and sub-models dropped from the final matrix during this step were placed into the MACA Research Catalog for potential development into future monitoring projects. Truncation was performed in the week following the MACA prioritization workshop, and resulted in production of the finalized "Sub-models x Vital Signs Matrix" discussed in Section 3.3.1 (Results) below.

3.3 Results of Vital Signs Prioritization and Selection Process

The major outcomes or products of the Vital Signs Prioritization and Selection process were tables or matrices of ranked Vital Signs. The MACA matrix presents ranking both for sub-models and for Vital Signs arranged within the sub-models. The CUPN table (Table 3.3) shows Vital Signs ranked by averaging individual park scores within a sub-model, while sub-models themselves are ranked by the number of parks that chose to rank them. In overview, the MACA "Sub-models x Vital Signs Matrix" is a fully-ranked outcome which will provide the MACA Prototype strong guidance in its selection of monitoring projects and protocols to initially develop and implement. While the MACA matrix suggests by its ranking a likely order and sequence of project initiation for the prototype, the actual project-development order followed will be modified by other considerations. The CUPN matrix is an initial guidance structure used to highlight Network-wide and park-level priorities. For some Vital Signs, the identification of measurable attributes for the Network will require additional refinement, based on the variance among input from thirteen different parks.

3.3.1 MACA Results Matrix

Conclusion of the MACA sub-models ranking step resulted in two products: a "Sub-models x Vital Signs Matrix", and a set of "less-important Sub-models" (Appendix B, p. 95). The matrix consisted of the six (6) sub-models that we had concluded would be most worthwhile and valuable to monitor, arranged in descending order (left-to-right columns in the matrix), together with their associated Vital Signs (ranked in descending priority as elements down the sub-model-columns). The higher-ranking Vital Signs within each sub-model are those that would more likely provide robust insight or connections among ecosystems contribute to our ecosystems understanding, are of management relevance and value, and which are thought to be reasonably efficacious for monitoring. The unprocessed matrix was subjected to further processing while the "less-important sub-models" list was incorporated into the park's research catalog (Appendix B, p. 96).

The final product of the MACA approach was a truncated version of the raw Sub-models x Vital Signs matrix (see Appendix B, p. 97). This matrix identifies Vital Signs grouped into 4 sub-models in a ranked structure, and retains the sub-models and Vital Signs relative values (ranking) as presented in the raw matrix. This finalized matrix identifies a set of system Vital Signs that will be monitored within the "initial configuration" MACA Prototype. Four of the Vital Signs identified in this matrix are covered under monitoring programs (and initial protocols) which are already in place at MACA. The remaining 11 Vital Signs will be addressed by "new" protocols that are either currently under development, or will be developed within the next 2 years. The 11 new protocols will be developed with the assistance of USGS-BRD, with design focus on initial implementation at MACA, followed by later possible adoption for use at other parks, both within CUPN and in other networks.

3.3.2 CUPN Results Matrix

The twenty top ranking Vital Signs for the CUPN are shown in Table 3.3. For the entire list of Vital Signs considered, see Appendix P. The CUPN Vital Signs were classified into three main groups:

- Network-Level High Concern: those considered high priority by a majority of parks
- Park-Level High Concern: those considered high priority by fewer than 7 parks
- Low Priority: those that ranked lower priority within each sub-model or for which research or inventory work was needed (see Sect. 3.3.4 Vital Signs Not Selected)

Table 3.3 Twenty High Priority Vital Signs for Cumberland Piedmont Network *(MACA not included)*

Ecosystem Sub-model	Priority	# Parks	Vital Sign Category	Vital Sign (ordered by # of parks)	Park Code
(Multiple)	Network High	13	Stressor	1) Adjacent Land Use/ Land Cover Changes	All
(Multiple)	Network High	13	Stressor	2) Invasive Plant Populations	All
(Multiple)	Network High	13	Stressor	3) Ozone levels and 4) Impacts on Native Plants	All
Aquatic Community	Network High	13	Driver	5) Water Quality and Quantity	All
Forest Community	Network High	13	Key property, Stressor	6) Forest Canopy & Herb Structure, Composition and 7) Forest pests	All
Wetland/ Aquatic Community	Network High	13	Key property	8) Riparian/Wetland Vegetation structure, composition, and extent	All (# may be modified once wetlands assessments are complete)
Special Vegetation	Network High	8	Key property	9) Changes in Vegetation Community type and extent	CARL,CHCH, COWP,FODO, KIMO,LIRI,NISI, STRI
Special Vegetation	Network High	8	Focal Resource	10) Plant Species of Concern Populations	CARL,CHCH, COWP,FODO, KIMO,LIRI,NISI, STRI
Grasslands Community	Park High	5	Focal Resource	11) Herbaceous structure and composition, %cover	CARL,COWP,NISI, SHIL, STRI
Glade Community	Park High	5	Focal Resource	12) Herbaceous structure and composition, %cover	ABLI,CARL,CHCH, LIRI, STRI
Grazer-Deer	Park High	4	Stressor	13)Deer populations and 14)impacts on forest/plant community	CHCH, KIMO, LIRI, SHIL (a few parks may want to be added)
Cave System	Park High	3	Driver	15) Cave Air Quality	CHCH, CUGA, RUCA
Cliffline Community	Park High	3	Stressor, Focal Resource	16) Climbing Impacts to Geologic formations and 17) Cliffline plant communities	CHCH,CUGA,LIRI
Aquatic Community	Park High	3	Focal Resource	18) Fish Populations (listed species and diversity)	CUGA,LIRI,SHIL (more parks may be added as fish inventories are completed)
Aquatic Community	Park High	2	Key Property	19) Benthic Macro-invertebrates	LIRI, STRI
Bird Community	Park High	2	Focal Resource	20) Priority Bird Populations	SHIL, STRI (more parks may be added as bird inventories are completed)

3.3.3 Combined Vital Signs with Potential Measures Table

The resulting list of Vital Signs from both CUPN and MACA was consolidated during the spring of 2004 during the merging of the Prototype with the Network (see Appendix D). To view the original list with justifications, see Appendix Q. After evaluation, some Vital Signs were merged and some in the park-high category were dropped from the short-term implementation schedule (next 3-5 years). The final version of the combined table (i.e., "short list") is shown in Table 3.4. For justification of each vital sign in the "short list", see Table 5.1 in Chapter 5 or individual Protocol Development Summaries in Appendix R.

3.3.4 Some Candidate Vital Signs not Selected for Initial Development

Many of the original candidate Vital Signs were not selected for initial monitoring under the CUPN and MACA Vital Signs Monitoring Plan. Greater functional understanding of park ecosystems can be obtained by monitoring more system components than by fewer. However, in keeping with our "do fewer things better" program philosophy, it was understood that our selected sets of Vital Signs should be small, and, ideally, functionally coherent and interconnected. Therefore, several candidate Vital Signs were ranked lower in our prioritization processes for a variety of reasons (some are provided in Table 3.5). Some lower ranked Vital Signs not selected for initial monitoring by CUPN and MACA include:

- Cave River Microbe Assemblage: Cave microbe community assemblages are important to park management, play key roles in the cave ecosystem energetics and nutrient flow, and have Service-wide application as an exportable protocol, since all cave systems contain microbes. However, MACA lacks baseline cave microbe inventory data and research is in progress.

- Mussel Host-fish identification: The Green River within MACA contains one of the most diverse assemblages of freshwater mussels in the nation including 7 federally endangered species. Fish are presumed to play a central role in the reproductive success of mussels by acting as larval (glochidium) hosts for distribution within river systems. At present, the specificity of these host-fish-mussel relationships is poorly understood. Although mussel host-fish identification and population monitoring is a park management interest, a significant lack of information exists and targeted research is needed.

- Deer populations & grazing impacts: Deer populations and direct and indirect grazing impacts were identified as potential vital sign(s) of interest by several parks in the CUPN and as a management issue at MACA. However, MACA lacks baseline information on both items.

- Cave Biota: Diverse cave-dwelling species are critical elements of a functioning cave ecosystem. Certain species in the cave invertebrate community have been identified as key to the MACA Prototype; however the CUPN caves are largely unsurveyed and uninventoried. Invertebrates were a group not funded by the Service-wide IM Program.

- Soil Biota, Chemistry, and Structure: Soil conditions are an integral part of many ecosystem functions and strongly influence the diversity of plant communities. The CUPN did not select this vital sign for initial monitoring due to the complexity and cost of evaluating soils data.

For a list of Vital Signs considered but not selected by the two program elements and reasons for lower priority ranking see Table 3.5.

Table 3.4 List of High Priority Vital Signs for the Cumberland Piedmont Network

Level 1 Name	Level 2 Name	Vital Sign	ABLI	CARL	CHCH	COWP	CUGA	FODO	GUCO	KIMO	LIRI	MACA	NISI	RUCA	SHIL	STRI
Air and Climate	Air Quality	Ozone and Ozone Impact	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚
		Visibility and Particulates										•				
		Atmospheric Deposition										✚				
		Air Contaminants										•				
	Weather and Climate	Weather	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Geology and Soils	Geomorphology	Stream/River Morphology										•				
	Subsurface Geologic Processes	Cave Air Quality					•					✚		•		
	Soil Quality	Soil Chemistry and Structure										◇				
		Soil Invertebrates and Associated Predators										◇				
Water	Water Quality	Water Quality and Quantity	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚
		Benthic Macro-invertebrates									◇	✚				◇
		Microbes										◇				
Biological Integrity	Invasive Species	Invasive Plants "early detection"	✚	✚	✚	✚	✚	✚	✚	✚	✚	•	✚	✚	✚	✚
	Infestations and Disease	Forest Pests	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚
	Focal Species or Communities	Amphibians										•				
		Birds										•			◇	◇
		Cave Aquatic Fauna										✚				
		Cave Beetles										✚				
		Cave Crickets										✚				
		Cave Entrance Invertebrate Community										•				
		Guano-dependent Invertebrate Communities										◇				
		Vegetation Communities	✚	✚	✚	✚	✚	✚	✚	✚	✚	•	✚	✚	✚	✚
		Mussel Diversity										✚				
		Fish Diversity									◇	✚			◇	
		Cave Bats										✚				
		Deer			◇					◇	◇	◇			◇	
	At-risk Biota	Allegheny Woodrats										✚				
		Plant Species of Concern		✚				✚		✚	•	•	✚			•
Human Use	Consumptive Use	Poached Plants										•				
Landscapes (Ecosystem Pattern and Processes)	Landscape Dynamics	Adjacent Land Use	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚
	Fire and Fuel Dynamics	Fire	•	•	•	•	•	•	•	•	•	•	•	•	•	•
	Nutrient Dynamics	Guano Deposition in Caves										◇				

✚ Vital Signs for which the Network will develop protocols and implement monitoring using funding from the Vital Signs or water quality monitoring programs.

• Vital Signs monitored by a Network park, another NPS program, or other federal or state agency using other funding. The Network will collaborate with these other monitoring efforts.

◇ High-priority Vital Signs for which monitoring will likely be done in future, but which cannot currently be implemented due to limited staff and funding.

[blank] Indicates the Vital Sign does not apply to the park, or for which there are no foreseeable plans to conduct monitoring.

Table 3.5 Some CUPN and MACA Vital Signs Not Selected for Monitoring

Program Element	Vital Sign Name	Reason for Lower Priority Ranking
CUPN	Bacteria/Periphyton/Phytoplankton/Zooplankton	Not well understood
CUPN	Cave Biota	Lack of inventory data
CUPN	Aquatic Fauna (other than fish, BMI)	Lack of inventory data
CUPN	Forest Fauna (other than birds)	Lack of inventory data
CUPN	Forest Ecological Processes	Research needed
CUPN	Glade Ecological Processes	Research needed
CUPN	Grassland Fauna (other than birds)	Lack of inventory data
CUPN	Glade Fauna (other than birds)	Lack of inventory data
CUPN	Soil Biota Structure and Chemistry	Not well understood
CUPN	Substrate Sediment, Structure and Chemistry	Not well understood
CUPN	Predators and Take (Grazer/Deer)	Low score
CUPN	Mast herb forage (Grazer/Deer)	Low score
MACA	Cave River Microbe Assemblage	Inventory and research needed
MACA	Guano deposition rate/composition/distribution	Research needed
MACA	Guano-dependent Invertebrate Communities	Research needed
MACA	Mussel Host-fish identification	Research needed
MACA	Soil Invertebrate distribution/association	Research needed
MACA	Predators associated w/ soil invertebrates	Research needed
MACA	"BMI" Winged-adult distribution	Inventory and research needed
MACA	Vernal-pool amphibians population	Inventory and research needed
MACA	Vernal-pool invertebrate assemblage	Inventory and research needed
MACA	FPOM/POM-contaminants relationships baseline data	Lack of inventory data
MACA	Deer pops & grazing impacts	Needs baseline research and information
MACA	Cave "entrance" plant communities (ref cricket & woodrat resources/diet)	Research needed

Chapter Four
Sampling Design

4.1. Introduction

The primary purpose of a sampling design is to ensure that data collected are representative of the target population(s), and sufficient to draw defensible conclusions about the resources of interest. Development of an adequate sampling design will help ensure the scientific merit of our monitoring program. We maximize our scientific validity through focus on careful and consistent use of probability-based sampling approaches that yield strong statistical inference about monitored Vital Signs. In addition, we place high value on efficient use of our limited monitoring resources. To this end, we emphasize careful logistic planning together with maximal use of sampling co-location and co-visitation, both within individual protocol designs, and across our overall sampling design. This chapter outlines 1) the overall sampling design to be used for monitoring Vital Signs in the 14 CUPN parks, 2) provides a brief summary of some key principles of sampling design, 3) describes how these principles will be employed in sampling terrestrial, cave, and aquatic ecosystems and 4) summarizes the CUPN-MACA Water Quality Monitoring Program. The specific designs for individual Vital Signs follow from these basic themes and incorporate variations as necessary. These details, together with appropriate location maps and analysis plans, will be presented in the monitoring protocols being developed for the individual Vital Signs. Several aspects of our sampling design are presented in Table 4.1.

The CUPN-MACA Monitoring Program, through its sampling designs, is emphatically geared to assessing and tracking Vital Signs at the park level. There is, in general, no a priori intent to try to make statistical inference across the entire Network for either status or trends in most Vital Signs. (Possible exceptions include ozone exposure, adjacent land use patterns and water quality, where multiple-park and Network-wide pattern descriptions may be useful.) We seek to extend and relate monitoring data from the parks into the surrounding regions and communities, and our sampling designs will support this goal through incorporating comparable methods and approaches, wherever possible, to those used in similar projects being performed by other entities in off-park areas.

This chapter is organized as follows: Section 4.2 summarizes key concepts and provides brief definitions for terms used later in the chapter. Section 4.3 discusses sampling in terrestrial systems. Section 4.4 discusses sampling in cave systems. Section 4.5 discusses sampling in aquatic systems, and Section 4.6 discusses key aspects of the CUPN-MACA Water Quality Monitoring Program and its design.

4.2. Sampling Concepts and Definitions

Discussion of our sampling design involves a few underlying concepts and specific statistical terms. This section describes these concepts and brief definitions of some key terms. Explicitly, our sampling design has been developed for ecological monitoring which is defined as the collection and analysis of repeated observations over time to document status and trends in ecological parameters. In general, monitoring is designed to provide unbiased statistical estimates of status and trends in large areas or entire study units. In contrast to research that addresses single questions or tests a specific hypothesis, monitoring focuses on collecting objective, scientifically defensible data to answer wide-ranging and broad hypotheses, where some of these hypotheses may be, at best, poorly defined at the outset. Long-term monitoring data may document correlation between management actions or natural changes and ecological parameters, and can provide the most complete picture of ecosystem changes over time. Monitoring, however, will not establish statistical cause and effect relationships between external changes ("drivers") and the

Table 4.1 Overall Sampling Design and Approach for Vital Signs Monitoring on CUPN Parks.

General design approach (typical dimensionality of sampling distribution), spatial allocation mode, and proposed site revisit plan are provided for 17 high-priority CUPN and MACA Vital Signs. Revisit plan notation is in year-increment scales (e.g., 1-4 means sample one year on, four years off).

Level 1 Name	Level 2 Name	Vital Sign	Overall Sample Design Approach	Spatial Allocation	Annual Revisit Plan (per site)
Air and Climate	Air Quality	Ozone and Ozone Impact	NA (air)	NA	Continuous (air)
			Terrestrial, 2 dimensional (impact)	NA	Annual (impact)
		Atmospheric Deposition	NA (air)	NA	Continuous (air)
			Terrestrial, 2 dimensional (impact)	NA	Annual (impact)
Geology and Soils	Subsurface Geologic Processes	Cave Air Quality	Cave, 3 dimensional	Stratified, Systematic	Continuous
Water	Water Quality	Water Quality and Quantity	Aquatic, 1 dimensional	Various	1-1, 2-5, 3-5
		Benthic Macro-invertebrates	Aquatic, 1 dimensional	Stratified, Random	Annual
Biological Integrity	Invasive Species	Invasive Plants "early detection"	Terrestrial, 2 dimensional	Grid, Systematic	2-3, TBD
	Infestations and Disease	Forest Pests	Terrestrial, 2 dimensional	Grid, Systematic	Annual
	Focal Species or Communities	Cave Aquatic Fauna	Aquatic, 1 dimensional	Adaptive Cluster Sampling	1-1
		Cave Beetles	Terrestrial, 2 dimensional, 1 dimensional	Systematic, Adaptive Cluster Sampling	Annual
		Cave Crickets	Terrestrial, 2 dimensional, 1 dimensional	Systematic, Adaptive Cluster Sampling	Annual
		Vegetation Communities	Terrestrial, 2 dimensional	Stratified, Random	2-3, 1-4, TBD
		Mussel Diversity	Aquatic, 1 dimensional	Stratified, Random	1-2
		Fish Diversity	Aquatic, 1 dimensional	Stratified, Random	1-1
		Cave Bats	Cave, 1 dimensional	Adaptive Cluster Sampling	1-1
	At-risk Biota	Allegheny Woodrats	Terrestrial, 2 dimensional	Stratified, Random	Annual
		Plant Species of Concern	Terrestrial, 2 dimensional	Population Census	TBD
Landscapes (Ecosystem Pattern and Processes)	Landscape Dynamics	Adjacent Land Use	NA	NA	NA

status of ecological parameters. The important utility of monitoring programs lies in their ability to detect changes in parameter status and to provide parks with information that supports development of effective resource management actions.

The CUPN-MACA program will use design-based approaches in monitoring. Such approaches emphasize objectivity and do not rely on detailed assumptions about the structure and nature of responses being measured. Rather, the design-based approach is based upon use of rigorous probability samples in developing estimates and extrapolating results to non-sampled units (McDonald 2003). Design-based analyses use the sampling apparatus (i.e., the way the sample was collected), rather than assumptions about responses, as the basis for replication and subsequent probability statements (confidence intervals) on estimates. As no assumptions are made about response nature, design-based analyses are held to be extremely difficult to challenge or argue over (ibid); a property which makes this approach well-suited for projects that could involve litigation and controversial public decisions.

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

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

Some key terms we will use are briefly defined in the following paragraphs. Our definitions and application are comparable to and follow the conventions of use established in other NPS network monitoring plans Detailed discussion on these terms may be found in Mendenhall et al. (1971), Sarndal et al. (1992), Levy and Lemeshow (1999), and Lohr (1999). In sampling, the target population consists of the entire collection of units or elements for which inference is intended. A subpopulation refers to a subset of units that may be of particular interest, which may be denoted by use of "strata" in a sampling design. Strata refer to subpopulations that are defined prior to drawing a sample, such as by some geographical of other criteria. Stratification is a fixed scheme for allocating effort in a sampling design, such as by distributing sites among three areas defined by elevation. Sample units are the individual units that are being evaluated within the "sample frame" (the area or subpopulation actually included within the sampling effort). For example, individual fish are sample units to estimate size of fish in a pond. The pond can be the sample unit when estimating the proportion of fish that are exotics in ponds across a park. Elements are individual items that are counted or measured, such as individual fish in a pond (whether or not the pond is the sampling unit). Responses are the measured values or quantifications being noted for elements and units in sampling (i.e., lengths of fishes, pH values, etc.). The sample is the set of sample units and their elements (i.e., the 10 fish caught to be measured to provide a length estimate for the target population or subpopulation).

Monitoring on CUPN parks will involve use of "panels" to spatially and temporally allocate sampling effort as a way to more effectively use limited sampling resources. A panel is a set of sampling units that will always be sampled during a single sampling occasion. Panel membership is defined by a membership design, which sets out how sample units are either included or excluded from being in a given panel. Once panels have been defined, a revisit plan is created to define how sampling effort will rotate among available panels over time (McDonald 2003). Revisit plans may include both "rotating panel"

and "split panel" designs. For example, a "rotating design" may consist of two 3-site panels in a river, with panels alternating in a sampling sequence over years. A "split panel" design could consist of a four-site panel scheduled for sampling every year, with another panel of 4 other sites scheduled for sampling every third year.

The CUPN-MACA program addresses a wide range of Vital Signs and ecological parameters within a variety of ecosystems and circumstances. Simply stated, there can be no one sampling design or approach that will adequately address all monitoring needs. Our designs will emphasize use of several major design and sampling themes, including simple and stratified random sampling, systematic sampling, cluster sampling, and, in some special cases, "total census" and targeted approaches. A simple random sample is one in which n units are selected from a population of size N via a random process, such that every unit has an equal probability of being chosen. A stratified random sample is one where the sampling frame is divided into distinct and mutually-exclusive subpopulations (strata), with n samples being randomly drawn from each stratum. Stratification can be used to both increase sampling efficiency and increase precision and information-yield. A systematic sample is one where sampling units are collected in some systematic pattern, such as within a grid or at fixed intervals along a transect. Generally, systematic sampling involves some randomization of the first sampling point. Cluster sampling is a grouping method where some localized set of units is sampled within a larger sampling frame that may be difficult or impossible to effectively randomly sample (such as when travel times are great, etc.).

Table 4.2 Sampling grid design established for 14 CUPN parks by NatureServe (2002-2004).

Grid size (presented in km), grid density (sampling points per hectare) and number of designated sampling points (intersections of vertices) vary between parks. The number of sampling points on a grid ranges from 12 at RUCA, to 47 at CUGA.

Park Group	Area (ha)	Sample Points	Grid Density	Grid Size (km)
Small Parks				
GUCO	89	15	1 sample point/6 ha	0.24 x 0.24
CARL	107	15	1 sample point/7 ha	0.27 x 0.27
RUCA	125	12	1 sample point/10 ha	0.32 x 0.32
ABLI	138	15	1 sample point/9 ha	0.30 x 0.30
FODO	226	15	1 sample point/15 ha	0.39 x 0.39
STRI	287	15	1 sample point/19 ha	0.44 x 0.44
COWP	341	16	1 sample point/21 ha	0.46 x 0.46
NISI	400	15	1 sample point/27 ha	0.52 x 0.52
Large Parks				
KIMO	1,597	21	1 sample point/76 ha	0.87 x 0.87
SHIL	1,607	20	1 sample point/80 ha	0.90 x 0.90
CHCH	3,311	32	1 sample point/103 ha	1.02 x 1.02
CUGA	8,274	47	1 sample point/176 ha	1.33 x 1.33
MACA	21,380	44	1 sample point/486 ha	2.20 x 2.20
River Canyon Parks				
LIRI	5,543	35	1 sample point/158 ha	1.26 x 1.26

4.3. Terrestrial Systems

Sample Selection

Sampling in terrestrial systems typically utilizes "two-dimensional" approaches and designs, where sampling effort is distributed across an area that incorporates substantial "width" relative to its length. In general, the sampling design for most CUPN-MACA terrestrial monitoring projects is based on use of the sampling grid established by NatureServe, in collaboration with the NPS, on each CUPN park (Nichols et al. 2000). CUPN parks range in size from ca 220 acres at Guilford Courthouse (GUCO) to more than 52,000 acres at Mammoth Cave (MACA). NatureServe has established a rectilinear sampling grid at each park, with park size factored into grid dimensions to ensure that each park has at least 12 within-park designated sampling points (see Table 4.2).

Most parks have additional sampling points located to ensure potential inclusion of specific habitats and vegetation communities of interest in a park-wide sampling design. Individual projects will use the established grid in different ways and scales, and may involve sampling of "all" points, of some systematic subset, or of some randomized or stratified-random subset of the total available points on each park. Use of the sampling grid will ultimately depend upon the parameter(s) being sampled for, park size, grid scale, sampling time required for each point (or plot established at a point), and available personnel. Regardless of specific approach (i.e., random, stratified, etc.), the same underlying grid can be used for multiple sampling protocols with different designs and scales.

By sharing a common underlying grid, multiple protocols using different approaches to spatial allocation can maximize effective co-location of sampling sites. Co-location refers to sampling the same physical unit for multiple parameters; an approach which can enhance analysis and interpretation of monitoring results through incorporation of spatial overlap. It also offers efficiencies of time and effort. For example, assessment of ozone impact on sensitive plant species, atmospheric-deposition, invasive plant species, detection of forest pests, and monitoring of selected vegetation communities, are all high-priority monitoring objectives on CUPN parks. Each of these Vital Signs will involve development of sampling approaches designed to effectively assess the specific parameters of interest. Figure 4.1 illustrates an example of superimposing several different survey designs on one grid. First, an appropriate grid is constructed on the available total sample frame (the hypothetical park map in Figure 4.1.). Vertices of the grid comprise the primary pool of potential sample points. Additional "off-grid" points are identified on the map to provide potential targeted sampling of specific habitats or communities. The sampling grid is now ready for use with multiple protocols at different scales and distributions.

Invasive plant species, for example, may be monitored with a rapid survey and data collection method that could use all grid points within the park in order to maximize spatial coverage and chance-of-detection. This would constitute a park-wide systematic sampling design. Impact on plants from exposure to ozone is a more labor-intensive and detailed quantification that involves careful sampling of multiple specimens of selected sensitive species within selected plots. This protocol may utilize only two plots on the hypothetical park. Ozone impact plot locations could be identified by randomization from amongst all points, or by randomization of a restricted candidate list defined by a hypothetical inclusion criterion of "plot must contain at least n individuals of each plant species being tracked". This random sample (or limited random sample) is represented on Figure 4.1 by the two blue-outline squares. Sampling for both invasive species and ozone impact monitoring may be co-located at the same point, as indicated by the blue outline square-and-dot on the map. Vegetation community monitoring is intensive and time-consuming, and is often restricted to specific habitats and areas in a park; therefore, sample size will likely be small. Vegetation community monitoring may also seek to capture effects from underlying soil types and/or slope and exposure aspects. In this hypothetical park example, two sampling strata are marked by background shading, and a set of sampling points, marked with larger circles, is randomly drawn from each proportionate to the area of the stratum, thus creating equal probability of selection. Both invasive species and vegetation communities would be monitored at the circled points. Two systematic sampling plot arrays, with different spatial scales, are shown by the sets of larger squares. These arrays could be used for sampling which could reasonably occur at larger spatial scales, such as an effort to track bird populations or for deer monitoring. Other terrestrial sampling efforts, such as a complete census for a rare plant, can be effectively overlain on the above systematic, random and stratified-random designs, as needed.

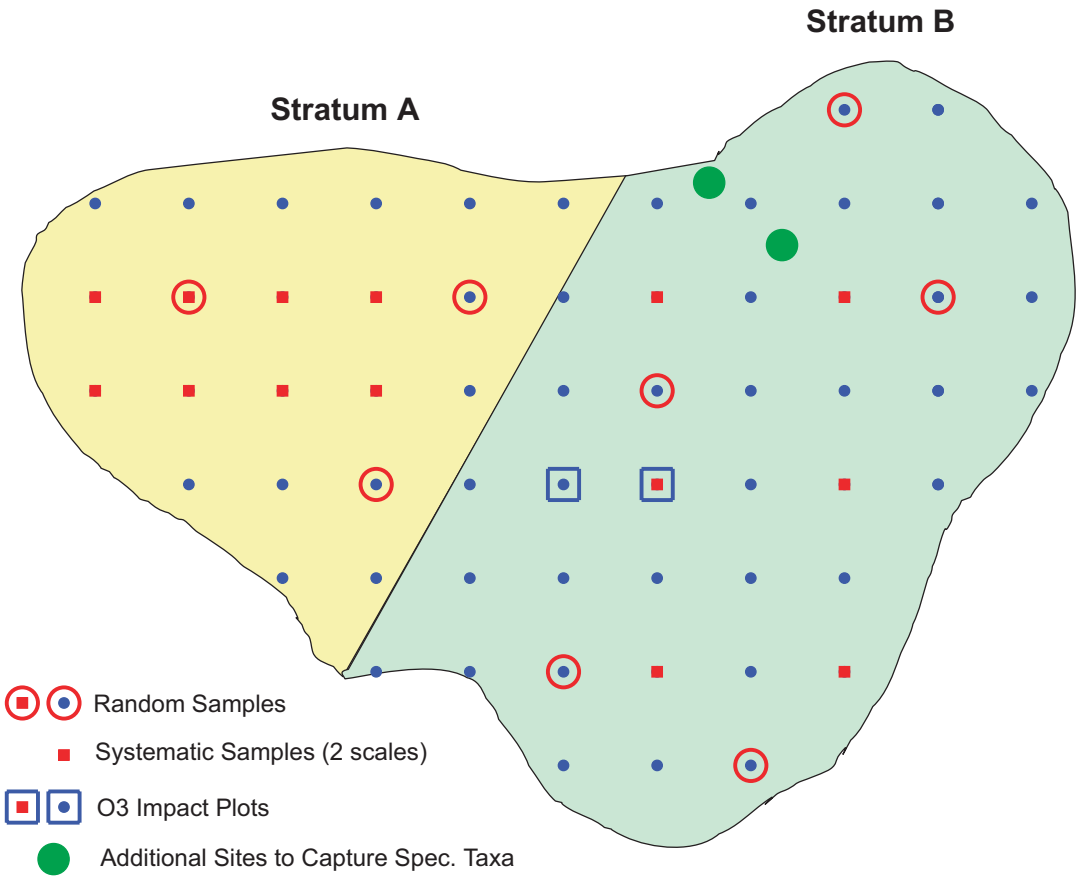


Figure 4.1 A hypothetical park grid, with representation of multiple sampling designs. The total possible sampling frame on the hypothetical park includes 60 grid points, plus 2 added "off-grid" points (large dots) for sampling targeted habitats or taxa. Two sampling strata are marked by background shading. Distribution of points used in simple random and stratified random sampling is indicated by circles. Systematic sampling designs in 2 scales are marked with small squares. Large squares indicate 2 points used for ozone sampling. As indicated by symbol combinations, the same point may be used for multiple designs (e.g., circled small square means a point used for both random and systematic sampling).

Panel Membership and Revisit Design

Panel membership and revisit designs describe how sites at a park or parks are sampled through time. In general, monitoring of vegetation communities in CUPN parks will occur within a "rotating panel" design where each panel of sites on a park will be sampled in a "2 years on,3 years off" [2 – 3] pattern. This revisit plan better accommodates an efficient Network-wide logistic plan, reduces potential damage to sensitive sites that may result from intensive sampling activity, allows more sites to be visited over time, and provides three-year windows in which to initiate management activities. The two-year periods of consecutive sampling statistically reduce the effect of annual variability on the detection of trends in plant communities that are temporally dynamic. Some vegetation communities may be put on an "always revisit" sampling schedule (specific parks and communities have yet to be determined), if so designated by specific contracting system experts. As vegetation communities strongly reflect the effects of seasonality and geographic location, all vegetation sampling will be conducted on a proximate "same date-range for a site each sampling occasion" basis.

Sampling for detection of forest pests (new or initial invasions of gypsy moth, hemlock wooly adelgid, ash borer) will, in contrast to the rotational sampling proposed for most vegetation communities, occur in an annual "always visit" design, where monitoring sites will be visited every year. An "always revisit" design is well suited to detect gross change and components of

individual change within a sampled community, and provides the finest temporal resolution, at the expense of limited spatial coverage across the resource of interest. In some cases, a "split-panel" design will be employed, where sampling will be distributed between an "always revisit" panel (providing trend detection strength) and a "rotating panel" (or multiple panels), which will be sampled on some "on-off" schedule to provide better assessment of status across the sample frame.

In designing Vital Signs monitoring for multiple park units at the Network scale, logistics may strongly constrain the survey design at any particular park. For example, vegetation community monitoring will be scheduled to occur at 13 CUPN parks distributed across parts of seven southeastern states. To improve sampling efficiency, CUPN will utilize a "sub-Network cluster" sampling and logistics plan, where the 13 smaller Network parks are grouped into three geographically-close monitoring "sub-Network" clusters (Figure 4.2). (For vegetation, and most other monitoring, MACA, with its larger park staff, will operate as a separate unit, with its own monitoring schedule.) Each cluster will consist of four or five parks, with sampling performed amongst the cluster's member parks on a rotational basis. Each cluster will have a dedicated sampling team, and sampling will occur on all three clusters, as shown in the hypothetical CUPN sampling schedule (Table 4.3.). (The CUPN cluster plan should be viewed in contrast to the "tour" plan being used in the HTLN, where a single Network monitoring team will shift between clusters ("tours") of parks on an annual basis.). This cluster concept serves to reduce travel time and costs through sequentially sampling parks in close proximity to each other and to the duty stations of the CUPN team leaders.

Parks and specific Vital Signs on parks within each cluster will be sampled within the membership and revisit designs for those parks and cluster. The general model for each cluster will be to sample in alternating years, or on some repeated schedule, such as a 2 – 3 staggered rotation, where some parks are sampled the 1st and 2nd of 4 years, others on the 2nd and 3rd years, etc., as shown in Table 4.3.

As noted before, Network- and region-wide inferences are not intended from most CUPN monitoring, and the study units within the parks are the primary framework for statistical interest.

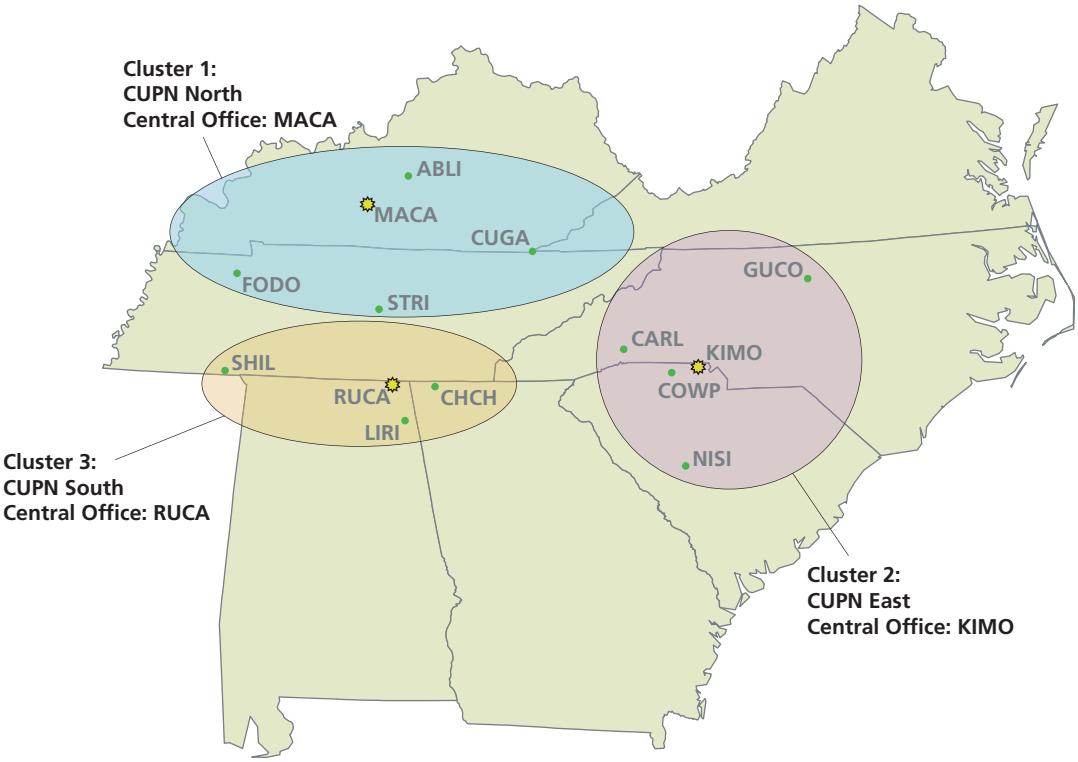


Figure 4.2 The three clusters of parks used for monitoring on the CUPN. Each cluster has a central office with a team leader to oversee sampling team rotation among parks within its cluster.

Table 4.3 A Hypothetical Vegetation Rotation Schedule for the Three CUPN Park Clusters.

In this example, parks will be sampled for vegetation monitoring on a staggered 2-3 rotation plan. In each year, the cluster sampling team will concentrate its sampling effort on one or 2 parks, as shown. The rotation pattern within each cluster would be designed to efficiently use staff and reduce travel time and mileage wherever possible. The vegetation sampling schedule will be adjusted to meet requirements for specific sampling projects as these projects are defined and developed.

Cluster	Park	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
CUPN NORTH	FODO	■	■				■	■			
	STRI		■	■				■	■		
	ABLI			■	■				■	■	
	CUGA				■	■				■	■
CUPN EAST	GUCO	■	■				■	■			
	CARL		■	■				■	■		
	COWP			■	■				■	■	
	KIMO				■	■				■	■
	NISI					■	■				■
CUPN SOUTH	CHCH	■	■				■	■			
	LIRI		■	■				■	■		
	RUCA			■	■				■	■	
	SHIL				■	■				■	■

Though we do not anticipate extrapolating from results to include "all parks", inter-park and Network-wide extrapolations are certainly of interest to the program, and will be developed, if possible, in the future.

Ozone exposure and impact represent a special case for CUPN terrestrial monitoring, such that monitoring will occur at a single, subjectively chosen site on most parks, and monitoring effort will be distributed in a "split-panel" logistical design across parks. CUPN parks will be grouped into two types, or classes, of monitoring panels. One panel will consist of those parks which require annual on-park monitoring owing to a lack of reliable data from any nearby off-park monitoring station. This panel will be designated "non-represented parks". Those parks whose ozone exposure is documented to correlate well with that recorded at off-park monitoring stations will be grouped into one or more "well-represented parks" panels. The "non-represented parks" will be revisited annually. The "well-represented parks" will be sampled on a 1 – 4 year rotating basis as a check on their continued status of being "well-represented" by off-park monitoring. The number of "well-represented parks" panels to be used is presently undefined, and will depend on how many such parks are identified from the 2004-05 sampling test. A hypothetical ozone schedule with an always revisit panel and 3 5-year rotation panels of "well-represented" parks is shown in Table 4.4.

4.4. Cave Systems

Caves and cave-related systems include salient natural and cultural resources for the CUPN, with four Network parks (MACA, CUGA, CHCH, and RUCA) featuring large, visitor-accessed and management-impacted caves. Caves remain poorly understood as functional ecosystems, and present many significant challenges for sampling and monitoring. Sampling designs for cave systems are highly idiosyncratic, as determined by the nature of caves on the specific park

Table 4.4 A Hypothetical Ozone Monitoring Schedule for 14 CUPN Parks.

For ozone exposure monitoring, CUPN parks will be grouped into two classes, "well-represented" and "non-represented". The "non-represented" parks will form one panel that will be monitored every year. The "well-represented" parks will be placed into two or more (4 are shown) panels that will be sampled on a staggered 1-4 schedule. Actual distribution of CUPN parks into monitoring classes will occur following completion of Network-wide sampling tests being performed in 2004-05.

Cluster	Park	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
CUPN Non-represented parks	A, B, C, D	■	■	■	■	■	■	■	■	■	■
	MACA	■	■	■	■	■	■	■	■	■	■
CUPN Well-represented parks	E, F	■					■				
	G, H		■					■			
	I, J			■					■		
	K, L, M				■					■	

and the specific parameter (species, habitat characteristics, potential threats, etc.) being monitored, and, in general, are strongly constrained by cave complexity and significant safety and logistical concerns. Key factors that influence cave sampling designs include surface access logistics, cave entrance access concerns, and huge variations in accessibility for sampling within caves. In addition, cave monitoring focuses strongly on evaluating management impact to the resources: there are few managed caves, and each is unique in terms of its management applications and scope (thus, replication within a design is very limited). Sampling within caves involves specialized skills and equipment, and occurs within extremely complex and irregular environments. In addition, cave biota pose strong challenges for sampling, owing to poorly understood habits and ecology coupled with a general lack of verified sampling methodology suitable for addressing these specialized organisms and habitats.

Sample Selection

Cave distributions across park landscapes tend to be highly irregular, and caves are often clumped along specific types of geological formations and features (cliff-lines, etc.). In cave sampling designs, effort is distributed at two major levels; "two-dimensional" distribution among caves at a park, and "one-dimensional" (linear) distribution within caves. Sampling designs for multiple caves rely strongly on careful criteria-based evaluation and classification of the park's caves prior to selection for inclusion in the sampling scheme. Multiple-cave sampling designs are stratified, and include both geographic strata and "blocking factors" (questions about potential management and visitor-use effects on resource status and trends). Probability is introduced into sampling among caves by randomizing from lists of "acceptable" candidate caves (the available sample frame), where acceptability is defined by a cave meeting surface accessibility, entrance accessibility, and internal complexity and accessibility criteria. In addition, "acceptable" candidates must, in the case of biological monitoring, be known to support the taxa of interest. (For example, those caves which are known to have few or no crickets will not be included in cave cricket monitoring). Figure 4.3 shows the distribution of cave locations being used for woodrat, cave cricket, cave beetle, and cave air-quality monitoring on MACA. The 50 "unmanaged caves" marked on the map constitute a restricted random sample of all caves on the park; the nine "managed" caves are the total available on the park. Cave entrances on the park are noted as map locations on a GIS layer. For woodrat monitoring, a data sort on "surface accessibility" limits consideration to caves located within 0.5 km of a park road, while the Green River (which can putatively limit woodrat movement across the park) provides geographic stratification of

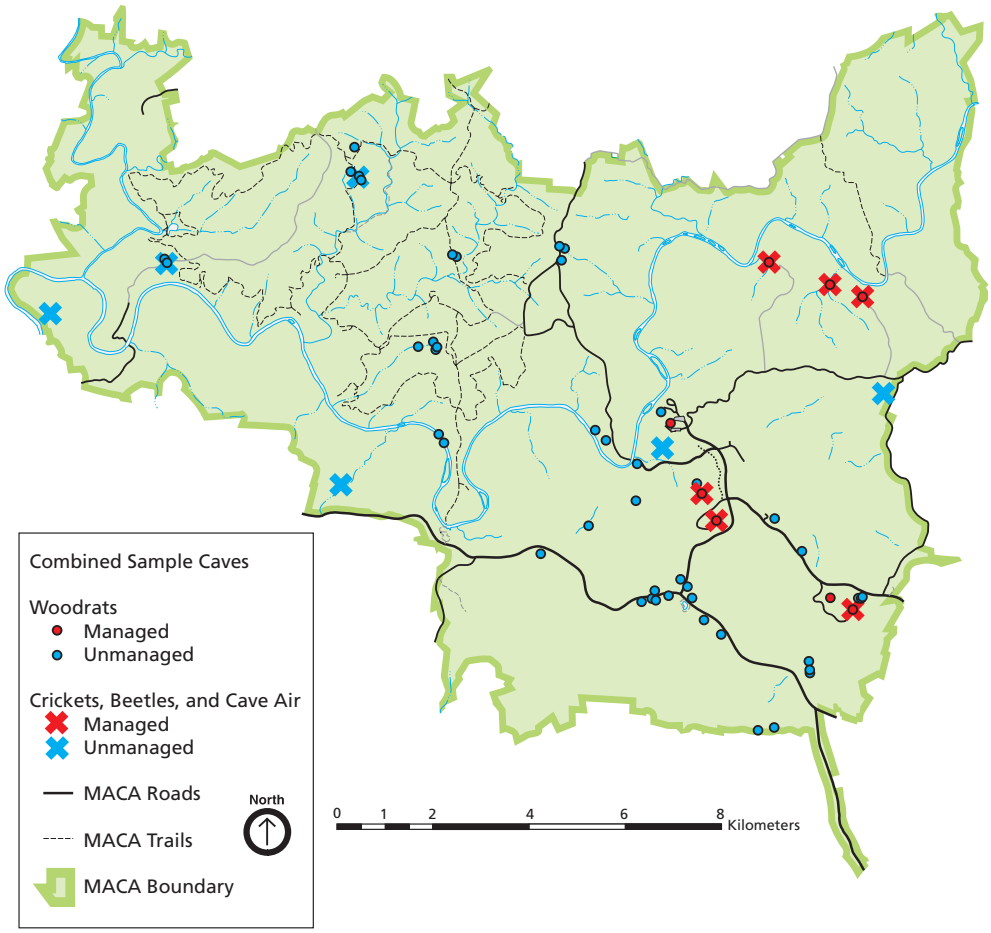


Figure 4.3 Distribution and approximate locations of caves (entrances) used for 4 monitoring protocols on MACA. Caves are identified as being either "managed" (red symbols), or "unmanaged" (blue symbols). Caves being sampled for woodrats are marked by dots. Cave crickets, beetles, and cave air parameters are all sampled on a co-visitation basis in the 12 caves marked by an "x" symbol. This sampling is co-located with woodrat sampling in 6 "managed" and 2 "unmanaged" caves.

park caves into 'North' and 'South' classes. The "managed" caves provide an unevenly distributed "blocking factor" in sampling and analytical designs for all cave protocols.

Cave entrance locations within the landscape make access to some caves extremely time-costly, and, in some cases, hazardous. "Surface access", incorporating surface travel distance from nearest road access and difficulty of cross-country travel (need for descending cliffs, etc.), is the first criterion used to identify potential sampling caves from the larger lists of "all caves" identified on park maps. Cave entrances differ widely in size and structure, greatly affecting accessibility by sampler personnel. This means that a given cave may be logistically ideal for access across the park landscape, yet quite difficult and hazardous to enter. Conversely, an easily-entered cave may be unsuitable for inclusion in a sampling design owing to its distant and difficult access route. "Cave entrance accessibility" is used to sort potential sampling caves by suitability of entrance for sampling personnel. Caves that meet both surface and entrance accessibility criteria can be included in the candidates list for the sampling design. Caves will be selected for use by random draw from the candidate list, with inclusion also being affected by meeting fauna-based sorting criteria in specific cases, as in the above example using presence of cave crickets.

Internally, caves vary widely in size, shape, and substrate complexity, making all spatial and area-based sampling within them problematical, as well as posing strong challenges to personnel who must move safely and effectively within the cave environment. This complexity also chal-

lenges development of effective, statistically-valid comparisons between and among caves for most parameters. Within-cave sampling is very comparable to sampling in a narrow stream habitat, and caves may be viewed as being linear, or essentially "one-dimensional" systems. The key property for within-cave site selection for all cave protocols is use of a very restricted "common" area for almost all sampling within a cave. For example, biotic and physical habitat sampling occurs mostly proximal to human-accessible entrances (within ca 100 meters), as this is the area that staff can reasonably access and effectively sample within time-frames of several hours. For most parameters, sampling does not currently extend (and has no foreseeable likelihood of ever being extended) into the deeper cave system (over 500 km long, in the case of MACA). On the other hand, use of similar entrance-proximal sampling regions in all caves for all parameters being considered does provide a large degree of sample co-location, and can feasibly support significant co-visitation. Co-visitation refers to sampling the same units for multiple parameters on the same occasion, an approach that can reduce travel costs and maximize use of personnel time. In cave sampling, this technique will greatly strengthen the multi-parametric integration by coupling biological monitoring with sampling for cave habitat conditions. In addition, both cave biotic and cave habitat sampling involve detailed spatial mapping based on fixed monitoring landmarks, and those same landmarks within a cave can be used in common for all protocols. Within-cave sampling designs include systematic sampling, stratified sampling, parameter-specific targeted sampling, and adaptive cluster sampling approaches for monitoring fauna, and a purposefully-located grid-and-column-based systematic sampling for monitoring the cave environment. Details of the within-cave sampling designs and parameter-specific sampling schedules are provided in the technical protocol documentation.

Panel Membership and Revisit Design

Sampling panel membership and revisit plans for cave resources are currently defined on a per-park and per-parameter (or protocol) basis. No Network-wide plan has been developed because there is no intent to extend inference about cave resources across the entire Network or over multiple parks. In addition, there is a lack of common cave resource monitoring objectives across parks, adding to the idiosyncratic nature of cave monitoring projects. Within a park, cave resource sampling (and analysis) can be integrated both spatially and temporally based on expected extensive co-location and co-visitation. Sampling of multiple caves for multiple protocols will be scheduled in a staggered-rotational-panel design. A multiple-protocol cave sampling design has been developed for the primary Network cave park (MACA) (see Table 4.5). Similar designs will be provided for the other Network cave resource parks, once detailed cave monitoring needs and questions have been fully developed and refined. In the MACA design, sampling for each protocol will be performed in some set of caves (caves = sample units), with many caves being used for most or all sampling efforts (sampling co-location at the "two-dimensional surface" level). In particular, as there are only nine "managed" caves (out of over 270 known caves on the park), all managed caves will be included for sampling for all parameters under all protocols.

The sampling plan among caves for the four protocols (cave crickets, cave beetles, woodrats, and cave air conditions) variably overlaps in space and time, as shown by the four panels indicated in Table 4.5. Panels (A) and (B) illustrate the strongly overlapped monitoring for crickets, beetles, and cave air conditions that occur in six "managed caves" (A), and the six "unmanaged caves" (B). All caves in panels A and B are sampled in the same internal areas (close spatial co-location), but involve differently overlapped schedules (partial co-visitation). Crickets are sampled on a bi-monthly schedule, while beetles are sampled every six months. Cave air sampling occurs on all cricket and beetle sampling dates, in conjunction with faunal sampling activities (complete sampling co-visitation) but also occurs at other times and on other sampling schedules. Woodrat sampling occurs in all nine "managed" caves (panel (C)), and in 50 "unmanaged caves" (panel (D)). Woodrat sampling spatially overlaps with the other three protocols in that it occurs in all of the managed caves and in some of the unmanaged caves that are used for cricket, beetle and cave air monitoring, but also occurs on different schedules than do the other protocols. Collectively, the four panels shown in Table 4.5 illustrate the broad integration obtained in MACA cave ecosystem monitoring through combinations of multi-protocol co-location and co-visitation. The resulting integration in sampling supports the development of possible statistical inter-class (unmanaged versus managed) comparisons for all parameters in a spatial and temporal context.

Table 4.5 Sampling Schedules for 4 Cave Monitoring Protocols (c=crickets, b=beetles, w=woodrats, and a=cave air parameters) in "Managed" and "Unmanaged" Caves.

Panel "A" caves are sampled monthly, panels "B" and "C", bi-monthly, and panel "D", every 6 months. Letter combinations within a panel indicate site co-visitation. Panel "A" is a fully-included subset of panel "C", while panel "B" includes only 2 caves out of the 50 in panel "D" (partial overlap and co-location).

Panel	2006												2007											
	Month												Month											
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
A 6 of 9 "managed" caves	a	cba	a	ca	a	ca	a	cba	a	ca	a	ca	a	cba	a	ca	a	ca	a	cba	a	ca	a	ca
B 6 "unmanaged" caves		cba		ca		ca		cba		ca		ca		cba		ca		ca		cba		ca		ca
C Up to 9 "managed" caves	w		w		w		w		w		w		w		w		w		w		w		w	
D 50 "unmanaged" caves					w						w						w						w	

The first two panels (A and B) represent a "semi-split, co-rotational design", involving sampling of diverse parameters for three protocols to address overlapped and related questions. Sampling for the fourth protocol (woodrats) is represented in two panels (C and D), constituting a simpler "split-panel" design, consisting of two non-related sets of sites that are sampled for one protocol on two different schedules.

4.5. Aquatic Systems

Aquatic systems are important sets of resources on several CUPN parks. Biological resources include fish, fresh-water mussels, and benthic macro-invertebrates. In addition to monitoring biological resources on a few parks, CUPN has a comprehensive Network-wide water quality monitoring program involving sampling park streams and rivers, karst groundwater, cave streams, springs and wetlands (see Section 4.6). River systems are essentially linear, and require different (typically, "one-dimensional") sampling approaches than either the terrestrial or cave habitats. The CUPN aquatic system sampling designs discussed in the following paragraphs focus on monitoring surface river faunal resources on MACA's reach of the Green River. Faunal monitoring on other CUPN river systems will be developed using approaches and sampling methods similar to those developed for MACA. For MACA, three major faunal Vital Signs are proposed for evaluation under the CUPN-MACA combined monitoring program: freshwater fish communities, freshwater mussel communities, and benthic macro-invertebrates. Sampling for the faunal Vital Signs will involve sampling site co-location, wherever possible, in order to maximize use of available site information. Sampling co-visitation is expected to be very limited, as sampling for fish and mussels are technical and labor-intensive efforts, and available staff are likely to be limited in number. Benthic macro-invertebrate sampling may co-occur with mussel sampling and with fish sampling, depending on other system constraints and availability of personnel. Limited water quality sampling will co-occur with fish, mussel, and invertebrate sampling, as detailed in those protocols (see Chapter 5). A separate sampling design and plan has been developed expressly for Network-wide water quality monitoring, and is described in section 4.6 of this chapter.

Sample Selection

MACA's reach of the Green River (approximately 42 km) is used as the primary model for developing faunal monitoring for CUPN river-based biological resources. For monitoring purposes, MACA's reach of the Green River is divided into functionally impounded and free-flowing zones, to reflect the effects caused by the US Army Corps of Engineers Lock and Dam 6 located at the downstream end of the park's reach. The MACA reach is divided into forty-two 1.0 km segments for primary location and distribution of sampling sites, as shown on Figure 4.4. For monitoring purposes, all 42 segments are considered to be equally accessible by sampling teams, and are considered to have equal probability for inclusion in simple, whole-reach sampling designs (proviso that no special habitat considerations are considered that would limit use of sites). MACA faunal sampling addresses whole-reach questions of community status and trends, and consideration of statistical comparisons between the upstream "free-flowing" and downstream "impounded" zones.

MACA river sampling designs use modified stratified random sampling to distribute target sites for all faunal protocols. As MACA river monitoring focuses strongly on tracking biological diversity at the "whole reach" level, and does not seek to address detailed questions such as proximity to confluences and tributaries, randomizing of segments for use without strong consideration of possibly close-together site-spacing is acceptable. (The linear nature of river systems leads to

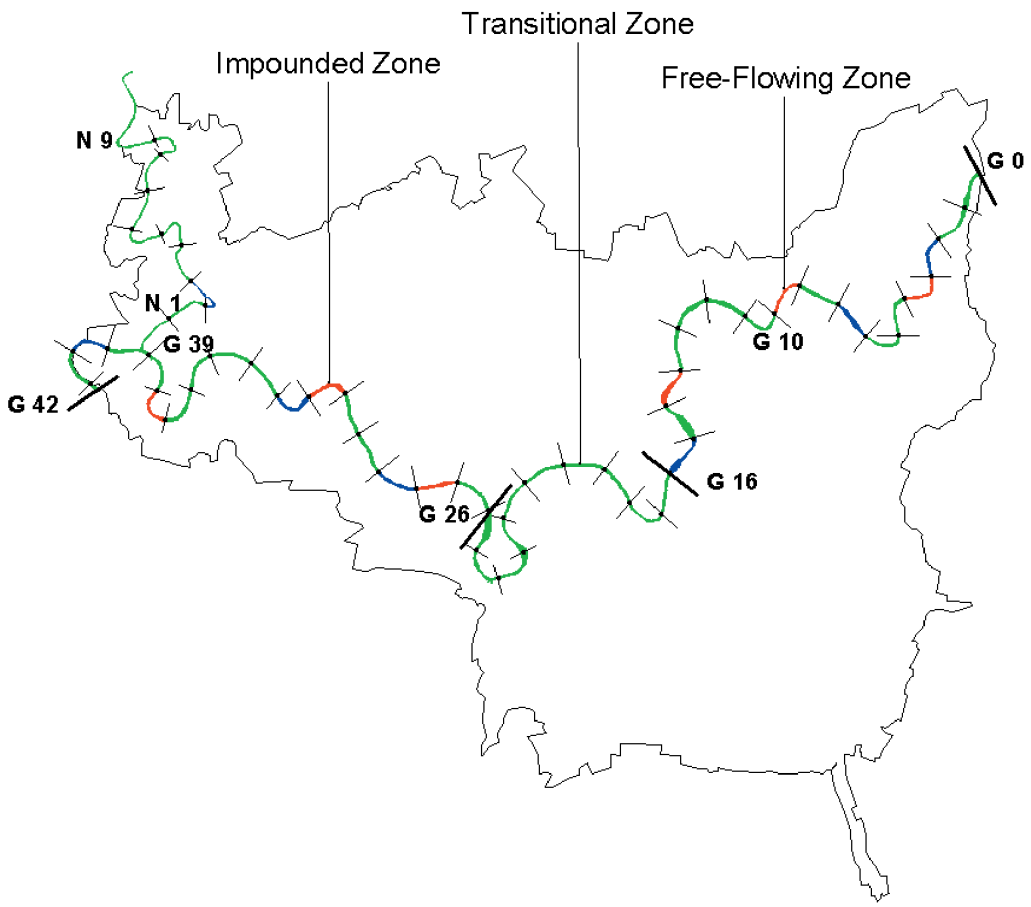


Figure 4.4 Map of the Green and Nolin Rivers on MACA. MACA's river reaches are divided into fixed 1.0 km segments for larger-scale distribution of sampling for all aquatic system protocols. MACA's reach of the Green River (42 km) is functionally divided into two distinct habitats ("impounded" and "free-flowing") for most protocols; providing stratification in some sampling designs. The red and blue segments show a stratified-random distribution of sampling segments for one protocol (fish community); red = permanent sampling sites, while blue = annually-redistributed sampling sites. Other protocols may co-locate on these same sites, depending on taxon-specific sampling requirements (e.g., mussel sampling will occur only in segments with riffle zones).

potential auto-correlation in some parameters measured at sites closer in proximity to one another. This auto-correlation is not deemed to be a major concern in most faunal monitoring planned for MACA or other CUPN river systems.) The total available sampling frame will initially comprise all 42 identified and marked segments. The MACA reach will include permanent stratification into two ca 12+ km sampling zones reflecting impounded and free-flow conditions, to allow consideration of the effects of the dam (Figure 4.4.). A constant segment length of 1.0 km is considered to be acceptable for adequate sampling and application of field protocols for fish, mussel, and benthic macro-invertebrate sampling, when multiple segments are to be used in a design (replication within the reach). Segment selection will, wherever possible, include co-location of sampling for multiple protocols. Actual inclusion of any specific segment in any one protocol sampling design is, however, strongly effected by taxon-specific sampling requirements. For example; one component of mussel monitoring on MACA, quadrat sampling for live mussels, is restricted by practicality to shallower water and riffle zones (deep-water SCUBA sampling is prohibitively expensive); the only segments that can be used for live mussel monitoring are those that include permanent and near-permanent shallows and riffle zones.

Panel Membership and Revisit Design

The general panel membership design for MACA Green River faunal monitoring is based on use of spatially-intermixed fixed permanent and annually randomly-redistributed segments in a permanently stratified distribution. The initial goal of the sample segment or site distribution plan is to support a statistically-balanced sampling design by using equal numbers of fixed and permanent sampling segments in each permanent stratum. Co-location of sampling for multiple protocols will depend on a given segment meeting the conditions and requirements for use set forth by all of the considered protocols. Co-visitation is not deemed feasible for most MACA river monitoring, and is not a driving consideration in either the panel membership or revisit designs. A typical river sampling panel will consist of n permanent segments and n annually-redistributed segments in each of two strata, as shown in Figure 4.4. This general segment and site distribution may be used for fish, mussels, and benthic macro-invertebrates in the Green River.

For monitoring fish, two sampling methodologies will be employed- electro-shocking in deeper waters, and seining in shallows and riffles. Use of any given river segment for either sampling method depends on the physical character of the segment (i.e., presence of a riffle zone and/or open pool areas). Sampling segment identification is performed as follows: First, three permanent segments are identified by randomizing from a list of segments acceptable for electro-shocking in each stratum. A "blocking factor" (no two permanent sampling segments can be directly adjacent to one another) is used to ensure broader distribution within the stratum. Following selection of the three permanent segments, three "annually-redistributed" segments are identified by randomizing from among the remaining electro-shocking-acceptable segments in the stratum. This process is repeated to select the sampling segments for application of the second methodology, seining. Any segment selected for the first panel (electro-shocking) may also be selected as either a permanent or annually-redistributed segment in the seining panel, if it meets the habitat requirements for such sampling. Segments which are identified for both electro-shocking and seining provide a within-protocol, multiple methodologies co-located sample. Any river segment that contains a permanent riffle or shallows may be selected for use in both fish (seining-based) and mussel monitoring, and could provide multi-protocol co-location of sampling.

Distribution of sampling for mussel monitoring (currently in early development) will follow a "two-methodologies, two-panel" design: quadrat sampling for live mussels will occur in six permanent segments, while sampling for mussel shell diversity will occur in muskrat middens that are identified in river segments selected in each sampling year. Mussel sampling segments are selected from the 42 total segments of the park's reach of the Green River, without use of a priori stratification. As acceptability of segments for mussel sampling is strongly constrained by having an accessible shallows and/or riffle zone, the list of acceptable segments is likely to be small. Consequently, no a priori rule barring use of directly adjacent segments will be used in this segment selection. Segments used for sampling mussel shells in middens will be selected by first identifying all likely candidate segments at the start of a sampling event. This list may include any or all of the previously-selected live-sampling segments, if such are found to contain middens. The list of acceptable segments (those containing at

least one midden) will then be randomized to identify a sampling set of *n* (TBD) segments. If sufficient acceptable sites are available in both permanent strata, the distribution of midden sampling segments will be balanced between the strata; otherwise, all acceptable segments will be treated as one pool for randomization. Once identified, mussel-sampling segments will be grouped into two panels: the fixed-*n* set of 6 permanent sites which are used for live sampling in each sampling year, and the (possibly varying *n*) set of segments used for midden surveys.

The proposed general revisit design for Green River fish and mussel sampling is presented in Table 4.6. Four panels are presented; two for fish (electro-shocking, "A", and fish seining, "B"), and two for mussels (live sampling, "C", and muskrat midden shell sampling, "D"). The fish panels include both "always revisit", permanent segments and sites, and "annually-redistributed" segments. The live mussel panel consists of six permanent, "always revisit" segments, while the midden panel consists of n segments that are newly identified in each sampling year. All segments and sites in both fish panels will be sampled on the same bi-annual schedule (a "1 – 1", or 1 year on, 1 year off, schedule). Mussel sampling will occur on a 1–1 schedule, with all segments and sites of both panels being sampled every other year. Where the same segment is being sampled for both fish and mussels, sampling co-location will occur, but each taxon will be sampled in different years (thus, no site co-visitation is anticipated).

4.6. The CUPN-MACA Water Quality Monitoring Design

Conservation of the surface and subsurface aquatic ecosystems of a park relies on the knowledge of, and the ability to recognize, long-term trends in water quality. Over the next few years, due to extensive monitoring efforts, many park managers and researchers will, for the first time,

Table 4.6 A proposed logistic plan for two protocols (fish diversity and mussel diversity) on the Green River (MACA).

Two sampling panels, together with proposed sampling schedules, are shown for each protocol. Each panel includes a set of sites that will be sampled on the indicated schedule with a given methodology. For both protocols, the same segments=sites may be used for both methodologies, providing that the targeted habitats for both methodologies exist within that same site ("within-protocol" co-visitation). The same segments may also be used for both protocols on a co-location basis, but are unlikely to be co-visited, due to staff and resource limitations.

Protocol	Panel	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Fish Diversity	A 6 Electro-shocking sites	■		■		■		■		■	
	B 6 Seining sites	■		■		■		■		■	
Mussel Diversity	C 6 "always revisited" live sample segments		■		■		■		■		■
	D n (TBD) muskrat midden segments		■		■			■			

be able to see the effects of landscape-scale use and change upon these aquatic ecosystems. Water quality monitoring data are central to any long-term aquatic system monitoring efforts. Rather than developing independent rationales and protocols, the CUPN-MACA will adapt sampling protocols as well as particular monitoring strategies (non-conditional synoptic sampling) from the United States Geological Survey (USGS) National Water Quality Assessment (NAWQA) program.

Water samples are taken regardless of flow and weather conditions, on fixed calendar dates. Sampling locations are either "integrator sites" (locations commonly at tributary confluences or springs which are representative of water quality issues within individual sub-basins) or "indicator sites" (locations downstream from either suspected or documented water quality threats or with pristine conditions). It is recognized that in order to best fit with other CUPN-MACA monitoring activities some flexibility in site selection is likely. This strategy, over the long-term, has proven to yield statistically valid data used to track long-term trends in water quality (Gilliom, et al., 1995).

Long-term monitoring is not designed to respond to catastrophic or singular events that might affect water quality such as a break in a sewer line, for example. Rather, the program is designed to form a comparative database of selected water quality parameters over time, from within an individual park or stream. Parks within a particular ranking category may be cross-comparable, but charting changes in water quality within a particular park is the main statistical use intended for the long-term data. Through an early series of Vital Signs workshops and other planning meetings with park managers, the water quality monitoring program was devised to meet the management objectives of the CUPN parks (Appendix G, Phase I Workshop Results and Appendix B, Conceptual Framework for MACA).

It is not the intention that the details of the CUPN Water Quality Monitoring Program and associated protocols and SOPs be addressed in this chapter. For sake of brevity details describing sampling rationale, schedule, budget, QA/QC, and data management can be found within the following appendices:

The "CUPN Water Quality Monitoring Program" (Appendix E) contains:

- Maps showing the location of each WQ sampling station. As each park is discussed individually, a separate map was prepared for each park. They are found at the end of each park's "Hydrogeological Assessment" section. Sites are also summarized in terms of impairment in a table, same section.
- A list of water quality parameters, both field and laboratory measures can be found in "Monitoring Parameters" section. A more detailed explanation can be found in the "Water Quality Parameters; Field Measures and Laboratory Measures" section.
- A discussion of sampling frequencies can be found in "Monitoring Responsibilities and Logistics" section.
- Personnel and sampling duties can be found in "Sampling Program" section.
- Sampling design and rationale are found in two sections, "General Discussion and Conceptual Plan" and "Sampling Design".

The "Water Quality Monitoring Protocol, Cumberland Piedmont Network" (Appendix S) contains additional elements of Section 4.6. This document contains:

- A complete discussion of protocols and associated SOPs.
- A detailed Data Management discussion is found in SOP #6 "Data Management". In combination with the Field and Laboratory QA/QC documents of the "CUPN Water Quality Monitoring Plan" (Appendix E of this document), this SOP assures data quality from the field, through the lab, and ultimately to the annual WQ data roll-up and reporting to individual parks.

Monitoring Objectives

Water resources of the CUPN range from the ancillary unnamed tributaries which harbor no rare or threatened aquatic species, to water bodies that provide an aesthetic backdrop to the park area, to nationally significant waters which are the core natural resources of parks. These waters also vary from pristine mountain springs and streams to urban rivers currently on the USEPA 303d list of impaired waters. Some parks' waters

(MACA, CUGA, and LIRI for example) contain rare or endangered species, provide an important recreational opportunity to the public, and may be mentioned in the park's Enabling legislation. Other parks' (CARL, ABLI for example) waters do not contain significant biological communities, nor are they used recreationally. They do, however, provide an important backdrop, in terms of general aesthetics or interpretation. In addition, the CUPN has several military parks (GUCO, NISI, FODO) where the water resources are not particularly important in terms of biological or recreational significance, nor are they important from a general interpretative standpoint. In short, not all water resources, nor park management objectives are equal in all parks of the CUPN. Therefore, the individual monitoring objectives (including the frequency of sampling and parameter lists) must be tailored to meet the overall park management objectives.

The monitoring objectives, based upon input from each park through Vital Sign Workshops can be stated as follows:

1. Determine if concentrations of selected parameters (key nutrients, bacteria, and key physical characteristics) are changing monotonically over time and estimate rates of change.
2. Provide a water quality benchmark to help compare changes in the aquatic biologic communities.
3. Provide data to determine the basic effects of atmospheric contaminants (acid precipitation).
4. Provide data to determine pollutant sources (non-point source contaminants versus point-sources).
5. Provide data to determine impacts to water quality by in-park activities within selected watersheds.
6. Determine if the park is meeting the designated use water quality requirements.

Sampling Parameters

At this time, each park (with exceptions of CUGA and LIRI which currently operate their own programs)has undergone two years of water-quality sampling. These data serve as a water-quality inventory in which a broad range of parameters (Table 4.7) were analyzed, including:

From this inventory, and examination of existing data a series of water quality reports was

Table 4.7. Water Quality Parameters Included in the Two-Year Inventory Phase.

Bacteria	Fecal Coliform
Nutrients	Ammonium
	Nitrite
	Nitrate
	Phosphate
Major Ions (dissolved)	Sulfate
	Calcium
	Magnesium
	Barium
	Chloride
	Sodium
	Fluoride
Other	Chlorophyll-a
	Atrazine
	Turbidity
	Total Organic Carbon
Sediment	Total Suspended
	Total Fixed
	Total Volatile
Field Measures	pH
	Water Temperature
	Specific Conductance
	Dissolved Oxygen
	Acid Neutralizing Capacity
	Discharge

prepared for each park. Data were interpreted, each parameter above was graphed and results discussed with park lead natural resource managers and or park superintendents. From the review of the water quality inventory a final list of long-term parameters was chosen for each park. For parks not yet sampled under the CUPN Program, LIRI and CUGA, there are active monitoring programs in place and based upon existing data, park managers were able to articulate the list or parameters to be monitored long term.

Field Parameters include the mandated "Core Four" measures, as well as acid neutralizing capacity and discharge. These "Core Four" parameters, mandated for all water quality monitoring programs by the Water Resources Division includes water temperature, specific conductance, pH, and dissolved oxygen. Additional data regarding air temperature, general meteorological conditions, barometric pressure, general estimate of precipitation during the previous week, flow condition, and notes of hydrologic observations will also be recorded at each site visit.

- Water temperature is an important and simple measurement that related to a host of other field and laboratory parameters. Although all in-situ field measurements are temperature-compensated, water temperature is a parameter listed in several designated uses in CUPN waters.

- pH is an inexpensive and key field measurement in nearly every CUPN waterbody. Although our waters do not have acid mine drainage common to Appalachian waters, many Network streams have little buffering capacity and are susceptible to decreased pH due to acid precipitation.

- Specific conductivity (spC) is reflective of the ionic strength (concentration) of the water. Two years of water quality inventory have

Table 4.8. Water Quality Parameters, by Park, to be Included in the Long-Term Program.

Park	Temp	pH	SPC	DO	ANC	Q	Bacti*	$N0_3$	$P0_4$	SO_4	Atra	Turb
ABLI	■	■	■	■		■	■	■				
CARL	■	■	■	■	■	■	■					
CHCH	■	■	■	■	■	■	■					
COWP	■	■	■	■	■	■	■					
CUGA	■	■	■	■	■	■	■					■
FODO	■	■	■	■		■	■					
GUCO	■	■	■	■	■	■	■					
KIMO	■	■	■	■	■	■	■					
MACA	■	■	■	■		■	■	■	■	■	■	■
LIRI	■	■	■	■	■	■	■	■	■	■	■	■
NISI	■	■	■	■	■	■	■					
RUCA	■	■	■	■		■	■	■				
SHIL	■	■	■	■	■	■	■					
STRI	■	■	■	■		■	■	■				

**Bacteria includes both* E. coli *and total coliform.*

Table 4.8a. Additional Water Quality Parameters Proposed to be Addressed by MACA During Its Rounds of Monthly Non-Conditional Synoptic Sampling.

TSS	Phyto-plankton	K	TOC	NH^4	CA	NA	MG	Li	Chloride	Fluoride	Barium
■	■	■	■	■	■	■	■	■	■	■	■

demonstrated that many CUPN waters have very low spC as they are recharged by silisiclastic or granitic strata and carry very low dissolved ionic loads.

- Dissolved Oxygen is again an inexpensive and easy field measure that is reflected in every designated use category of park waters. Dissolved oxygen is of course vital to aerobic aquatic life. Depressed oxygen levels may be an indicator of eutrophic conditions.

- Barometric Pressure is recorded prior to taking dissolved oxygen measurements. Barometric pressure, in this case, is absolute pressure – taking into account site elevation – and is used to calibrate the dissolved oxygen meter at each site visit.

- Acid Neutralizing Capacity (ANC), similar to alkalinity except the sample is not filtered prior to analysis, is important to monitor as an indicator of a stream's ability to buffer additional acid loads. The two-year inventory has shown that many CUPN waters have very low ANC values, low enough that a revised protocol (Appendix S) was developed to accurately measure bicarbonate concentrations.

- *E. coli* and total coliform are indicator bacteria for the presence of animal wastes, including human. During the two-year inventory we used fecal coliform as a bacterial indicator, but for better reproducibility, ease of analysis, and concordance with new state regulations we have decided to switch to *E. coli* and total coliform MPN tests (Appendix S).

- Discharge (Q) is determined by stream velocity profiles at wadable streams and estimated (flow conditions) for non-wadeable streams. Discharge can be of great interpretative importance in determining potential sources (point or non-point) of contaminants by calculating flow-weighted values, and mass-flux (loading) analysis.

- Nitrate is considered the limiting nutrient for streams of the CUPN. The two-year inventory showed cause to include nitrate at ABLI, RUCA, and STRI where nitrate levels approach state designated use limits. Previous water quality monitoring at LIRI have also shown high levels of nitrate at that park.

- Phosphate and sulfate has been shown to be of occasional high values at LIRI, and will be included in the long-term. Review of existing data and the two-year inventory did not show that phosphate and sulfate was an issue at other CUPN parks.

- Atrazine, one of the most commonly applied herbicides in the country (a member of the triazine-class of broad-leaf herbicides) have been found in the waters of LIRI. The two-year inventory effort did not indicate atrazine to be present above detection limits in the other CUPN parks.

- Turbidity has long been a key monitoring parameter at CUGA and LIRI and will be continued at those parks. The two-year inventory showed predictable increases in turbidity during high flow events. It is possible that in the future that turbidity will be added to all CUPN parks, providing an acceptable field turbidity protocol can be adapted.

Recommended Sampling Sites

Several criteria were used in choosing sampling sites.

- The site's utility as an "integrator site" – located at the downstream end of a stream, spring, or tributary which are of interest because of presence or absence of significant sources of pollutants within their watersheds.

- The presence of significant aquatic resources in a stream segment, where water quality trend information is needed to corroborate biological trends, or to provide park managers an early warning of potential problems.

- The management interest of a particular site, be it either legislative (protection status mandated by park legislation or management plans) or regulatory (placement on non-attainment (303d) list.

- The presence of existing water quality data at a given site. While most sites in the CUPN have not been sampled prior to this program, some have. An existing water quality record adds to the utility of establishing long term trends if reoccupied in this program.

- The accessibility of the site. Since each park will be sampled synoptically during a single day, sites must be chosen that allow easy and quick access during all flow conditions.

- The ability to safely access a sampling site. Since many water samplers will be alone, sites must be accessed safely in all conditions.

It is not possible to describe each of the nearly 100 sampling sites in this chapter. A complete description of each site, as well as the rationale for inclusion is found in Appendix E "Water Quality Monitoring Program for the CUPN-MACA".

Developed primarily from protocols of the USGS NAWQA, the CUPN-MACA Water Quality Program is designed to provide an integrated assessment of the spatial distribution of general water-quality conditions in relation to hydrologic conditions and major sources. The fixed monthly, bi-monthly, or quarterly (based upon Water Resources Ranking) sampling schedule provides comparative statistics for the selected sites and parameters under variable flow conditions.

The USGS NAWQA program rationale will serve as the foundation for the CUPN-MACA water quality monitoring efforts. There will be, due to matters of budget, logistics, and relevance, modifications to the NAWQA sampling schedule. These matters are discussed later in the CUPN-MACA Water Quality Monitoring Program, Appendix E.

Through dialogue at Vital Signs Workshops, conversations with park resource managers and superintendents, and hydrological assessments, a list a candidate sites was made and then ranked. The lower cut-off was made to include only the highest priority sites in any given park that can be sampled during one day. Furthermore, rather than subdividing sites into groupings, individual parks were ranked on the relative importance of their water resources.

During the summer of 2001, MACA hydrologist Joe Meiman visited each CUPN park to conduct hydrogeologic assessments. A major objective of the assessments was, through dialogue with park managers, to compile a list of potential monitoring sites. Sites were chosen based upon management needs (recreational use for example), biological reasons (occurrence of listed species), and to align, if possible, for future co-location with sites for aquatic biological monitoring. In nearly every case, sites were chosen by the NAWQA rationale, to reflect integrator locations as defined above. Some parks (SHIL, MACA, LIRI, CUGA) have active programs or a recent history water quality monitoring. In these cases, the sampling sites chosen for this program are the same or a sub-set of past sites.

Parks are ranked in accordance to the significance of their water resources although in light of additional data and park management objectives these rankings may change prior to the final draft of the WQ program. Category One parks will be sampled on a fixed monthly date for two years followed by five "off years" before the cycle starts again. Category Two parks will be sampled once every two months every other year. Category Three parks will be sampled quarterly every other year.

Category One parks– Water resources are central to the park's establishment or mission. High amount of recreational use activities. Contains federally or state listed threatened, endangered or rare aquatic or dependent species. Known exceedences of key water quality standards or 303d listed waters. High probability of water resource damage with little or no information of fundamental elements of hydrogeology or water quality.

CHCH, CUGA, LIRI, MACA, RUCA, SHIL, STRI

Category Two parks– Water resources, although important with respect to general interpretation or aesthetics, are not central to park establishment or mission. Limited or no recreational use. Contains no federally or state listed threatened, endangered or rare aquatic or dependent species.

ABLI, CARL, KIMO

Category Three parks– Water resources not central or perhaps not even mentioned in park establishment or mission. No recreational use. Contains no federally or state listed threatened, endangered or rare aquatic or dependent species. In general, water resources are ancillary in nature and management.

COWP, GUCO, FODO, NISI

MACA is a Prototype Park, and as such, a substantial additional effort will be made to monitor the quality of its waters. MACA, being identified as a Category One park, will participate in monthly non-conditional synoptic sampling under the auspices of the rest of the CUPN program. In addition, as a Prototype park, MACA will take on additional sampling and protocol design/testing during the five year "off period". These efforts will focus on both topical (tem-

Table 4.9. Water Quality Sampling Schedule for CUPN-MACA parks.

One complete cycle, plus one year, is shown.

Park	Freq.	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10
ABLI	BiMo		■		■		■		■
CARL	Qrtly	■		■		■		■	
CHCH	Mntly	■	■						■
COWP	Qrtly	■		■		■		■	
CUGA	Mntly	▲	▲	▲	▲	■	■	▲	▲
FODO	Qrtly		■		■		■		■
GUCO	Qrtly		■		■		■		■
LIRI	Mntly	▲	▲	▲	▲	■	■	▲	▲
KIMO	BiMo	■		■		■		■	
MACA	Mntly	▲	■	■	▲	▲	▲	▲	▲
NISI	Qrtly		■		■		■		■
RUCA	Mntly			■	■				
SHIL	Mntly			■	■				
STRI	Mntly	■	■						■

▲ Additional park-specific water quality monitoring

poral, spatial, and parametric) and flood-pulse (run off) sampling. The CUPN program will cover the analytical costs, like any other CUPN park for the associated parameters listed in Table 4.8 during the normal non-conditional monthly rounds. The cost of any additional parameters (Table 4.8a) will be borne by MACA.

Initial water quality sampling for the CUPN began in late 2002. This primary round, using the same protocol (Appendix S) and sample frequency as will be used throughout the program (Table 4.9), was basically a water quality inventory and protocol testing effort.

Chapter Five
Sampling Protocols

Monitoring protocols are detailed study plans that explain how data are to be collected, managed, analyzed, and reported, and are a key component of quality assurance for natural resource monitoring programs. Protocols are necessary to be certain that changes detected by monitoring actually are occurring in nature and not simply a result of measurements being taken by different people or in slightly different ways. . . . A good monitoring protocol will include extensive testing and evaluation of the effectiveness of the procedures before they are accepted for long-term monitoring. Peer review of protocols and revisions are essential for their credibility. The documentation should include reviewers' comments and authors' responses. (Oakley, et.al, 2003)

5.1 Protocol Development Schedule

On March 22-24, 2004, an interagency program review was held at Mammoth Cave National Park. A five-person review team was appointed by the two agencies to provide recommendations regarding the scientific direction and administrative organization and operation of the prototype and Network monitoring efforts. The review team included the following five members:

- Dr. Steven Fancy (NPS National Monitoring Program Leader)
- Mr. Ron Kerbo (NPS National Cave Management Program Coordinator)
- Mr. Larry West (NPS Regional IM Coordinator, Southeast Region)
- Dr. Paul Geissler (USGS-BRD National Park Monitoring Project Coordinator)
- Dr. Edward Pendleton (USGS-BRD, Aquatic Ecology Branch Chief, Leetown Science Center).

Recommendations from this team included a schedule for development of sampling protocols for the short list of seventeen Vital Signs (Appendix D contains the full list of recommendations). Sampling protocols for the CUPN-MACA monitoring program will follow the NPS-USGS standards published in Oakley et al., 2003. The recommended target completion dates are shown in Table 5.1.

The CUPN-MACA program completed full development of three draft protocols by December 15, 2004. One full protocol for Water Quality Monitoring is included in this report as Appendix S, and was sent along with the other two

Table 5.1 Recommended Schedule for Protocol Development

Allegheny Woodrats	Dec. 15, 2004
Cave Crickets	Dec. 15, 2004
Water Quality	Dec. 15, 2004
Cave Air	Dec. 15, 2005
Cave Aquatic Fauna	Dec. 15, 2005
Cave Beetles	Dec. 15, 2005
Fish Community Diversity	Dec. 15, 2005
Passive Ozone SOP (part of ozone and ozone impacts on plants)	Dec. 15, 2005
Benthic Macroinvertebrates	Dec. 15, 2005

protocols for Woodrats and Crickets for review by the Southeast Regional Office and Southern Appalachian Cooperative Ecosystem Study Unit. Due to information gathered during FY04, two of the 2005 protocols (BMI and Cave Aquatic Fauna) will be moved to the 2006 list.

Network protocols for Invasive Plants, Adjacent Land Cover Change, and Vegetation Communities are also high priority; however, these protocols are currently under development by several other IM Networks, and protocol development work for the CUPN will be done in collaboration with other networks to ensure a cost-effective approach and to promote comparability of data among networks. Other high-priority protocols that will be completed by the Network after 2005 include Rare Plants, Forest Pests, Mussel Diversity, Atmospheric Deposition, and Cave Bats (see Table 5.2 for current schedule).

5.2 Prototype Role in Protocol Development

As discussed in the previous chapter, protocol development often involves a multi-year research effort to determine the appropriate spatial and temporal scale for sampling and to test monitoring procedures before they are implemented for long-term monitoring. To assist with the design and testing phase, the Servicewide IM Program and USGS Status and Trends Program provide higher levels of funding and staffing to the MACA Prototype. MACA has a larger professional staff than other parks in the Network and is providing technical expertise and assistance with protocols needed by other parks in the Network. Thus far, this assistance has been essential for the testing of both the water quality and ozone monitoring sampling designs, and will also apply toward development of future Network-wide protocols, such as forest pests.

5.3 Protocol Development Summaries

For CUPN-MACA, three full protocols were submitted for review in December 2004 and the remaining fourteen Vital Signs are covered by a "placeholder" protocol development summary (PDS). One-to-two page summaries are required for monitoring protocols planned for implementation within the next 3-5 years. The PDS describes why the protocol is needed, the specific issues and questions being addressed, the specific measurable objectives, the proposed methodological approach, and other details. The PDS includes the following material:

- Protocol: [title of the protocol]
- Parks Where Protocol will be Implemented: [names or 4-character codes for the parks where the protocol is likely to be implemented over the next 5 years]
- Justification/Issues being addressed: [a paragraph or two justifying why this protocol needs to be developed]
- Monitoring Questions and Objectives to be Addressed by the Protocol: [specifics if possible]
- Basic Approach: [description of any existing protocols or methods that will be incorporated into the protocol, the basic methodological approach and sampling design]
- Principal Investigators and NPS Lead: [the name and contact information for the Principal Investigators and for whoever in the NPS is responsible for working with the P.I.s to ensure that the protocol meets Network needs.]
- Development Schedule, Budget, and Expected Interim Products: [describe costs, length of time, and interim products (annual reports, sampling designs, etc.) expected]

The PDS files for the seventeen protocols CUPN-MACA will develop and implement monitoring using funding from the Vital Signs or water quality monitoring programs can be found in Appendix R. For all details on checklist related to Water Quality, refer to the protocol in Appendix S.

Table 5.2 CUPN-MACA Monitoring Protocols Planned for Implementation Within the Next 5 Years
(Color-coded by protocol completion date)

	December 2004		December 2005		After 2005		In Collaboration with other Networks and Service-wide NPS
Vital Sign - National Level 3	**Protocol Name**	**Parks**	**Justification**				**Measurable Objectives**
Water Chemistry	Water Quality and Quantity*	CUPN all 14 parks	Water, and water quality, affect and drive terrestrial, aquatic, and cave ecosystems, and, further more, serves to tie the ecosystems together into a functional whole, through vital transport of nutrients, provision of natural habitats, and conveyance and distribution of chemical and physical threats and stressors. Water quality is impacted by a wide range of "point-source" and "non-point-source" contaminants, plus in-stream flow regime alterations related to dams and development of adjacent land-use. Water quality is an issue to park managers throughout the CUPN, although the importance of water resources vary from park to park. For some parks, surface waters support diverse vertebrate and invertebrate fauna, including significant diversities of fishes and fresh-water mussels. Water-borne contaminants and changes in river flow regimes have enormous potential to adversely affect many of these species, including several Federally-listed mussel species. In other parks, groundwater flowing through karst aquifers are very important (nine of the fourteen CUPN parks have karst). These karst aquifers are directly linked to surface waters in the form of recharge, typically via sinkholes and sinking streams. Cave streams support diverse and unique aquatic fauna, like the Federally-listed cave shrimp at MACA, and State-listed species at RUCA. Water quality issues are not unique to CUPN- in fact, water and water quality is a central issue across the NPS, and is the focus of a large and growing monitoring program being pursued at several levels across the region and the country.				1. Perform synoptic, non-conditional water quality sampling using in-place USGS NAWQA standards and appropriate sampling designs. 2. Compare quantitative and qualitative data from the park's water quality monitoring program with data collected in adjacent and regional water quality monitoring programs. 3. Correlations will be drawn between aquatic biomonitoring in concert with water quality monitoring (at the same sites and over the same time period).
Cave Communities	Cave Crickets	MACA	Important attributes that supported monitoring cave cricket populations are that cave crickets: (1) constitute a key nutrient import link from the surface terrestrial ecosystem into the severely nutrient-limited cave ecosystem; (2) directly subsidize three distinct subsurface communities with its eggs and feces and are a driver for these dependent communities; 3) could be effective indicators of ecosystem dynamics, as crickets forage on the surface, and modification and management of cave entrances and/or infrastructure could affect cricket exit/entry at managed caves; and 4) due to high evolutionary convergence, cave crickets (i.e., genera Hadenoecus and Ceuthophilus) are likely excellent indicator species among many/most cave ecosystems and so the protocols developed for the CUPN-MACA program could be adapted for use in other National Park Service cave/karst units across the United States.				1. Determine temporal changes in population structure (i.e., age class and sex ratio) of cave crickets in sets of managed and less-managed on the park. 2. Assess potential effects of management actions (e.g., alteration of cave entrances) on cricket ecology within actively managed caves. Project focus will include assessment of cave-entrance modification effects on cricket exit/entry patterns, management effect on reproduction rate and population structure, and localized impacts on cricket use of ceiling roosts.

Vital Sign - National Level 3	Protocol Name	Parks	Justification	Measurable Objectives
T & E Species and Communities	Allegheny Woodrats	MACA	Key reasons for monitoring Allegheny woodrats at Mammoth Cave National Park (MACA) are that woodrats (1) ranked high in MACA's Vital Signs Prioritization and Selection Process; (2) are considered a "species of concern" by the U.S. Fish and Wildlife Service and occurs on more state endangered and threatened species lists than does any other rodent species in the U.S.; (3) they are important to the nutrient-poor cave ecosystem because they import organic material which supports a specialized cave invertebrate community; (4) are considered good indicators of the condition of the park's surface and cave ecosystems because they respond to changes in resource conditions; and (5) they are relatively common, occurring in many caves in the park.	1. Determine current population structure and cave-use status and long-term trends of Allegheny woodrat populations in "natural" caves on the park. 2. Establish current use-status and determine trends in use of managed caves by Allegheny woodrats on the park. 3. Determine if trends in Allegheny woodrat population status and structure differ between managed and "natural" caves within the park.
Ozone	Ozone Levels and Ozone Impacts	CUPN all 14 parks	Key reasons for monitoring ozone exposure and ozone-impact on Network parks are that (1) ozone is a priority anthropogenic threat to park natural resources across the U.S.A, with significant levels of impact occurring in the southeastern region; (2) many plants native to the region are known to exhibit visible injury to foliage at current ambient ozone levels, and could thus be good indicators of changes in impact levels: (3) many plant species are specifically identified as management objectives on parks, and (4), comparable regional and national data-sets exist that will facilitate placing park-specific ozone exposure and impact into a larger context. Cumulative ozone exposure monitoring will provide baseline information for understanding ozone damage levels measured at the leaf-level, ozone impacts on plant growth and interactions with the environment, and long-term ozone effects that are expressed at plant community and ecosystem levels.	1. Determine the cumulative ozone exposure levels on ozone-impact monitoring sites on MACA and other CUPN parks on a growing-season basis. 2. Determine the correlation between on-park exposure and that measured at nearby off-park monitoring stations. 3. Determine the correlation between ozone exposure being experienced on parks with proximity to potential major ozone sources. 4. Determine the correlation of ozone exposure with park topography and feature elevation on larger parks, such as CUGA and MACA.
Caves/karst Features and Processes	Cave Air Quality	MACA, CUGA, RUCA **	Key reasons for monitoring air conditions in caves are that air conditions are (1) a key driver of biological and geological activity and processes in cave ecosystems; (2) air temperature and relative humidity regimes directly impact historic, cultural, and archeological resources in caves; (3) cave management activities (gates, doors, lighting, in-cave structural modifications) and visitors can directly alter cave air conditions; and (4) efficient techniques for measuring and monitoring cave air parameters are readily-exportable to cave-resource units across the national park system.	1. Develop efficient and exportable/adaptable methods for cross-sectional estimation, modeling and single-instrument monitoring of airflow for a cave cross-section. 2. Determine the status and long-term trends in airflow in cave cross-sections of interest to management. 3. Develop efficient, single-instrument-and estimation model-based methods for monitoring air temperature and relative humidity adjacent to surfaces of interest in a cave room. 4. Determine the status and long-term trends in cave air temperature and relative humidity in selected cave air-spaces.

Vital Sign - National Level 3	Protocol Name	Parks	Justification	Measurable Objectives
Cave Communities	Cave Beetles	MACA	Significant attributes that support monitoring cave beetles include: (1) beetles are a primary cause of cave cricket egg mortality; and are thought to be an important driver of cave cricket population dynamics: (2) cave beetles could serve as a secondary indicator representing a community of cave-dwelling invertebrates they subsidize through their feces (a community that would be very difficult to directly monitor); (3) cave beetle populations and activity patterns are assumed to respond to and so could reflect the effects of management actions on cave entrances and/or infrastructure; and 4) due to high evolutionary convergence, egg predator beetles (e.g., genera Neaphaenops, Darlingtonea, and Rhadine) are likely excellent secondary indicator species among many/most cave ecosystems and so the protocols developed for MACA could be adapted for use in other cave/karst parks across the United States.	1. Estimate relative abundance of cave beetles in relationship to cave entrances (e.g., effect of distance from cave entrance) and over time in sets of managed and non-managed caves at MACA. 2. Determine effects of space and time on beetle population structure (i.e., 2-stage age class, and adult sex ratio) in sets of managed and non-managed caves at MACA.
Fishes	Fish Diversity	MACA, LIRI, SHIL **	Key reasons for monitoring fish diversity are that (1) fish constitute a significant, diverse biological and functional component of the Green River ecosystem, (2) trends in fish diversity may serve as a useful and ecologically broadly-integrated indicator of potential shifts in the condition of the river ecosystem as it responds to anthropogenic actions, and (3) fish play a central role in the reproductive success of the diverse mussel fauna found in the Green River.	1. Establish the current diversity and relative abundance of fish species in upstream fluvial, mid-reach transition, and downstream impounded zones of the Green River, and in the park's reach of the Nolin River. 2. Determine the trend in species diversity and relative abundance over time (years) in the park's reaches of the Green and Nolin Rivers. 3. Determine if trends are the same in all four river zones, or if trends differ among the zones and between the Nolin and Green reaches.
Wet and Dry Deposition	Atmospheric Deposition and Impact on Sensitive Native Plants	MACA	Key reasons for monitoring atmospheric-deposition-impact on MACA are that (1) atmospheric acid-producing pollutants are priority anthropogenic threats to park natural resources across the U.S.A, with significant levels of impact occurring in the southeastern region; (2) many native plant species (including species listed under the Endangered Species Act) are known to be acid-pH-sensitive, and could thus be good indicators of changes in impact levels: (3) impact on acid-pH-sensitive plant species is specifically identified as a management objective on MACA, and (4), comparable regional and national data-sets exist that will facilitate placing park-specific impacts into a larger resource-impact, plant community and ecosystem context.	1. Determine the current NOX and SOX levels, and growing-season trend in these levels, on MACA. 2. Determine soil pH levels trends on atmospheric-deposition-impact monitoring sites on MACA on a growing-season basis. 3. Estimate atmospheric-deposition-induced damage levels in selected acid pH-sensitive native plant species on MACA on an annual basis in selected native stands. 4. Estimate changes and rate-of-change in distribution and abundance of selected acid pH-sensitive plant species on atmospheric-deposition-impact monitoring sites on MACA. 5. Estimate reproductive success via assessment of seed-set and seed viability for acid pH-sensitive native plant species on MACA.

Vital Sign-National Level 3	Protocol Name	Parks	Justification	Measurable Objectives
Aquatic Macro-invertebrates and Algae	Benthic Macro-Invertebrates	MACA LIRI STRI **	Key reasons for monitoring the aquatic benthic macro-invertebrate (BMI) community on MACA and two other CUPN parks (Little River Canyon and Stones River) are that (1) benthic macro-invertebrates area a valuable park resource that collectively represent a significant, diverse biological and functional component of the river ecosystem; (2) trends and shifts in BMI diversity and community structure are documented to be a powerful and ecologically broadly-integrated indicator of changes in water quality and environmental condition in a river ecosystem as it responds to anthropogenic actions; and (3) the winged adult stage of some benthic macro-invertebrate taxa (e.g., stoneflies, caddisflies, and mayflies) constitute a major food resource to bats at MACA. Bats are a fauna of special interest to MACA resource managers because they include species listed under the Endangered Species Act of 1973.	1. Refine and redevelop the "Index of Biological Integrity (IBI)" currently in use in the MACA BMI monitoring protocol to incorporate currently accepted taxon-specific sensitivity scoring and updated standard sampling and analytical practices 2. Determine the trend in BMI IBI value over time (years) in MACA's reach of the Green River 3. Determine if trends are the same in all three river zones, or if trends differ among the zones (in MACA's reach of the Green River).
Insect Pests	Forest Pests	CUPN all 14 parks	Key reasons for monitoring forest pests on MACA and other CUPN parks are that (1) invasive and native insect, fungal and bacterial species pose significant individual and collective threats to park forest tree species across the southeastern region; (2) both specific forest tree species and communities are major focal resources for park management at most CUPN parks; (3) early detection of invasive forest pests offers park managers their best opportunity to develop appropriate conservation responses to these threats, and; (4) park and Network-wide forest pest monitoring can contribute to wide-scale and multi-agency efforts at understanding and combating these important threats to our native resources.	1. Develop or provide early detection of Hemlock Wooly Adelgid invasion and infestation on MACA and other CUPN parks currently thought to be free of this pest. 2. Develop or provide early detection of other invasive forest pests (i.e., Gypsy Moth, Southern Pine Beetle, etc.) into parks currently threatened by these pests infesting on park-adjacent lands. 3. Estimate current infestation levels and distributions of specific forest insect, fungal and bacterial pests on CUPN parks. 4. Determine trends in infestation-level and distribution of specific forest pests on CUPN parks.
Cave Communities	Cave Aquatic Fauna	MACA	Key reasons for monitoring cave aquatic fauna (CAF) diversity at MACA are that (1) CAF constitute a significant, diverse biological and functional component of the cave stream and river ecosystem, (2) the CAF on the park include several endemic species of special interest, including species listed under the Endangered Species Act of 1973, (3) trends and shifts in CAF diversity and relative abundance are a potentially useful and ecologically broadly-integrated indicator of changes in environmental conditions of the cave river ecosystem as it responds to anthropogenic actions, and (4) some species within the CAF, including the Kentucky Cave Shrimp, are potentially threatened by stocking of invasive sport fish into the Green River. The Green River joins into the cave river system via springs, which may permit entrance of invasive predators into the cave river system. A CAF monitoring protocol currently exists and is in limited implementation at MACA. The extant protocol (Pearson, WD & TG. Jones, 1996) will be evaluated and revised, as needed, to meet current methodological, technical, and NPS format standards.	1. Refine and redevelop the "modified Index of Biological Integrity (IBI)" currently in use in the MACA CAF monitoring protocol to incorporate standard sampling and analytical practices. 2. Determine the trend in CAF IBI value over time (years) in the park's cave rivers. 3. Determine if trends are the same in all selected cave river zones, or if trends differ among the zones.

Vital Sign-National Level 3	Protocol Name	Parks	Justification	Measurable Objectives
Freshwater Invertebrates	Mussel Diversity	MACA	Key reasons for monitoring mussel diversity at MACA are that: (1) monitoring mussel diversity in the form of tracking a diversity index (species-richness and relative abundance) will yield important information that can contribute to developing future management actions aimed at river resource management and preservation, (2) information on mussel diversity and general muskrat predation impact data and data on the possible preferential selection of Asiatic Clam by muskrat will contribute to the park's efforts toward conservation of Federally-listed mussel species in the Green River, (3) diversity, abundance and trends data would help identify actual declines in the resource which would mandate development of management actions to mitigate impacts and suggest research to identify and address specific system threats, (4) muskrat predation impact data will contribute to the park's understanding of mussel assemblage dynamics within the Green River, (5) trend information for native populations of selected mussel species could contribute to assessing the operational success of the park's mussel culture facility and re-stocking program for reared T & E mussels into the Green River, (6) trend information could support park efforts to remove Lock & Dam #6 by evaluating differences in mussel diversity among the impounded, transitional, and free-flowing sections of the river within MACA, (7) trend information could contribute to evaluation of the changes in water release schedules and regimes recently implemented by the U.S. Army Corps of Engineers at the Green River Dam, along with possible contribution to assessment of CREP program effects on water quality in the Green River, and (8) muskrat predation impact data will contribute to park management evaluation of management actions, including proposed enhancement of river otter populations on the park.	1. Establish a baseline status and diversity index for mussels in the Green River. 2. Evaluate possible trends in mussel diversity through analysis of annual diversity indices in three zones of the Green River. 3. Compare mussel diversity indices determined for the three zones among sites and over time. 4. Determine the current impact of muskrat predation (as manifest in shell middens) on fresh-water mussel species in upstream fluvial, mid-reach transition, and downstream impounded zones of the Green River. 5. Determine the trend in predation rates over time in the park's reaches of the Green River. 6. Determine if trends in muskrat predation are the same within and among all three river zones over time.
Mammals	Cave Bats	MACA	Key reasons for monitoring cave-roosting bats at Mammoth Cave National Park (MACA) are that cave-roosting bats (1) ranked high in MACA's Vital Signs Prioritization and Selection Process; (2) two species of cave-roosting bats are listed as "endangered" and one species of cave-roosting bats is considered a "species of concern" by the U.S. Fish and Wildlife Service; (3) are important to the nutrient-poor cave ecosystem because they import organic material which supports a specialized cave invertebrate community; and (4) are considered good indicators of the condition of the park's surface and cave ecosystems because they respond to changes in resource conditions.	1. Establish current status and determine trends of summer cave-roosting bat populations (estimates of relative abundance, age class ratios, sex ratios, or other parameters) within selected caves within the park. 2. Determine if trends of summer cave-roosting bat populations (as above in 1.) differ between managed and unmanaged caves within the park. 3. Determine trends of rare/endangered hibernating bat relative abundance in, and usage of, known hibernacula (managed) caves. 4. Determine if a correlation exists between cave temperature and relative humidity trends and rare/endangered hibernating bat relative abundance in, and usage of, known hibernacula.

Vital Sign-National Level 3	Protocol Name	Parks	Justification	Measurable Objectives
T & E Species and Communities	Plant Species of Concern	CARL CHCH COWP FODO KIMO LIRI NISI MACA† STRI	Both threatened and endangered species and poached species are critical resources to several parks. The last known population of Kral's Water Plantain is in the Little River system (USFWS 1991), and the endangered Green Pitcher Plant and Harperella are also found there (LIRI). The Lookout Mountain (CHCH) population of the federally endangered Mountain Skullcap is listed as one of the last ten remaining populations (USFWS 1996). The Tennessee Coneflower population at STRI is one of five remaining (USFWS 1989). The federally threatened Dwarf-Flowered Heartleaf at COWP is one of 14 remaining populations (USFWS 1989) and the Price's Potato Bean (FODO) is one of twenty-five (USFWS 1993). Ginseng and golden seal are both actively poached from several parks each year and the need for law enforcement has increased.	1. Assist park with the evaluation of long-term trends in plant distribution, numbers, and health of Krals Water Plantain, Green Pitcher Plant, and Harperella found at LIRI. 2. Assist park with the evaluation of long-term trends in plant distribution, numbers, and health of Mountain Skullcap found at CHCH. 3. Assist park with the evaluation of long-term trends in plant distribution, numbers, and health of Tennessee Coneflower found at STRI. 4. Assist park with the evaluation of long-term trends in plant distribution, numbers, and health of Dwarf-flowered Heartleaf found at COWP. 5. Assist park with the evaluation of long-term trends in plant distribution, numbers, and health of Price's Potato Bean found at FODO. 6. Assist park with the evaluation of long-term trends in plant distribution, numbers, and health of Ogelthorpe Oak found at NISI. 7. Assist park with the evaluation of long-term trends in plant distribution, numbers, and health of Piedmont Ragwort and Carolina Hemlock found at CARL. 8. Assist park with the evaluation of long-term trends in plant distribution, numbers, and health of Eastern Turkeybeard and Georgia Aster found at KIMO. 9. Determine parks/species that are experiencing declines in populations due to poaching (Ginseng, Goldenseal, Galax, Flame Azalea).
Land Cover and Use	Adjacent Land Use	CUPN all 14 parks	The need to track changes in adjacent landuse are critical to park managers for many reasons, and can be described in four main categories: 1) habitat fragmentation: parks may be experiencing a loss in biodiversity due to changes in habitats outside park boundaries from agricultural and sivicultural practices and road development. Some natural ecosystems in the Southeast already show trends for high losses of habitat, such as longleaf pine forests and wetlands (US EPA Southeastern Ecological Framework 2002); 2) increased pollution sources: parks may be experiencing an increase in water-borne contaminants resulting from chemical spills, roadway and railroad run-off, industrial, urban/residential and agricultural waste and run-offs, and air-borne contaminants from agricultural herbicides and pesticides, industrial stack-emissions, and automotive exhaust gases; 3) increased avenues for invasive pests: disturbed lands, road development and sivicultural practices may be causing an increase of invasive plants and/or forest pests; 4) audio/visual change: some parks are concerned with impaired viewsheds and increased light and noise pollution	1. Determine changes in landuse type and cover for buffer areas surrounding park units. 2. Determine any correlations between changes in adjacent landuse and water quality/air quality. 3. Determine any correlations between changes in adjacent landuse and invasive species impact on park lands. 4. Determine whether changes in adjacent landuse are increasing parks role to function as links in wildlife corridors or as hotspots for biodiversity. 5. Estimate how changing landuse will affect viewsheds, light and noise levels. 6. Work with cultural resources staff to determine how adjacent landuse changes may affect parks' ability to interpret the period of interest.

Vital Sign-National Level 3	Protocol Name	Parks	Justification	Measurable Objectives
Vegetation Complex	Vegetation Communities	CUPN 13 smaller parks	The monitoring of vegetation communities is a combined Vital Sign that captures multiple high-priority interests of CUPN parks. Significant natural communities of interest for this category include: grasslands, riparian areas and wetlands, calcareous glades, granitic domes, various forest types, and clifflines. The preservation of vegetation communities is key to the primary mission of all CUPN parks. For historic parks, strategic battles and home sites were based upon the location of natural communities, such as, open oak woodlands at COWP, the glades at STRI and CHCH, riparian forests of SHIL and FODO, and the domes at CARL. Many parks are restoring these historic landscapes and would like to track community-level changes over time. To serve as a baseline, an ecological classification and vegetation mapping effort is currently underway for all CUPN parks. In addition, there are currently over 250 grid-based plots that were established for plant and vertebrate inventories conducted during 2002-04. The next step is to use these data to determine the highest-priority communities for monitoring each park. These will include those with global, national, state, and park level significance.	1. Using Natural Heritage program methodology, determine the ecological ranks of selected vegetation communities (G3 and higher) and monitor any changes in those ranks over time (all parks). 2. Determine the long-term trend in spatial distribution of selected vegetation communities. (all parks) 3. Determine if glades and domes are maintaining their degree of openness? (6 Parks) 4. Identify invasive plant species spreading into selected natural communities. (all Parks) 5. Determine if forest pests are spreading into selected vegetation communities. (all Parks) 6. Assist fire effects monitoring to determine if prescribed burn goals have been successful to reach a desired future condition. (at least 4 parks are currently burning) 7. Develop baseline for cliffline vegetation communities and monitor changes from climbing activities.
Invasive /Exotic Plants	Invasive Plants	CUPN all 14 parks including MACA†	Invasive pest plants are negatively impacting the native and highly endemic floras of Cumberland Piedmont parks, reducing biological diversity, degrading natural landscapes, and disrupting natural ecological processes at multiple spatial and temporal scales. Ecological impacts of invasive plants include loss of endangered and threatened species, disruption to natural community and successional processes, disruption of native plant and animal associations, and alteration of natural fire regimes. The need to track changes in invasive plant populations is critical to determine the success of invasive plant control, to detect early invasions and predict new invasions before they cause significant impact. In a series of reports (2003-2005), NatureServe has identified invasive plants as the major threat to natural vegetation communities at several parks. Working together with Exotic Plant Management Teams (EPMT), the CUPN will focus on "early detection" monitoring of new exotics for each park.	1. Determine current extent of aggressive invasive plant species within the parks. (EPMT) 2. Determine significance of resources being encroached upon. (EPMT) 3. Determine correlations between changes in adjacent landuse and invasive species impact on park lands. (potential research project) 4. Identify new invasive plants migrating into parks and which ones need to be on a watch list. (CUPN) 5. Monitor changes in glade/forest vegetation as woody invasives such as privet and wisteria are treated/removed. (CUPN-part of veg monitoring) 6. Monitor changes in grassland associated species (vegetation, birds, insects) as non-native grasslands are converted to native warm-season grasses.

*Monitoring of this vital sign will be addressed by at least two SOP's in the extant CUPN-MACA (surface stream/river) Water Quality Protocol.
**Monitoring protocol will be developed and implemented at MACA (only), initially.
†At MACA, protocol for this vital sign will be developed and implemented by MACA-SRM.

Chapter Six
Data Management

This chapter provides an overview of the CUPN-MACA data management program. Data management planning is currently being addressed at three levels of detail (Figure 6.1). First, there are two chapters in this document (Chapters 6 and 7) that provide summary information excerpted from the overall Data Management Plan (DMP) (see Appendix T). The DMP itself contains more detail about the overall data management program. At the third (highest) level of detail, a specific monitoring protocol captures the standard operating procedure (SOP) for the data management of each Vital Sign. This approach ensures the Network has adequately considered and can articulate their data management standards and strategies before data collection begins.

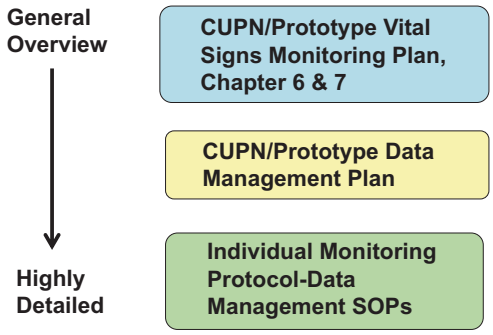


Fig. 6.1 Data management planning/guidance documents.

6.1 Long-term Data Management Goals

Database management planning is an attempt to organize efforts such that the long-term goals of the Inventory and Monitoring program are met. The CUPN-MACA data management program has five main goals:

- Develop a data management process that supports and enhances the inventory and long-term ecological monitoring goals and objectives of the Cumberland Piedmont Network, MACA Prototype, and National I&M Program.
- Ensure long-term integrity and availability of data products produced and/or utilized by the Network and Prototype.
- Facilitate adoption and use of high-quality data management principles, policies and procedures as an integral part of day-to-day Network and Prototype activities.
- Maintain properly trained staff members that understand their roles and responsibilities for data collection, entry, analysis, and reporting.
- Ensure adequate hardware and software resources (tools) for managing data are available.

6.2 Scope of Data

The scope of data management for the CUPN covers the Vital Signs monitoring program, biological inventory data, related natural resource data, and base cartographic layers. Management of these data sources is covered in the Data Management Plan (Appendix T). This chapter and Chapter 7 will highlight a portion of that plan by focusing on data used within the Vital Signs monitoring program.

There are several key ways that Vital Signs data will serve as the measure of success for the monitoring program: 1) Vital Signs data will be used to represent and detect trends in selected indicators of park ecosystems, which will then be used to make statements regarding the status of the overall condition of the ecosystem. The ability of the program to properly interpret and communicate data will drive many park management decisions; 2) Data will also be used as a trigger for manage-

ment actions when abnormal conditions arise. The ability to know the difference between natural variation and abnormal variation, therefore, rely on proper use of the data; 3) Data will track progress toward performance goals and restoration efforts. The parks will at last have a program in place that will help answer many questions related to the Government Performance Results Act (GPRA). To summarize, our ability to properly manage data will be the ultimate test of the monitoring program. If the data fail, our program fails. We, therefore, have made a commitment to develop and follow data management concepts laid forth in the Vital Sign Monitoring Protocols and the attached Data Management Plan (Appendix T).

6.3 Data Management Roles and Responsibilities *(modified NCCN material, portions of which were adapted from the NPS Prairie Cluster Prototype Data Management Plan 2002).*

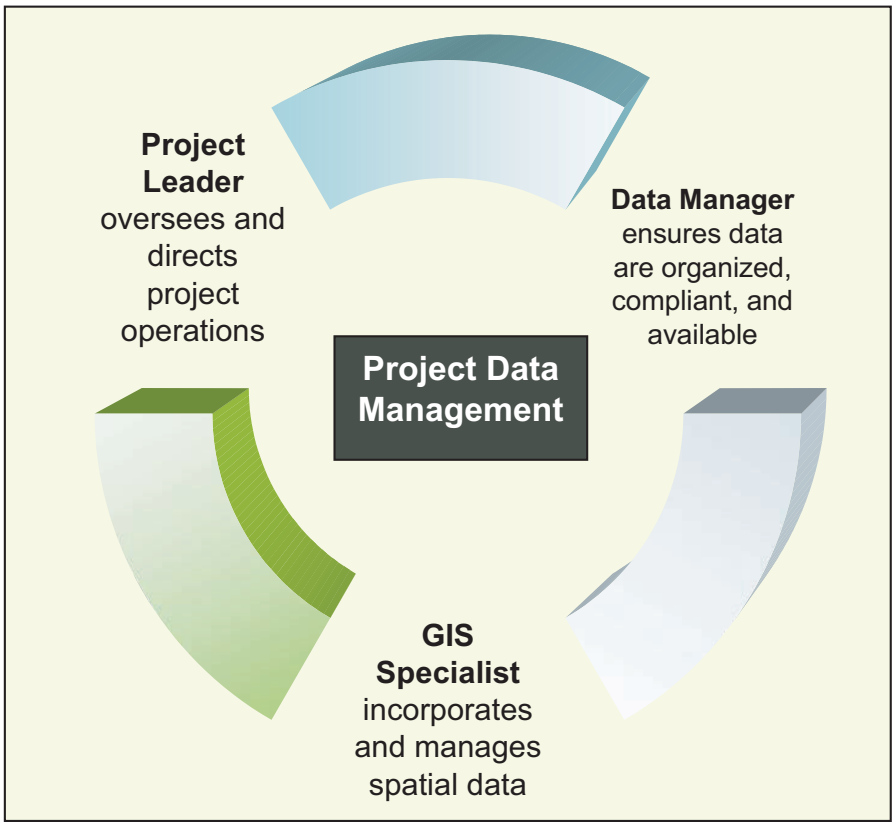
Project leaders, data managers, and GIS specialists comprise the central data management team for inventory and monitoring projects. Each is responsible for certain aspects of project data, and all share responsibility for some overlapping tasks. Because of the collaborative nature of project data management, communication among project leaders, data managers and GIS specialists is essential to meeting program goals. The following section outlines the individual and shared responsibilities of each role. For more details on roles and responsibilities, see Chapter 2 of the DMP.

Project leaders: The project leader is accountable for data quality during all phases of the project, including collecting, entering, handling, reviewing, summarizing, and reporting data. Developing project documentation and metadata are crucial elements of the project leader's role.

Data managers: The data manager is responsible for ensuring the compatibility of project data with program standards, for designing the infrastructure for the project data, and for ensuring long-term data integrity, security, and availability.

GIS specialists: The GIS specialists manage spatial data themes associated with Network inventory and monitoring projects, as well as other spatial data related to the full range of park resources. They also maintain standards for geographic data and are responsible for sharing and disseminating GIS data throughout the Network.

Fig. 6.2 'Core Roles' for effective projectdata management



6.4 Overview of Data Management Process *(modified OLYM material from J.Boetsch)*

A project can be divided into five primary stages: planning and approval; design and testing; implementation; product integration; evaluation and closure (Figure 6.3). Each stage is characterized by a particular set of activities that are carried out by various people involved in the project.

I. Planning and Approval is where many of the preliminary decisions are made regarding data scope and objectives. Existing data sources should be reviewed at this point.

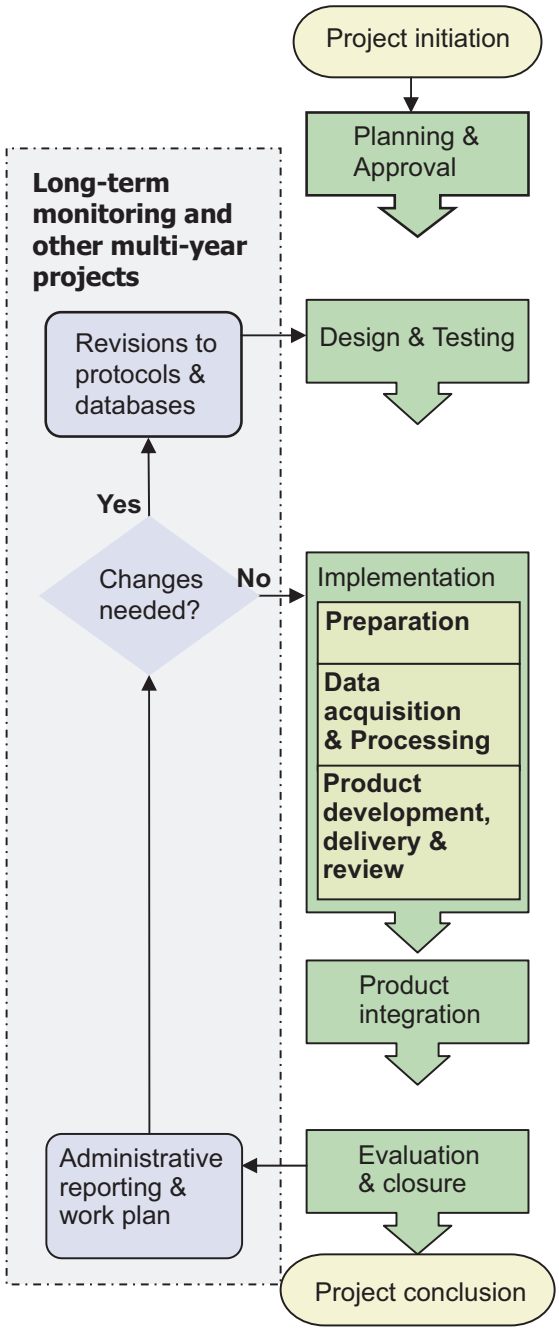
II. Design and testing is where the details are worked out regarding how data will be acquired, processed, analyzed, reported and made available to others.

III. Implementation is where data are acquired, processed, error-checked and documented. This is also when products such as reports, maps, GIS themes, and other products are developed and delivered.

IV. Product Integration is where data products and other deliverables are integrated into national and network databases, metadata records are finalized and posted in clearinghouses, and products are distributed or otherwise made available to its intended audience.

V. Evaluation and Closure After products are catalogued and made available, program administrators, project managers, and data managers should work together to assess how well the project met its objectives, and to determine what might be done to improve various aspects of the methodology, implementation, and formats of the resulting information.

Figure 6.3 Conceptual model of project work flow



Examples of activies done during each phase
(core data management activities in **bold**)

- background review of related existing information
- identify measurable objectives and target population
- proposal, budget, solicit and secure funding
- permits, compliance*
- develop study plan
- identify project deliverables
- contracts/agreements

- develop methodology and/or adapt existing methods”
- **define SOPs, procedures, and guidelines**
- **create/revise data sheets and data dictionaries**
- **data structure design and modifications**
- database system construction
- **preliminary pilot work**
- **initiate metadata development**
- Identify destinations for deliverables
- peer review

- logistics planning, hiring, contracting, training
- installation of equipment and monitoring plots
- equipment purchasing and maintenance

- **data collection, acquisition of external data sets**
- **data entry, data processing, quality assurance, validation, certiication**

- **summarization and analysis, map production**
- **interpretation and reporting – annual reports, trend analysis, technical reports, final reports**
- **metadata development**
- **product review, revision of products not meeting requirements**

- **finalize and post metadata and data products**
- **catalogue products**
- **integrate project data with national databases**
- **archival and records management**
- **distribution of products to intended audience**

- evaluate how well this project met its objectives, and what modifications need to be made to methods, procedures, data design,etc.
- **sign off – project requirements have been met, deliverables are complete and avaiable.**

* *Determination of permit and compliance requirements often requires detailed knowledge of project methods, which are often not fully developed until after the planning and approval stage; therefore, methods development and compliance is an iterative process.*

For more detailed information on the data management process, see Chapter 3 of the DMP.

6.5 Key Data Tools for Metadata and Archiving

Data documentation is a critical step toward ensuring that data sets are useable for their intended purposes well into the future. This involves the development of metadata, which can be defined as information about the content, quality, condition and other characteristics of data. Additionally, metadata provide the means to catalog datasets, within intranet and internet systems, thus making their respective datasets available to a broad range of potential data users. Following is a brief description of metadata tools used by CUPN-MACA.

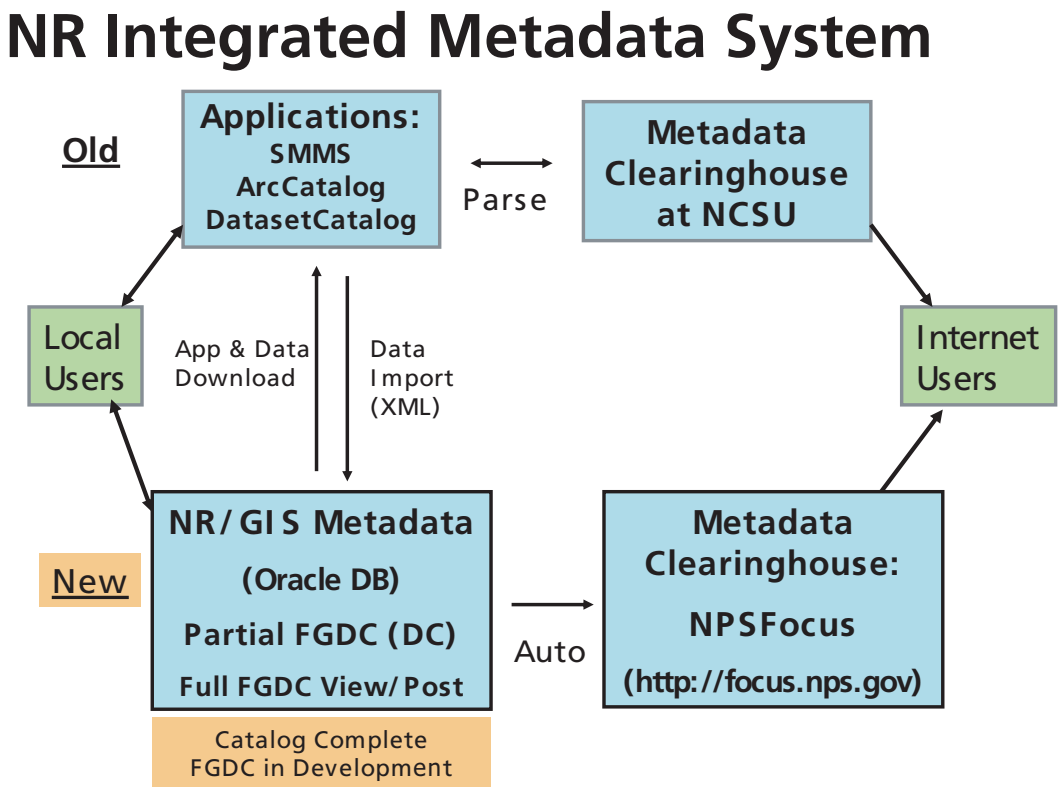
Dataset Catalog: "Dataset Catalog" (http://science.nature.nps.gov/im/apps/datacat/index.htm) is a tool for cataloging abbreviated metadata on geospatial and biological data sets pertaining to park(s) and/or a network. It provides users a means whereby they can inventory, organize, and maintain information about data set holdings locally. While Dataset Catalog is not intended to be an exhaustive metadata listing, it does assist parks and networks in meeting the mandates of EO 12906. With the current version of Dataset Catalog (Version 3), records can be exported in Extensible Markup Language (XML) and used to complete metadata compliant with the Federal Geographic Data Committee (FGDC) standard. The IM Program recommends that all relevant datasets at IM parks and networks be cataloged in at least simple Dataset Catalog format. The CUPN-MACA Monitoring program plan will begin using the new version of Dataset Catalog in 2005-06.

Spatial Metadata Management System: "SMMS" (http://imgs.intergraph.com/ssms/) is a tool with the capability to create, edit, view, and publish metadata that is compliant with FGDC requirements. SMMS uses an MS Access database structure combined with an advanced FGDC-compliant metadata editor. The software allows selection of views depending on whether the user wants the full standard, biological, or the minimal compliant view of Sections 1 and 7. There is on-line Help to describe the purpose, usage or mandatory status of metadata elements. The context-sensitive help file provides the FGDC definition for each field on the screen. In addition to Help files, there are sample metadata records for most sections that provide "real world" examples. The NPS Integrated Metadata System Plan recommends SMMS for FGDC Biological Profile and other geospatial metadata creation. The CUPN-MACA GIS staff will migrate from SMMS to ArcCatalog in 2005-06.

ArcCatalog: "ArcCatalog" (http://www.esri.com/software/arcgis/arcinfo/index.html) is a management tool for GIS files contained within the ArcGIS Desktop suite of applications. With ArcCatalog, users can browse, manage, create, and organize tabular and GIS data. In addition, ArcCatalog comes with support for several popular metadata standards that allow one to create, edit, and view information about the data. There are editors to enter metadata, a storage schema, and property sheets to view the data. With ArcCatalog users can view GIS data holdings, preview geographic information, view and edit metadata, work with tables, and define the schema structure for GIS data layers. Metadata within ArcCatalog is stored exclusively as Extensible Markup Language (XML) files. The NPS Integrated Metadata System Plan recommends ArcCatalog for gathering GIS-integrated geospatial metadata. An optional, but highly recommended extension for ArcCatalog is the "NPS Metadata ArcCatalog Extension" (http://science.nature.nps.gov/im/units/mwr/gis/metadata/metadata_tools.htm) developed by NPS Midwest Region GIS Technical Support Center. The extension fixes several ArcGIS 8 metadata errors and provides added functionality for NPS users. Development is also underway to provide Biological Profile editing capability and NPS Profile support. The CUPN-MACA GIS staff will begin using ArcCatalog for metadata in 2005-06.

Until recently many NPS data stewards collected, parsed, and stored metadata (and GIS data sets) in the NPS GIS Clearinghouse managed by North Carolina State University (NCSU) (Fig. 6.4). However, efforts are currently underway at the servicewide level, to unify and streamline metadata development. This new approach utilizes existing desktop metadata creation applications, as well as an on-line integrated metadata database (NR-GIS Metadata) and a web based data server (NR-GIS Data Server). "NR-GIS Metadata" and "Data Store" (http://science.nature.nps.gov/nrdata/) will comprise a web-based system to integrate the data dissemination and metadata maintenance functions. It will be possible to update Dataset Catalog records in the NR-GIS Metadata database or in the source

Fig. 6.4 NR Integrated Metadata System



Adapted from I & M Data Management Workshop, March 2004

desktop application (i.e., ArcCatalog, Dataset Catalog, and SMMS). Non-sensitive NR-GIS Metadata records are automatically posted to "NPS Focus" (http://focus.nps.gov/). The evolution of metadata tools and clearinghouses is shown in Figure 6.4. The parsing process ensures that metadata are compliant with FGDC format standards, and Oracle is the online database management system. For more detailed information on data documentation, see Chapter 7 of the DMP.

6.6 Data Quality

Data quality is achieved by planning effective sampling designs, field methods, data entry programs, data version control procedures, and appropriate training for each person involved in the project. Planning quality into the data to prevent errors is quality assurance (QA). Inspecting or appraising the quality of data after it has been produced is quality control (QC). Both QA and QC are necessary, but overall data quality will be the highest when emphasis is placed on quality assurance.

Effective quality assurance procedures merge aspects of data verification planning and data validation planning. Data verification is an internal check and is being performed by the field collectors as they carefully record the observations on the field data sheet, the data entry staff as they look twice at the number before tabbing to the next field, and the computer program as it allows only numeric data, for example, to be entered. Validation is an external or third party check of the data. By planning into the process a means for effective validation, problems with the data may be found before they are external failures and become extremely costly. Verification and validation themselves are part of the quality control process.

The importance of planning for quality in data and information before a project begins is critical. Quality assurance methods should be in place at the inception of a project and continue through all project stages to final archiving of the data set. All Network employees from the Network Coordinator to the data entry technicians--not only the data manager--should take pride in data quality. People are the most important factor in the data quality process. Everyone plays a

Table 6.1 Costs of Quality

Cost	Sample Activities	Return on Investment (ROI)
Planning, Preparation	Developing standards, personnel training	Highest ROI
Appraisal, Inspection	Data verification and validation	Modest ROI
Internal Failure	Correcting erroneous data before it leaves its original project data manager	Negative ROI
External Failure	Being notified of erroneous data by a data consumer and correcting that data, paying fines connected with lawsuits, etc.	Extremely Negative ROI (and embarrassing)

part in achieving high quality data products and is responsible for the quality of the results generated from his or her task(s).

At first glance, it may seem that the primary goal of data quality would be to produce accurate data. But when one takes a closer look and remembers the purpose of the data, that of managing natural resources, accuracy becomes a more complex matter consisting of several components. One component of data quality sometimes overlooked is that of reliability. Generally, reliability consists of two quality parameters: 1) the percent of entries that are incorrect, i.e., frequency of errors (normally referred to as mean time between failures, MTBF), and 2) error magnitude (i.e., criticality of errors, or mean time to repair, MTTR). If a two-digit numeric entry is off by a decimal place, the error is significant. If a numeric entry has six significant digits and the sixth digit is off by one, the error is completely insignificant, having an accuracy of up to 99.999 percent. In another case, if a six-digit species number is off by one digit, it represents a different species.

Error significance, therefore, is dependent on the type of data. The overall data accuracy goal should represent a reasonable and attainable level of quality based on the intended use of the data and the potential consequences of making a wrong policy or natural resource decision. Because of this, no global rules can be made as to the required accuracy of data, other than to say that the process for ensuring correct data incorporates all reasonable assurances and practices.

Quality costs! Quality costs time, money, effort, and, in this context, possible poor decision making, if poor quality data are allowed to be disseminated to ecologists and policy makers.

The goal, therefore, is to make the best investment in quality as possible. In general, as with all investments, the earlier the effort is made, the better the return on investment (ROI). Total Quality Management (TQM) as a quality program describes the four costs of quality (listed in descending order of effectiveness) as: planning, appraisal, internal failure, and external failure (Table 6.1). That is, it is much cheaper to plan good quality into a product than it is to recall the product after it has been distributed.

6.7 Data Storage and Archiving

Digital data will be stored in a repository that ensures both security and ready access to the data in perpetuity. As of 2004, CUPN-MACA relies on a 600 GB server with a level-5 RAID (redundant array of independent disks) array for data storage. The server is located in a locked, climate-controlled room. All backups are performed and monitored by MACA IT system administrators. The CUPN-MACA are in the process of purchasing a dedicated tape backup server, with fireproof storage for backup tapes. The new equipment should be operational prior to the end of 2005.

Data will be archived into a standard directory structure with user-access levels appropriate to meet the need for long-term storage, protection, and dissemination of the data. Figure 6.5a illustrates the current directory structure for both active and archived data files. Figure 6.5b GIS folder structure follows the GIS-Theme Manager format.

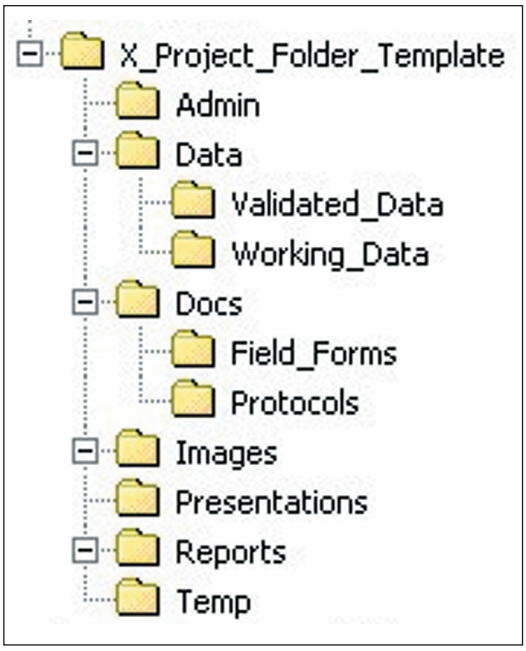


Figure 6.5a Vital Sign folder structure

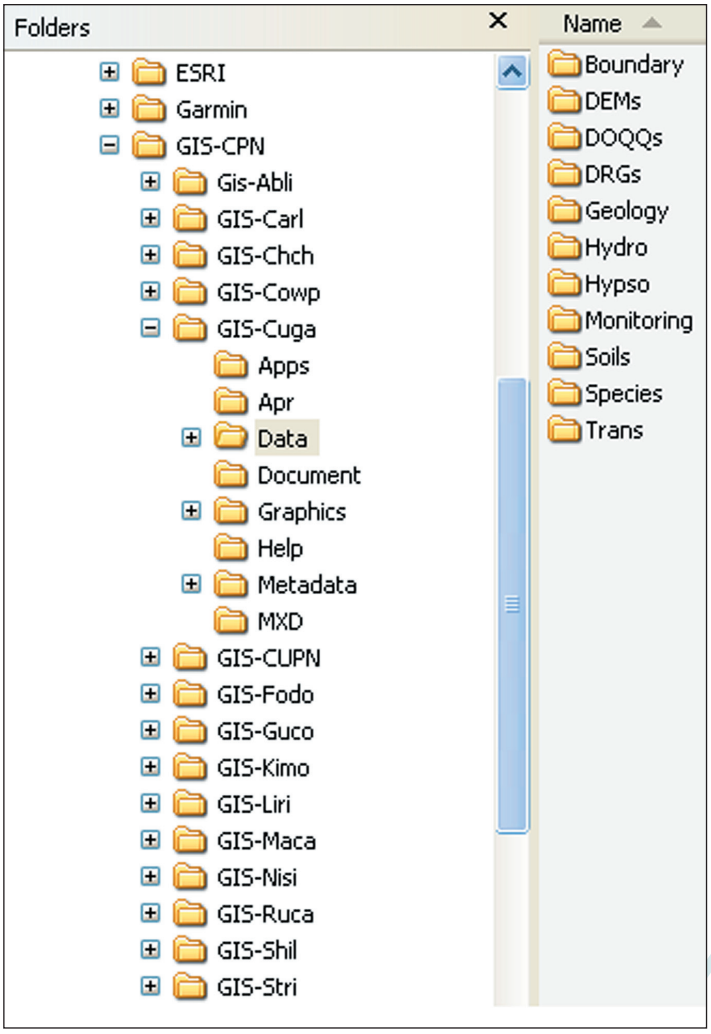


Figure 6.5b GIS Layers folder structure

Chapter Seven
Data Analysis and Reporting

In this chapter, we describe approaches to how data collected by the monitoring program will be analyzed, including who is responsible and how often analysis will occur. We also describe the various reports and other products of the monitoring effort, including the purpose of the report, who the intended audience is, how often they will be produced, who is responsible for these products, and what the review process will be. A monitoring program is essentially an information system; interpreting and communicating derived information and their implications for effective park management to all appropriate audiences is therefore the primary product of the Vital Signs program. The CUPN-MACA data analysis and reporting strategy rests upon providing relevant and reliable ecological monitoring data to park staff regarding resource conditions that enables them to make appropriate management decisions and protect park resources.

7.1 Data Analysis

Selection of specific analytical tools for interpreting monitoring data is a function of monitoring objectives, assumptions regarding the target population, and the level of confidence that is desired or practical given natural and sampling variability. Each monitoring protocol (Chapter 5) will contain detailed information on analytical tools and approaches for data analysis and interpretation, including rationales for a particular approach, advantages and limitations of each procedure, and standard operating procedures (SOPs) for each prescribed analysis.

There will be two main categories of data analysis conducted by the CUPN-MACA Vital Signs monitoring program. The first and only analysis available during the start-up (years 1-5), will be an annual summary. The second type of analysis will be used to detect long-term trends and will become available after multiple years (5-10) of monitoring have been completed. The exception will be in those cases where long-term data sets already exist, such as with the MACA water quality monitoring program and adjacent landuse.

Annual Summary:

Park managers will use the information supplied on an annual basis to report progress towards performance goals. These data also will be used to detect abnormal conditions, where those are well defined, such as when comparing water-quality data to limits defined by state or federal guidelines. The summary analysis for annual reports of Vital Signs monitoring will include descriptive statistics (mean, standard deviation, sample size) for all primary variables included in the project.

Long-Term Trend Analysis:

In addition to the annual summary, the Vital Signs program is engaged in the long-term evaluation of park ecosystems. As a working definition, we define 'long-term' to be five or more years. The methods used to analyze long-term data will vary, depending upon the Vital Sign being monitored. Our Network is currently planning and implementing several analysis techniques to address long-term data analysis for monitoring projects. For example, after two cycles of Water Quality monitoring we are planning to prepare reports using linear regression trend analysis.

Exports to statistical packages and other software

At times, data will need to be exported out of the database to other software applications. The Network is planning to export data from MS Access databases for most statistical analysis beyond the statistical means, standard deviations,

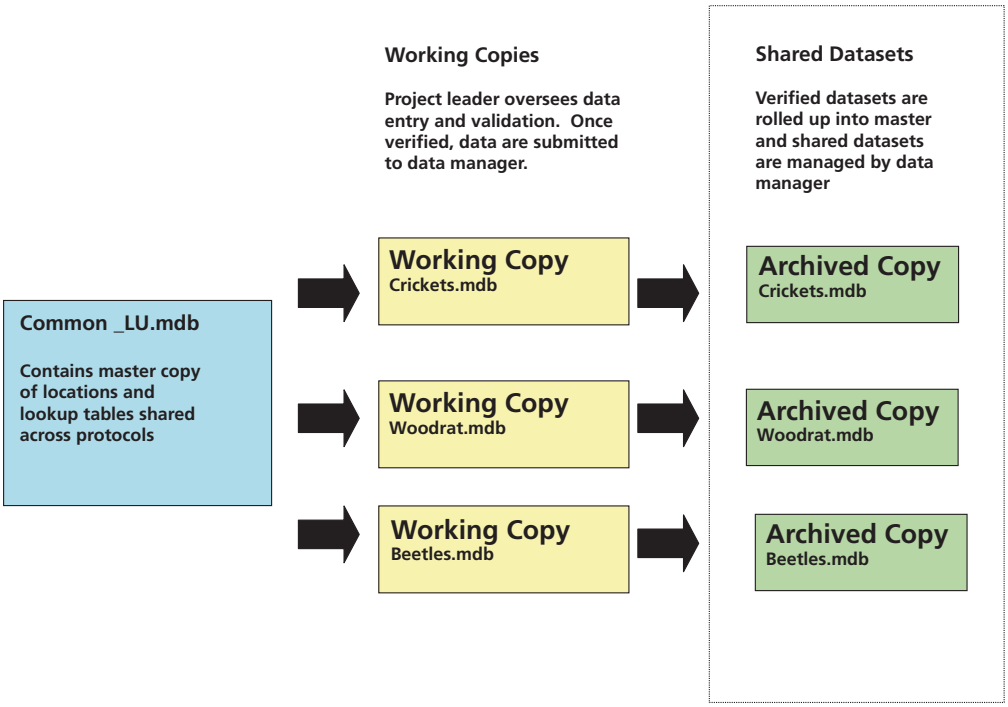


Figure 7.1 Data flow from program databases to shared data sets available to others for further analysis and synthesis.

and other descriptive statistics. The Network will use third party statistical software for frequency distribution plots, tests for normality, and analysis of variance such as SAS, SPSS and SigmaPlot. Other external software requiring data exports will most likely include special application software such as GS+ for geostatistical analysis.

Data managers will work with Project Leaders to ensure that databases are cleaned and compiled yearly to an archived location. This will provide an archival back-up copy of the data, and permit a final copy to be available for analysis and reporting purposes (see Figure 7.1). A review of the data analysis will be performed by a quantitative ecologist or other statistical expert, to ensure the proper interpretation of results is being provided to parks and other users of the data.

7.1.1 Data Analysis Timeline for CUPN-MACA Vital Signs

For each monitoring protocol, there will be an analysis schedule to ensure that data are distributed in a timely manner (Table 7.1). For some Vital Signs with linkage to Performance Management (GPRA) goals, the schedule needs to accommodate the parks' deadlines. Other schedules will be driven by General Management planning, Resource Stewardship planning, etc.

7.2 Data Reporting

Several types of reporting tools will be used to circulate information from the Vital Signs monitoring program. Some information will be distributed as annual reports and long-term trend reports, while others will be internal reports, such as those for quality assurance/quality control. Additional tools such as websites, email, newsletters, and brochures will be used to help distribute this information. Park-level reports will be the main tool for communication with park managers. These annual reports will focus on one park and will include information from multiple Vital Signs. Long-term trend reports will be vital sign-specific, and will include multiple parks. Each report will be designed through coordination between project leaders and data managers (with oversight from the Network/Prototype coordinators), and the design will be tailored to meet the needs of the intended audience. Table 7.2 summarizes the various written reports that CUPN-MACA staff will generate.

Table 7.1 Data Analysis Schedule for CUPN-MACA (color coded by protocol completion date).

December 2004	December 2005	After 2005	In Collaboration with other Networks and Service-wide NPS

Monitoring Protocol	Parks	Annual and Long-Term (5-10 yrs) Trends Analysis	Data Analyst(s)	Target Protocol Date
Cave Crickets	MACA only	Annual and 5 yr Trends	Prototype Entomologist	2004
Allegheny Woodrats	MACA only	Annual and 5 yr Trends	Prototype Coordinator	2004
Water Quality and Quantity	CUPN all 14 parks	Annual and 10 yr Trends	Hydrologist	2004
Ozone (air component)	CUPN all 14 parks	Annual and 5 yr Trends	AQ Specialist	2005
Cave Air Quality	MACA, CUGA, RUCA*	Annual and 3 yr Trends	Prototype Physical Scientist	2005
Cave Beetles	MACA only	Annual and 5 yr Trends	Prototype Entomologist	2005
Fish Diversity	MACA, LIRI, SHIL*	Bi-annual and 5 yr Trends	TBD	2005
Atmospheric Deposition (air component)	MACA only	Annual and 5 yr Trends	AQ Specialist	Ongoing
Atmospheric Deposition (impacts component)	MACA only	Annual and 5 yr Trends	TBD	2006-2007
Benthic Macro-invertebrates	MACA, LIRI, STRI*	Annual and 5 yr Trends	Prototype Entomologist	2006-2007
Forest Pests	CUPN all 14 parks	Annual and 5 yr Trends	TBD	2006-2007
Cave Aquatic Fauna	MACA only	Annual and 6 yr Trends	TBD	2006-2007
Mussel Diversity	MACA only	2-3 yrs and 10 yrs Trends	TBD	2006
Ozone (impact component)	Initial testing by MACA Prototype	Annual and 5 yr Trends	TBD	2006-2007
Cave Bats	MACA only	Annual and 6 yr Trends	Prototype Coordinator	2007
Plant Species of Concern	CUPN 8 smaller parks	Annual and 5 yr Trends	TBD	2006-2007
Adjacent LandUse	CUPN all 14 parks	10+ yrs Trends	GIS Specialists	2006-2007
Vegetation Communities	CUPN 13 smaller parks	5-10 yr and 10 yr Trends	TBD	2006-2007
Invasive Plants	CUPN 13 smaller parks	Annual and 5–10 yrs Trends	TBD	2006-2007

*Monitoring protocol will be developed and implemented at MACA (only), initially.

Table 7.2 Summary of CUPN-MACA Written Reports.

Type of Report	Purpose of Report	Primary Audience	Frequency	Initiator	Review Process
Annual Administrative Report & Work Plan	Account for funds and FTEs expended. Describe objectives, tasks, accomplishments, products of the monitoring effort. Improve communication within park, Network, and region.	Superintendents, technical committee, CUPN-MACA staff, regional coordinators, and Service-wide program managers; Administrative Report used for annual Report to Congress	Annual	Network & Prototype Coordinators	Reviewed and approved by CUPN-MACA Board of Directors, SER Regional Coordinator, and Service-wide Program Manager
Program Review Reports	Document formal review of operations and products – includes the effectiveness of reports and other Network venues in communicating results to all audiences in an appropriated and useful manner, the use of results in management decision making, and the ability to engage external scientists via data sharing or in the design of complementary resource-monitoring studies.	Superintendents, park resource managers, CUPN-MACA staff, Service-wide Program managers, external scientists	5-year intervals	Network & Prototype Coordinators, Ecologists/Scientists, Data Managers/GIS Specialists	Reviewed at regional and national level, CUPN-MACA Board of Directors, Science & Technical Committee
Annual Reports for each park	Document monitoring activities for all Vital Signs monitored during the year. Document the number of samples for each Vital Sign and relative attributes. Document related data management activities (database updates, QA/QC changes). Describe the status of each monitored resource in the park. Document changes in monitoring protocols. Communicate monitoring efforts to resource managers.	Park resource managers, CUPN-MACA staff, external scientists	Annually	Network & Prototype Coordinators, Ecologists/Scientists, Data Managers/GIS Specialists	Reviewed at Network-Prototype level
Summary of Annual Reports for each park	Same as Annual Reports (above), but summarized to highlight key points for non-technical audiences.	Park superintendents, interpreters, general public, partners	Annually	Network & Prototype Coordinators with input from interpreters	Reviewed at Network-Prototype level
Long-term Trend Reports	Describe and interpret trends of individual Vital Signs using a summary of annual reports. Describe and synthesize relationships among Vital Signs that display cross correlation. Highlight resources in need of management action, and recommend types of actions.	Park resource managers, CUPN-MACA staff, external scientists	Every 5-10 years for all Vital Signs	Network & Prototype Coordinators, Ecologists/Scientists	Peer reviewed at the Network-Prototype and regional level

Type of Report	Purpose of Report	Primary Audience	Frequency	Initiator	Review Process
Summary of Long-term Trend Reports	Same as Long-term Reports (above), but summarized to highlight key findings and recommendations for non-technical audiences.	Park superintendents, interpreters, general public, partners	Commensurate with reporting frequency of Long-term Trend Report	Network & Prototype Coordinators with input from interpreters	Reviewed at Network-Prototype level
Scientific journal articles and book chapters	Document and communicate advances in knowledge.	External scientists, park resource managers	Variable	Network & Prototype Coordinators, Ecologists/Scientists, Data Managers/GIS Specialists	Peer reviewed through journal or book editor
Symposia, workshops, and conferences	Review and summarize information on a specific topic or subject area. Receive feed-back from park resource managers. Communicate latest findings to peers. Identify emerging issues and generate new ideas.	Resource managers of NPS and other federal and state agencies, CUPN-MACA staff, external scientists	Variable, opportunities include: George Wright Society, bi-annual meeting of Network park resource contacts, MACA Science Conference, and regional/ national professional meetings.	Network & Prototype Coordinators, Ecologists/Scientists, Data Managers/GIS Specialists	May be peer reviewed through editor if written papers are published
Park/Regional Newsletter Articles	Review and summarize CUPN-MACA activities and findings of general interest. Describe the role and purpose of the Network to non-technical audiences.	Park and regional staff, agency partners and cooperators	Monthly	Rotated among CUPN-MACA staff	Reviewed by Network-Prototype staff and park/ regional staff
Information Highlights for Park/Regional Divisions	Summarize key CUPN-MACA activities and findings of general interest.	Park and regional staff	Variable	Network & Prototype Coordinators, Ecologists/Scientists, Data Managers/GIS Specialists	Reviewed by Network-Prototype staff
Brochures	Overview the Inventory and Vital Signs Monitoring program. Summarize key findings by CUPN-MACA of general interest.	Park superintendents, interpreters, general public, partners	Variable	Network & Prototype Coordinators with input from interpreters and information specialists	Reviewed by Network-Prototype staff and information specialists
Website	Centralized repository of all final reports and protocols - to ensure products are easily accessible in commonly-used electronic formats.	Park superintendents, resource managers, CUPN-MACA staff, service-wide program managers, external scientists, external partners, students, general public	As reports complete review; updated regularly	Network & Prototype Coordinators, Ecologists/Scientists, Data Managers/GIS Specialists	Finalized products will be posted following NPS guidelines

To the extent possible, reports will be automated using the Natural Resource Database Template (MSAccess database). In some cases other database programs may be used, such as NPStoret. The development of automated reporting will greatly facilitate the data distribution workload.

7.3 Water Quality Example of Data Analysis and Reporting

7.3.1 Annual Analysis and Reporting for Water Quality

Water Quality (WQ) data begins with collection of field parameters at designated sampling sites, followed by analysis of collected water samples, as specified by the CUPN-MACA Water Quality Monitoring Plan. On a monthly basis, data will be entered into a Servicewide digital database (NPStoret) at the CUPN office. Once per year, data will be uploaded to WRD, for incorporation into a national level database (EPA Storet). See Figure 7.2 for a data flow diagram.

Each park with active WQ monitoring sites during the previous fiscal year will receive an annual WQ report, sent by the end of October. Data will be filtered from NPStoret for each park and a report will be generated. In addition, to better inform park managers, WQ data will be graphed (parameter versus time) and compared against designated use standards for each water body. Park managers will easily see if their waters are meeting designated use criteria (see Figure 7.3 below). A short narrative about each parameter, including possible contaminant sources and data interpretation, will be provided.

7.3.2 Long-Term Analysis and Reporting for Water Quality

The core of the CUPN-MACA WQ program, like the USGS National Water Quality Assessment program (NAQWA), is based on monthly non-conditional sampling at fixed sites for parks with 'high-priority' water resource issues. Sampling frequency is "on" for two years, followed by five "off" years. Some parks with less extensive priorities are sampled bi-monthly every other year, while others are sampled quarterly every other year. A minimum of seven years is required before a comparison of "high-priority"

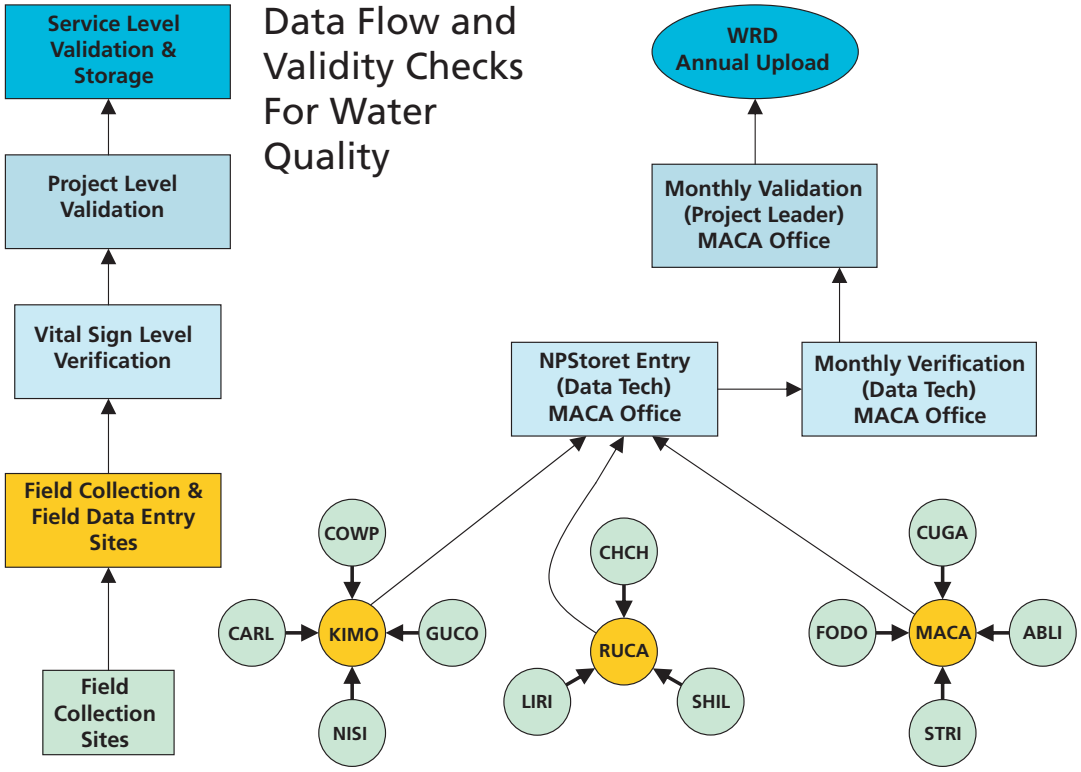


Figure 7.2 Data flow diagram and validity checks for water quality monitoring.

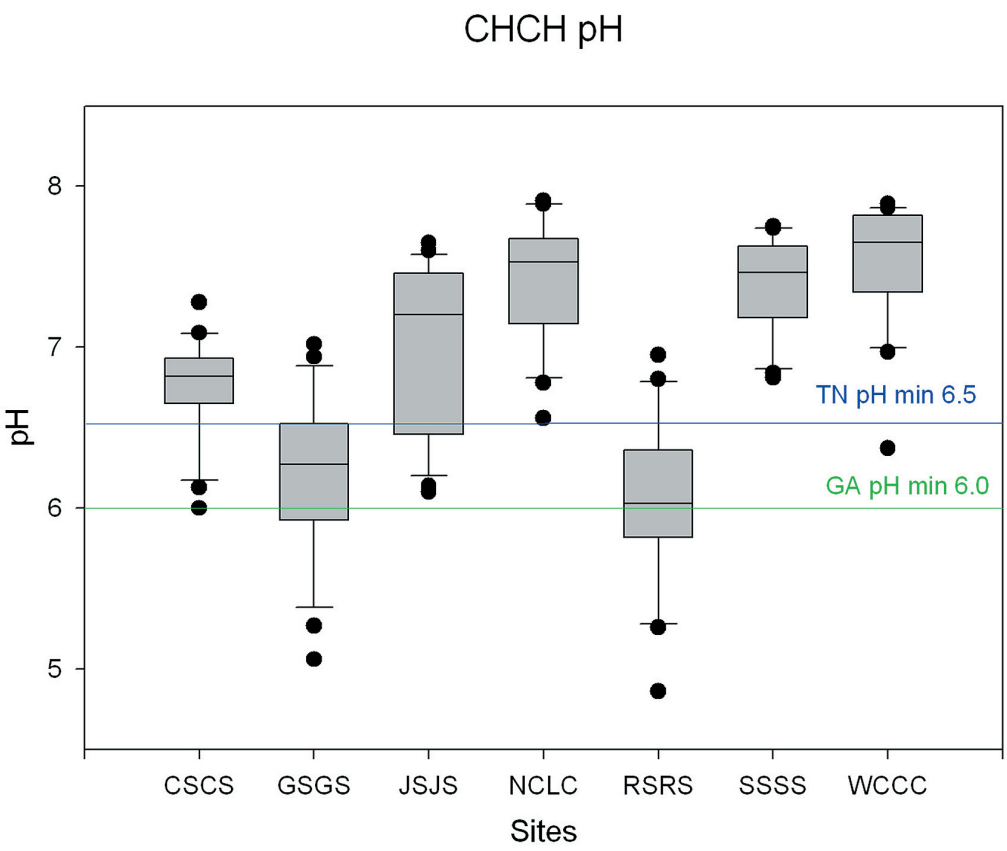


Figure 7.3 An example graphic from a water quality report submitted to Chickamauga and Chattanooga National Military Park showing pH summary for FY2003-04.

park waters can be made. Even after two full rounds of sampling, only simple statistical analysis can be made, as long-term trend analysis will require a minimum of three or four complete rounds. After a substantial amount of data are collected, linear regression trend analysis will be performed on a per-park per-parameter basis. Also, as each park in the CUPN is sampled with the same protocols generating the same parameters, descriptive water quality comparisons will be made across the Network, in a similar fashion to the USGS NAWQA National Synthesis.

Chapter Eight
Administration/Implementation of the Monitoring Program

8.1 Board of Directors and Science and Technical Committee

The Board of Directors (Board) comprises five Network park Superintendents and the Southeast Region (SER) IM Coordinator. One Superintendent is elected to serve as Chairperson for a two-year term. Board members serve for three years. Terms are renewable other than the Chair, which rotates off at least one term. At a minimum, one new board member is added from the remaining parks every two years, at the time a new chairperson is selected, and one sitting member steps down. The SER IM Coordinator is a permanent member of the Board. The SER IM Coordinator and the Chairperson facilitate meetings, and communications between members and the Network parks. The CUPN Coordinator and the Mammoth Cave National Park Prototype Coordinator serve as advisors to the Board.

Board of Directors *(As of July 2005)*

Regional IM Coordinator – *Larry West*

Superintendent Carl Sandburg National Historic Site – *Connie Backlund*

Superintendent Cumberland Gap National Historic Park – *Mark Woods (Chair)*

Superintendent Little River Canyon National Preserve/Russell Cave Natl Monument – *John Bundy*

Superintendent Mammoth Cave National Park – *Vacant*

Superintendent Stones River National Battlefield – *Stuart Johnson*

The Regional IM Coordinator and MACA Superintendent serve as continuing members, and the four other members serve two-year terms rotated among CUPN Superintendents. One standing member becomes Chair and Chair rotates off at least one two-year term.

Responsibilities of the Board:

- The Board of Directors (Board) will promote accountability and effectiveness by reviewing progress toward goals, quality controls, and Network expenditures.
- The Board will collaborate with the Network Coordinator, Science and Technical Committee, and Network parks' natural resource staffs in the overall design and implementation of Vital Signs monitoring and in other management activities related to the Natural Resource Challenge.
- The Board shall contribute to and decide on strategies and procedures for leveraging Network funds and personnel to best accomplish Vital Signs monitoring and other natural resource needs of Network parks.
- The Board consults on hiring of new personnel using funds provided to the Network and from other funds sources. They will seek additional funding from other sources to leverage Network funds provided through the Servicewide program.
- Professional guidance from and partnerships with other individuals and organizations will be solicited by the Board.
- Annually, the Board will review and approve the Network Annual Work Plan and associated budget.

In addition, the MACA-SRM Chief and the MACA Superintendent approve the Prototype annual budget.

Science and Technical Committee

The Science and Technical Committee is comprised of natural resource managers and sci-

entists, including scientists from outside the National Park Service. The Committee includes the CUPN IM Coordinator; Mammoth Cave Prototype Coordinator; park natural resource managers; and a minimum of two scientists with knowledge of sampling procedures, monitoring techniques, and statistical methods that will serve as reviewers to evaluate conceptual designs, monitoring strategies, and ecological relevance of monitoring proposals. Committee membership is approved by the Board. Members serve an indefinite term.

The list of current (as of July 2005) committee members approved by the Board in FY2004 is:

Chief of Natural Resources, Cumberland Gap National Historic Park -Reis Collier

Chief of Natural Resources, Kings Mountain National Military Park – *Chris Revels*

Chief of Natural Resources, Little River Canyon National Preserve – *Mary Shew*

Coordinator, Cumberland Piedmont Network – *Teresa Leibfreid*

Coordinator, Mammoth Cave National Park Prototype – *Steve Thomas*

Coordinator, Southern Appalachian Cooperative Ecosystem Study Unit – *Ray Albright*

Ecologist, United States Geological Survey-Biological Resources Discipline – *Bob Woodman*

Hydrogeologist, Mammoth Cave National Park – *Joe Meiman*

Responsibilities of the Science and Technical Committee:

The Committee will advise the Board and Network parks on the development of the Network monitoring Plan and identification of monitoring objectives by:

- compiling and summarizing existing information about park resources and the findings and recommendations of scoping workshops;
- assisting in the development of a network monitoring strategy;
- assisting in the selection of indicator species communities, and processes for "Vital Signs;"
- evaluating initial sampling designs, methods, and protocols to assure they are scientifically credible;
- participating in the development of the Annual Work Plan and Annual Reports;
- reviewing annual data reports, IM deliverables, and otherwise acting as a peer science review group; and
- developing materials for and facilitating the Five Year Program Review.

Products and recommendations of the Science and Technical Committee will be presented to the Board for discussion, possible modification, and approval. When necessary, the CUPN IM Coordinator may recommend to the Board of Directors the formation of ad hoc specialist groups to accomplish specific studies/tasks. No such group is formed without inclusion of a specific "sunset" provision.

Each year the Science and Technical Committee and the Board will prepare a budget for the Committee including travel, per diem, and other costs associated with the conduct of Committee meetings. Science and Technical Committee costs are summarized in the Network Annual Work Plan.

8.2 Staffing Plan

The CUPN-MACA administrative structure is shown in Figure 8.1, followed by a discussion of staff and associate positions currently employed by the program.

Cumberland Piedmont Network Staff and Associates

The CUPN has its main office located in Mammoth Cave National Park (KY); two satellite offices are located in Kings Mountain National Military Park (SC), and Russell Cave National Monument (AL). The CUPN is jointly administered by the Southeast Regional Office located in Atlanta and MACA in Kentucky.

Cumberland/Piedmont Network Administrative Chart

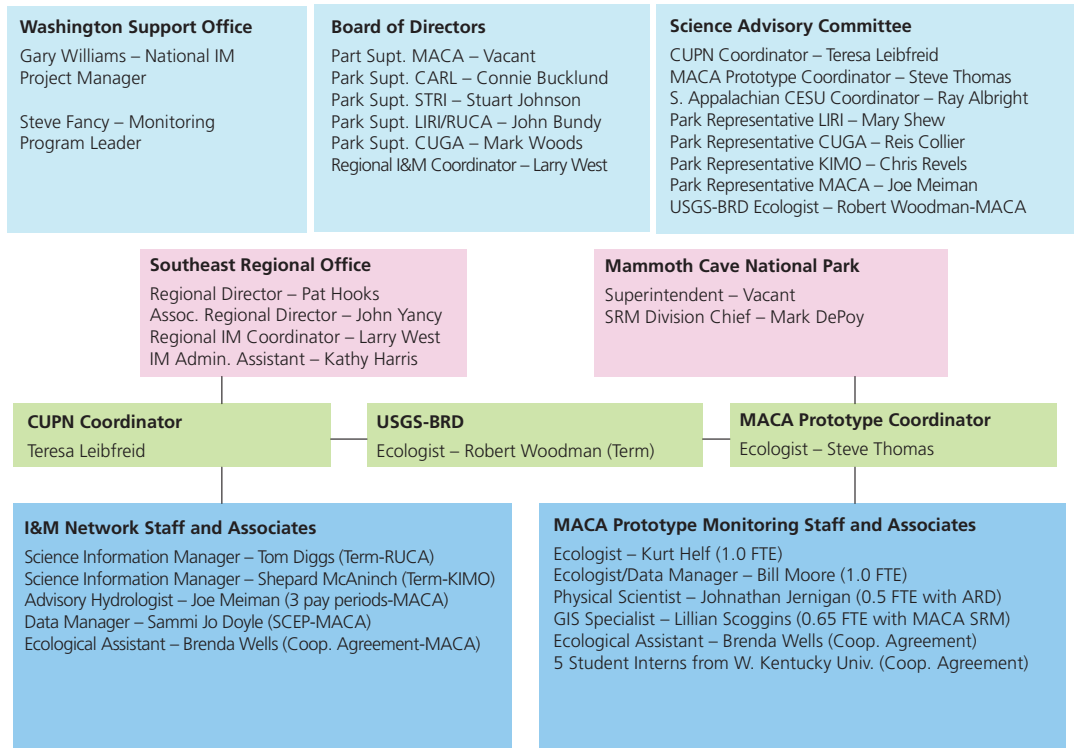


Figure 8.1 CUPN Network Administrative Chart (as of July 2005)

Network Coordinator (1.0 FTE) – The Network Coordinator provides overall leadership, management, and coordination of the Network IM Program, and consults regularly with the SER IM Coordinator, Prototype Coordinator, Science and Technical Committee, and Board to ensure efficient program management. The Coordinator is responsible for maintaining the administrative record of the Network, including project direction and funding. The Coordinator provides leadership in the development and implementation of inventory and monitoring protocols and special studies, and ensures scientifically credible products as programs outcomes. In addition to programmatic oversight, the Coordinator is responsible for staff supervision, budget management, and acts as liaison for IM activities on the 13 smaller parks. This position coordinates with the MACA Prototype Coordinator to develop a combined Vital Signs Monitoring Plan, and Annual Administrative Report and Work Plan. This position also acts as the Government Technical Representative for cooperative agreements related to species inventories (14 parks), vegetation mapping (14 parks), wetlands mapping (10 parks), and curatorial management (13 parks). The Coordinator serves as Chair of the Science and Technical Committee meetings and coordinates Committee business. This position is duty-stationed at Mammoth Cave National Park in Kentucky.

Science Information Specialists (2.0 FTE Terms) – The Science Information Specialists (SIS) coordinate Inventory and Monitoring (IM) activities for a subset of parks in the Cumberland Piedmont Network (CUPN). The job focuses on management of databases and GIS generated by park inventories and long-term monitoring. The SIS also conducts a Water Quality Monitoring program for the parks according to the schedule set forth by the CUPN Water Quality Monitoring Plan. The SIS also acts as the onsite coordinator for field activities related to the IM program. These positions are duty-stationed at Kings Mountain National Military Park in South Carolina (oversight of 5 NC/SC parks) and Russell Cave National Monument in Alabama (oversight of 4 AL/GA/TN parks).

Data Manager (SCEP) – This position manages the NPSpecies database, tracks budget and cooperative agreements databases, assists with monitoring tasks (e.g., ozone) and GIS management. This position is located at Mammoth Cave National Park in Kentucky.

Ecological Assistant (Coop. Agreement-MACA) – The Ecological Assistant catalogs biological specimens into the Automated National Catalog System + database, manages archival materials (data and reports) related to the Network IM program, and is responsible for producing archival quality prints from digital photographs. This position also assists with fieldwork in the Network's Water Quality Monitoring program and with GIS management. This position is shared with the Prototype through a cooperative agreement with WKU and is located at Mammoth Cave National Park in Kentucky.

Advisory Hydrologist (3 pay periods per year) – The Advisory Hydrologist trains and advises WQ field staff to meet goals of the CUPN-MACA Water Quality Monitoring Program, is the lead on WQ Monitoring Plan and Protocols, provides assistance to Network parks on WQ related project statements, performs summary analysis on WQ data. This position is base funded by MACA-SRM and is located at Mammoth Cave National Park in Kentucky.

Quantitative Ecologist-vacant (TBD) – The Quantitative Ecologist will assist the Network with protocol development, statistical review of incoming data, and serves on Science and Technical Committee. This position may be shared through an interagency agreement with USGS-BRD and will be located at Mammoth Cave National Park in Kentucky.

MACA Prototype Monitoring Staff and Associates

These staff members are duty stationed at MACA, but provide technical assistance and support to all parks in the Network. Because of the Prototype's emphases on protocol development and technical support, staff assist with designing and testing monitoring protocols needed by other parks in the Network. In addition to the initial emphasis on protocol development, there is a long-term role for Prototype staff in developing and testing new approaches to data analysis, synthesis, and reporting of monitoring results. Below, existing Prototype staff and associates positions are identified, and their specific responsibilities are listed.

Prototype Coordinator (1.0 FTE) – Programmatic oversight, staff supervision, schedule staff time and tasks, ensure deadlines are met, budget management, co-development (with CUPN Coordinator) of the Network Monitoring Plan and Network Annual Administrative Report/Work Plan, MACA annual summary report for all active Vital Signs monitoring, project leader of two Prototype Vital Signs: woodrat monitoring and cave bat monitoring (duties include: supervision of quality assurance and quality control measures, oversight of field personnel, data collection, data management, analysis, and reporting), vertebrate ecology-related technical assistance to Network parks, and Science and Technical Committee member.

Ecologist/Data Manager (1.0 FTE) – Ensures compatibility of project data with program standards; designs infrastructure for the project data; ensures long-term data integrity, security, and availability; field data collection assistance to various Network Vital Signs monitoring projects; and vertebrate ecology-related technical assistance to other parks in the Network.

Ecologist (1.0 FTE) – Project leader of three Prototype Vital Signs: cave cricket monitoring, cave beetle monitoring, and benthic macroinvertebrate monitoring (duties include: supervision of quality assurance and quality control measures, oversight of field personnel, data collection, data management, laboratory and numerical data analysis, and reporting), and invertebrate ecology-related technical assistance to Network parks.

GIS Specialist (0.65 FTE) – Manage spatial data themes associated with Network inventory and monitoring projects, as well as other spatial data related to the full range of park resources; incorporate spatial data into the GIS; maintain standards for geographic data; responsible for sharing and disseminating GIS data throughout the Network; and co-project leader of adjacent landuse Network Vital Signs monitoring (duties include: supervision of quality assurance and quality control measures, obtain data, data management, data analysis, and reporting); and field data collection assistance to various Network Vital Signs monitoring projects. This position is shared with MACA-SRM.

Physical Scientist (0.5 FTE) – Project leader of cave air quality monitoring (duties include: supervision of quality assurance and quality control measures, oversight of field personnel, data collection, data management, analysis, and reporting), field data collection assistance to various Network Vital Signs monitoring projects,

and mathematical/statistical-related technical assistance to other Prototype monitoring projects and Network parks. This position is shared with MACA-SRM.

Ecological Assistant (Coop. Agreement shared with CUPN) – Catalog biological specimens into the Automated National Catalog System + database, store specimens in the MACA cultural storage area using appropriate museum archival procedures, and archive Prototype monitoring project datasets, photographs, reports and field sheets.

5 Student Interns from Western Kentucky University (Coop. Agreement; costs shared with university) – Provide field, office, and laboratory technician assistance with various Prototype/Network Vital Signs monitoring projects, duties include: collection supplies/equipment preparation and clean-up, data collection, laboratory sample analysis, database development, data entry, and limited data analysis and reporting.

8.3 Integration with Park Operations

To facilitate communication and integration among all parks in the Network, the CUPN has three offices. The central office is co-located with the Prototype at MACA, and two other offices are located at smaller parks in South Carolina and Alabama. The potential for CUPN to provide on-the-ground assistance, attend park meetings, and provide data management support is greatly enhanced by this arrangement. In 2004, Network staff participated in battlefield restoration planning, rare plant surveys, and provided GIS assistance. Network staff also are involved actively in the regional review of many park-level planning documents, such as Fire Management Plans, Cultural Landscape Plans, and General Management Plans. CUPN staff help support field crews (with databases and/or on-the-ground support) for Exotic Plant Management Teams and Fire Effects Monitoring. In 2004 and 2005, park staff worked with CUPN-MACA staff to implement a Network-wide array of passive ozone monitors. Though most park staff are hard-pressed to find extra time, the weekly replacement of ozone filters was something they were able to incorporate into their work schedule. It gave us the opportunity to describe the Vital Signs program to maintenance, interpretation, administration, and law enforcement personnel during the park-by-park training sessions.

The Network also acts as liaison to meet database management and curatorial requirements for other IM projects, such as a recently funded Network-wide aquatic insects inventory. Through the assistance of Mammoth Cave National Park's curatorial program, specimens and data are initially to be routed and stored at MACA. The Network can then provide assistance with data entry into NPSpecies and ANCS+. In addition to the Annual Work Plan and Accomplishments Report, the CUPN keeps parks informed of IM activities by entering Investigator's Annual Reports (using the NPS online research permit system) and by providing trip reports for field activities such as monthly WQ monitoring.

At a more detailed level of integration, the Prototype is embedded within the Division of Science and Resources Management (SRM) at MACA. Integration with other park operations involves a variety of avenues. Two-way communication with staff from such operations as resource management, administration, interpretation, law enforcement, and facilities management is critical. Information from the Prototype to and from these other entities flows via annual reports, monthly reports, monthly all-park staff meetings, quarterly articles in park newsletters, emails, lectures to seasonal interpretive staff, and oral reports of resource protection or facility maintenance needs. In addition to communication, technical assistance will be provided to other park operations staff to promote integration. At MACA, for example, the Prototype's GIS specialist assists the law enforcement division with production of maps for the prescribed fire program and assists with conducting the actual burns. This GIS specialist also, periodically provides maps and related support to facilities management division staff. The Prototype coordinator and ecologist/data manager provide technical assistance to facilities management division staff by assessing trees slated for removal for potential as endangered bat habitat. Prototype ecologists assist the MACA interpretive division with public education talks, and law enforcement/facilities management with occasional nuisance wildlife control. The MACA Prototype staff are currently integrated with the SRM staff and frequently assist each other with various tasks. For example, the SRM air resource specialist provides technical assistance to the CUPN-MACA program for ozone monitoring. While the Prototype coordi-

nator and ecologist/data manager conduct annual breeding bird surveys for the SRM.

8.4 Partnerships

Some Key Partners

U.S. Geological Survey/Biological Resources Discipline – Provides technical scientific and financial support to the Prototype and Network for programmatic and protocol development through its USGS Status and Trends program. The Prototype anticipates receiving four years (mid FY 2002 – mid FY 2006) of direct assistance from the USGS/BRD in the form of a term Ecologist stationed at MACA, associated support funds, and funding for development of specific monitoring protocols. During FY 2004/05 the Prototype received technical assistance from another USGS/BRD scientist, Dr. Craig Snyder (stationed at Leetown Science Center, WV), to help with sampling design testing for the fish diversity monitoring protocol. After FY 2006, the Prototype and other parks in the Network may be able to obtain additional funding from the USGS through a competitive process currently being developed.

Western Kentucky University (WKU) – (1) The Prototype has entered into a cooperative agreement with the university to provide five student interns (one from Chemistry Department, one from Geology/Geography, one from Computer Science, and two from Biology) who each work up to 20 hours per week during the school year and 40 hours per week during the summer doing field, office, and laboratory technician work. The Prototype pays half of the students' salaries and the university pays the other half. The overhead costs on all agreements with WKU are also shared (10% NPS, 12% WKU). (2) A second cooperative agreement, cost-shared between the Prototype (35%) and the Network (65%), provides the services of a full-time ecological assistant to catalog and store collected biological specimens and Vital Signs monitoring project datasets, photographs, reports and field sheets. The rest of the Network also assigns some GIS and WQ data management and field duties to this individual. (3) To help cover data management activities, the CUPN has a SCEP position with WKU to provide a full-time data manager. (4) The Water Quality Laboratory for the CUPN-MACA Monitoring program went through a major reorganization in FY 2004. Previously housed at MACA, a cooperative agreement was formed between the park and the university to combine the staff and equipment to increase productivity through increased staffing and student support, as well as expand analytical capabilities. Through the cooperative agreement, the WQ laboratory has purchased an atomic absorption spectrometer and become certified for microbiological analysis. (5) For FY 2004/05, the Prototype contracted with the university to provide technical expertise (Dr. Phillip Lienesch, Ichthyologist) with testing methods for fish sampling as part of development of the fish diversity monitoring protocol.

NatureServe – In FY2002, a cooperative agreement was entered between NatureServe and two IM Networks (APHN and CUPN). The scope-of-work includes establishment of field plots, development of vegetation classification keys, and inventory of vascular plants. This project provides fundamental information to describe and classify existing vegetation communities, and will serve as a baseline for the monitoring of selected vegetation communities, such as granitic domes and cedar glades.

NPS-Air Resources Division – In FY 2004, the CUPN-MACA Monitoring program collaborated with Dr. John Ray (NPS-ARD, Denver, CO) to develop and test a passive ozone monitoring array across all 14 Network parks. Sample analyses and report analyses were coordinated through Dr. Ray. This arrangement is continuing through a second round of testing in FY 2005.

8.5 Support of Field Sampling Done "In House"

8.5.1 Staff Training and/or Previous Experience

Network and Prototype staff include several professional scientists with diverse backgrounds and skills who will be utilized to administer and implement various monitoring protocols by serving as "project leaders" or "co-leaders". For example, the Prototype's invertebrate ecologist, who will likely be project leader for the cave cricket- and cave beetle-monitoring protocols, has conducted surveys of, and research on, these organisms for nearly a decade. The project leader for the woodrat and cave bat protocols

is an ecologist and has conducted woodrat and bat monitoring in and around the park for over seven years. While the MACA hydrologist who is the water quality/quantity monitoring project leader has more than 12 years of water monitoring experience. Limited supplementary training may be required for some project leaders to augment their existing skills but this is not expected to be a regular on-going need once the program is fully operational, except during times of staff turnover.

Field data collection, data entry, and limited data analysis and reporting for each protocol performed "in-house" will be accomplished by a combination of student interns, Student Conservation Association (SCA) interns, volunteers, and other CUPN-MACA Monitoring program staff who are not the project lead, all under the direction of a particular project leader. The various monitoring project leaders will be responsible for properly training these interns, volunteers, and co-workers following procedures outlined in the particular protocol Staff Training SOPs. It is anticipated that most training will be conducted in house.

8.5.2 Dedicated Field Equipment

Due to the Prototype's unique emphasis on development and testing of monitoring protocols, as well as its integration with MACA's relatively well-supported SRM Division, it has acquired or has access to a significant amount of field equipment. Such equipment includes, but is not limited to, 3 four-wheel drive GSA vehicles; 2 boats/trailers with outboard motors purchased in 2003; a boat outfitted with electro-shocking equipment; an air quality station with continuous and integrated fine particulate matter samplers, continuous gaseous pollutants analyzers, integrated acid and mercury deposition samplers, integrated ammonia sampler, and continuous meteorology and fire weather sensors; a Soil Climate Analysis Network station (SCAN); a Climate Reference Station; a visibility camera; 9 sonic anemometers and data loggers, 2 pair of night vision goggles and infrared LED lights, 4 laser levels, four 5.1 megapixel digital cameras, a laptop computer dedicated to field work, 4 hand-held GPS units and 2 backpack units, and >200 woodrat live traps.

The two satellite offices are equipped with water quality monitoring field probes, flow rods, portable incubators, and GPS units. Supplies for water sampling are periodically shipped from the MACA office. In addition, both offices are equipped with hand-held portable computers (Panasonic Toughbooks) and Arcpad to provide field assistance for projects such as the vegetation classification and mapping. The offices have full GIS capabilities (hardware/software) and often provide assistance to Network parks.

8.5.3 Laboratory Work

As mentioned in section 8.4 above, the former MACA-based Water Quality Laboratory has moved to Western Kentucky University and operates under a cooperative agreement between the park and the university. The laboratory contains numerous instruments and equipment, including an atomic absorption spectrometer (AA), an ion chromatograph (IC), a total organic carbon analyzer (TOC), a spectrofluorometer (SPEC), a muffle furnace, several autosamplers, and balances. The lab is certified for microbiological analysis for drinking-water and water analyses. The AA, IC, TOC, and SPEC all are maintained and calibrated through maintenance agreements with the manufacturers. The laboratory has implemented an approved quality assurance/quality control plan. In addition to the Water Quality Lab, MACA has a newly remodeled biological laboratory dedicated to natural resource monitoring. This lab is outfitted with two vented hoods, multiple storage cabinets and countertops, two microscopes with external light sources, two sinks, three desktop computers, and two refrigerators and two freezers.

8.5.4 Safety Considerations

Approved Job Hazard Analyses (JHAs) exist at MACA for most, if not all, activities likely associated with implementation of the proposed monitoring protocols. As an example, three key JHAs are included in Appendix U. A general JHA will be developed to cover safety considerations common to all CUPN-MACA monitoring activities such as weather conditions, communications (e.g., two-way radios, advanced notification of anticipated location and return time, emergency procedures and contacts, etc.)

8.6 Periodic Reviews

The CUPN-MACA Monitoring program will undergo programmatic reviews at approximately 5-year intervals. Periodic program reviews are an essential component of quality assurance for any long-term monitoring program, and are conducted specifically to evaluate and improve the program. Since monitoring protocols are works in progress, the opportunity for augmentation or revision of standard protocols to improve efficiency or effectiveness will occasionally arise. Every protocol will address the revision process in order not to jeopardize the long-term value of data sets or otherwise jeopardize the integrity of the program. However, to ensure that revisions have not had this effect, and that protocols are providing scientifically credible, relevant information that address the high-priority needs of park managers, individual protocols will need periodic review. Each IM-approved and implemented protocol will be peer reviewed roughly every 5 years for protocols that involve annual sampling, and after every 5 sampling periods or every 10 years (whichever comes first) for protocols with more protracted sampling schedules (e.g., adjacent landuse, certain vegetation communities). Before beginning any work on developing a new protocol (not in this monitoring plan), a study plan will be written and will undergo peer review. A draft of the new protocol will also undergo peer review and will require IM-approval before implementation.

Chapter Nine
Sampling Schedule

9.1 Sampling Schedule

The current Network-wide sampling schedule (Table 9.1) is a composite of the known and anticipated sampling schedules for monitoring protocols in place or yet to be developed. Each protocol schedule includes a project-specific sampling schedule that identifies appropriate sampling periods or seasons, within-season sampling frequency, and longer-term sampling cycles, if applicable. Sampling scheduling and frequency are based upon the vital sign-specific sampling design(s), as well as Network-level planning for efficient distribution of available sampling resources among many protocols, across fourteen parks, over time. The Network schedule must consider both temporal aspects and constraints in specific sampling efforts allocated to each project. Sampling schedules will also reflect understanding of the best or most-reasonable interval at which to sample a given resource.

For example, ozone exposure monitoring should be performed across growing seasons, and because ozone levels (and the source emitters) change over multiple temporal scales (from hours to among years), should be monitored every year. Scheduling of ozone impact assessment (sampling visible plant damage) will consider that such damage is slowly accumulated over growing seasons, and is thus best assessed later in a season. Other Vital Signs, such as the measurement of encroachment by woody edge species into glade communities, may be effectively monitored on a once-per-5-year cycle.

As summarized in the Water Quality Monitoring Protocol (Appendix S), sampling effort will be effectively rotated among parks in a schedule where parks will be monitored monthly, two out of every seven years, or bi-monthly/quarterly every other year, depending on resource significance and management issues. This design will allow reasonably intense sampling for two-year periods at each park, yet will distribute limited sampling resources so that all fourteen CUPN parks get some sampling within a seven year period.

The overall schedule takes into consideration the fact that different Vital Signs may be effectively monitored at different sampling frequencies, and with different intervals and rotation across years. Ideally, the overall schedule will effectively shuffle and distribute project schedules to efficiently and effectively utilize available sampling resources in each year. Vital sign-specific schedules and frequencies will be detailed in each protocol being developed for the Network.

Table 9.1 Network Sampling Schedule (color coded by target completion date of protocol)

December 2004	December 2005	After 2005	In Collaboration with other Networks and Service-wide NPS

Monitoring Protocol	Parks	Sampling Season	Sampling Frequency	Target Completion Date	Related Tasks
Cave Crickets	MACA only	Year-round	Bi-monthly sampling across 12 caves per run	2004	
Allegheny Woodrats	MACA only	Spring and/or Fall, managed caves year-round	Cross-park. One or two sampling runs per year. Managed caves bi-monthly	2004	
Water Quality and Quantity	CUPN all 14 parks	Year-round	Monthly at 6 CUPN parks, 2 yrs on-5 yrs off; 2 parks bi-monthly, EOY; 5 parks quarterly, EOY. MACA will continue annual WQ monitoring (topical and/or flood pulse sampling) during the "5 yrs off" period.	2004	1) Baseline WQ monitoring study begun in 12 parks (2003-2005)
Ozone (air component)	CUPN all 14 parks	May-Oct growing season	Weekly passive sampling at park sites, continuous monitoring by mobile monitor units rotated among parks	2005	1) Baseline study initiated (2004-2005)
Cave Air Quality	MACA, CUGA, RUCA*	Year-round, variable periods	Continuous sampling for defined periods by site	2005	1) Cave AQ is active at two parks
Cave Beetles	MACA only	Year-round	Two sampling runs per yr	2005	
Fish Diversity	MACA, LIRI, SHIL*	Low flow period (summer or fall)	Bi-annual sampling	2005	1) Fish inventory (2004-2006) for 11 parks
Atmospheric Deposition (air component)	MACA only	Year-round at weather station; growing season at impacts site	Composite and weekly intervals	ongoing	
Atmospheric Deposition (impacts component)	MACA only	Growing Season	One or two sampling runs per yr (Mid-& End-season or End-season only)	2006-2007	1) Baseline soil parameters and Nitrogen cycling research completed by 2005

Monitoring Protocol	Parks	Sampling Season	Sampling Frequency	Target Completion Date	Related Tasks
Benthic Macro-invertebrates	MACA, LIRI, SHIL*	May-October, low-flow period	One sampling run per yr	2006-2007	
Forest Pests	CUPN all 14 parks	Season is host-tree and pest taxon dependent	One sampling run per yr per season needed to detect taxa of interest	2006-2007	
Cave Aquatic Fauna	MACA only	Low flow season	Bi-annual sampling at each site; sampling staggered among sites	2006-2007	
Mussel Diversity	MACA only	Low flow periods (summer or fall)	One sampling run every 2-3 yrs	2006	1) Baseline mussel monitoring completed by 2005
Cave Bats	MACA only	Winter (hibernation) and Summer (maternity)	Bi-annual sampling at each site; staggered among sites	2007	1) Cave bat inventory and baseline research completed by 2005
Ozone (impact component)	Initial testing by MACA Prototype	Growing Season (May – October)	One or two sampling runs per yr (Mid-& End-season or End-season only)	2006-2007	
Plant Species of Concern	CUPN 8 smaller parks	Season is taxon- dependent	One sampling run per yr	2006-2007	1) Assist CHCH with Skullcap monitoring FY04
Adjacent Land Use	CUPN all 14 parks	Leaf-off aerial photography	N/A	2006-2007	1) Baseline Study Complete for two parks; 2) Fire Buffer Mapping-ongoing
Vegetation Communities	CUPN 13 smaller parks	Season is community-dependent	Sampling on 3, 5 or 10 year cycles; staggered among parks	2006-2007	1) Baseline Veg Classification (2002-2005); 2) Baseline Veg Mapping (2002-2006); 3) Wetlands mapping (2003-2006)
Invasive Plants	CUPN 13 smaller parks	Season is pest taxon dependent	One or two sampling runs per yr, as needed to assess taxa of interest	2006-2007	1) Coordinate with EPMT

*Monitoring protocol will be developed and implemented at MACA (only), initially.

Chapter Ten
Budget

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Chapter Eleven
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Glossary

Glossary of Key Terms and Concepts

(Based upon http://science.nature.nps.gov/im/monitor/Glossary.htm)

Attributes – any living or nonliving feature or process of the environment that can be measured or estimated and that provide insights into the state of the ecosystem. The term Indicator is reserved for a subset of attributes that is particularly information-rich in the sense that their values are somehow indicative of the quality, health, or integrity of the larger ecological system to which they belong (Noon 2003). See indicators.

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

Conceptual model – a visual or narrative summary that describes or identifies some important components of a system, together with some of the possible interactions among them. For ecosystems, models may include both biotic and abiotic components, such as organismal populations or physical properties of the environment, plus an array of interactions that can include how agents of change influence the structure and function of the natural system.

Degradation – an anthropogenic reduction in the capacity of a particular ecosystem or ecosystem component to perform desired ecosystem functions (e.g., degraded capacity for conserving soil and water resources). Human actions may degrade desired ecosystem functions directly, or they may do so indirectly by damaging the capacity of ecosystem functions to resist or recover from natural disturbances and/or anthropogenic stressors (derived from concepts of Herrick et al., 1995, Ludwig et al., 1997, Whisenant 1999, Archer and Stokes 2000, and Whitford 2002).

Disturbance – "...any relatively discrete event in time that disrupts ecosystem, community, or population structure and changes resources, substrate availability, or the physical environment" (White and Pickett 1985:7). In relation to monitoring, disturbances are considered to be ecological factors that are within the evolutionary history of the ecosystem (e.g., drought). These are differentiated from anthropogenic factors (stressors, below) that are outside the range of disturbances naturally experienced by the ecosystem (Whitford 2002).

Driver – see ***ecosystem drivers.***

Ecological effects –are the physical, chemical, biological, or functional responses of ecosystem attributes to drivers and stressors.

Ecological indicator – see ***indicators.***

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 function – the flow of energy and materials through the arrangement of biotic and abiotic components of an ecosystem. Includes many ecosystem processes such as primary production, trophic transfer from plants to animals, nutrient cycling, water dynamics and heat transfer. In a broad sense, ecosystem function includes two components: ecosystem resource dynamics and ecosystem stability (Díaz and Cabido 2001).

Ecosystem condition (health) – a metaphor pertaining to the assessment and monitoring of ecosystem structure, function, and resilience in relation to the notion of ecosystem "sustainability" (following Rapport 1998 and Costanza et al., 1998). A healthy ecosystem is sustainable.

Ecosystem integrity – see ***ecological integrity.***

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.

Focal attributes/organisms – species/organisms that play significant functional roles in ecological systems by their disproportionate contribution to the transfer of matter and energy, by structuring the environment and creating opportunities for additional species/organisms, or by exercising control over competitive dominants and thereby promoting increased biological diversity (derived from Noon 2003). [Encompasses concepts of keystone species, umbrella species, and ecosystem engineers.]

Functional groups – groups of species that have similar effects on ecosystem processes (Chapin et al., 1996) – frequently applied interchangeably with functional types.

Functional types –sets of organisms sharing similar responses to environmental factors such as temperature, resource availability, and disturbance (= functional response types) and/or similar effects on ecosystem functions such as productivity, nutrient cycling, flammability, and resistance / resilience (= functional effect types) (Díaz and Cabido 2001).

Indicators (general use of term) – 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.

Indicators of ecosystem health (specific use of term) – measurable attributes of the environment (biotic or abiotic) that provide insights regarding (1) the functional status of one or more key ecosystem processes, (2) the status of ecosystem properties that are clearly related to these ecosystem processes, and/or (3) the capacity of ecosystem processes or properties to resist or recover from natural disturbances and/or anthropogenic stressors (modified from Whitford 1998). In the context of ecosystem condition, key ecosystem processes and properties are those that are most closely associated with the capacity of the ecosystem to maintain its characteristic structural and functional attributes over time (including natural variability).

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

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

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

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

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 the NPS I&M 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).

Research – has the objective of understanding ecological processes and in some cases determining the cause of changes observed by monitoring. That understanding is needed for determining the appropriate management response to threats. Research is generally defined as the systematic collection of data that produces new knowledge or relationships and usually involves an experimental approach, in which a hypothesis concerning the probable cause of an observation is tested in situations with and without the specified cause. The NPS monitoring program includes a research component to design sampling protocols for various types of park resources at different locations and spatial scales.

Resilience – the capacity of a particular ecological attribute or process to recover to its former reference state or dynamic after exposure to a temporary disturbance and/or stressor (adapted from Grimm and Wissel 1997). Resilience is a dynamic property that varies in relation to environmental conditions.

Resistance – the capacity of a particular ecological attribute or process to remain essentially unchanged from its reference state or dynamic despite exposure to a disturbance and/or stressor (adapted from Grimm and Wissel 1997). Resistance is a dynamic property that varies in relation to environmental conditions.

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

Trend – as used by the NPS I&M 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 – 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).