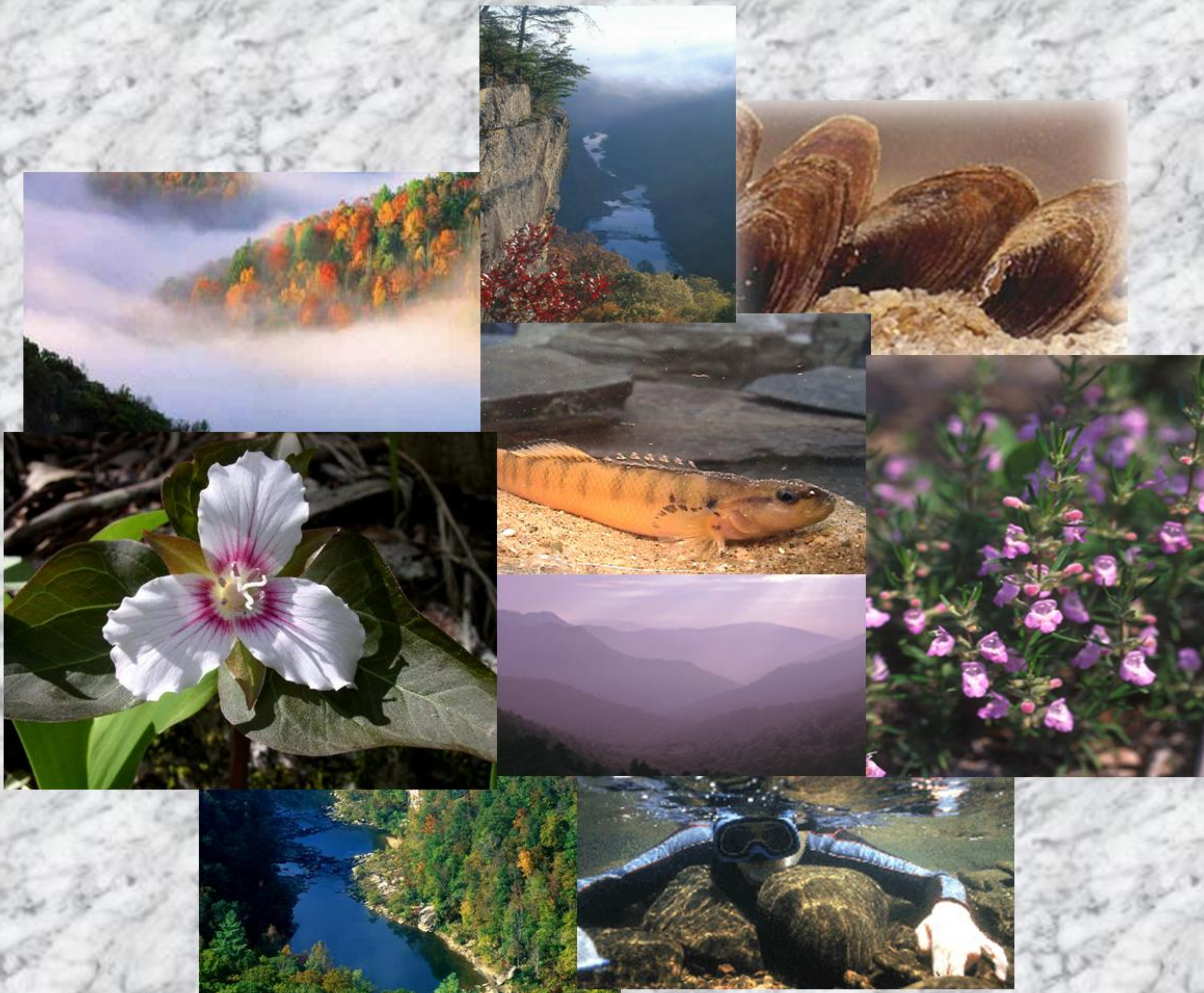
National Park Service
U.S. Department of the Interior

Appalachian Highlands Inventory and Monitoring Network

Vital Signs Monitoring Plan



Big South Fork National River and Recreation Area

Blue Ridge Parkway

Great Smoky Mountains National Park

Obed Wild and Scenic River

September 30, 2005

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Vital Signs Monitoring Plan

by

Robert G. Emmott, Nora Murdock, Patrick Flaherty and Jack Ranney

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EXECUTIVE SUMMARY

> **"We have to know what we have, how and why it is changing, what changes we can accommodate, and which we must combat."**
>
> -Fran Mainella
> Director, National Park Service

Knowing the condition of natural resources in national parks is fundamental to the National Park Service's (NPS) ability to manage park resources "unimpaired for the enjoyment of future generations". Funded by the Natural Resource Challenge, NPS has implemented a strategy to institutionalize natural resource inventory and monitoring. This effort was undertaken to ensure that the 270 park units with significant natural resources possess the information needed for effective, science-based resource management decision-making. The national strategy consists of a framework having three major components: 1) completion of basic resource inventories upon which monitoring efforts can be based; 2) creation of experimental prototype monitoring programs to evaluation alternative monitoring designs and strategies; and 3) implementation of ecological monitoring in all parks with significant natural resources.

Parks with significant natural resources have been grouped into 32 inventory and monitoring (I&M) networks linked by geography and shared natural resource characteristics. The network organization facilitates collaboration, information sharing, and economies of scale. Parks within each of the 32 networks work together and share funding and professional staff to plan, design, and implement an integrated long-term monitoring program. The Appalachian Highlands Inventory and Monitoring Network (APHN) consists of the Appalachian National Scenic Trail (APPA - the southernmost 836 miles), Big South Fork National River and Recreation Area (BISO), Blue Ridge Parkway (BLRI), Great Smoky Mountains National Park (GRSM - Prototype Monitoring Program), and the Obed Wild and Scenic River (OBRI). GRSM implemented a separate monitoring program over a decade ago when it was selected as a prototype by the national I&M Program, and was involved in this Vital Signs selections process only in an advisory capacity; the GRSM I&M Program is administered separately from the rest of the Network. APPA has not received funding for implementing long-term monitoring, and although the Appalachian Trail was included in the Network's planning and Vital Signs selection process, implementation of a monitoring program for that park is currently on hold. **This Vital Signs Monitoring Plan is the APHN's strategy and blueprint for long-term ecological monitoring at BISO, BLRI and OBRI.**

The complex task of developing an ecological monitoring program requires a substantial front-end investment in planning and design to ensure that monitoring will meet the parks' most critical information needs and produce ecologically relevant and scientifically credible data that are accessible to managers in a timely manner. This Vital Signs Monitoring Plan is the culmination of a multi-year planning effort that: 1) outlines APHN monitoring goals and the planning process used to develop the monitoring program; 2) summarizes existing information concerning park natural resources and resource management issues across the Network; 3) provides a conceptual model framework for APHN park ecosystems; 4) selects and prioritizes Vital Signs; 5) presents a sampling framework for aquatic and terrestrial ecosystems in the parks; 6) summarizes monitoring protocols, 7) describes the Network's approach to data management, and 8) provides information on program administration, funding, and operations.

Selecting the few best Vital Signs to monitor from the enormous diversity that exists in the APHN parks' complex and threatened ecosystems is not an easy or straightforward task. However, the Vital Signs selection process revealed that Network parks share a number of similar resource management issues and monitoring needs. Striking a balance between identifying common needs and addressing park-specific issues will continue to be the greatest and most important challenge for the Network as the APHN implements long-term Vital Signs monitoring in the parks.

The APHN Vital Signs Monitoring Plan identifies a suite of Vital Signs for monitoring, including some which are already being monitored in the parks by other entities (see Table 3.1 in the text). The table below, presented in the national Vital Signs framework format, indicates those Vital Signs for which the Network is preparing and implementing monitoring protocols over the next 5 years. Field implementation follows completion of peer reviews and approval of each protocol by Regional and WASO I&M staff:

Level 1 Category	Level 2 Category	Level 3 Category	Network Vital Sign	Measures	BISO	BLRI	OBRI
Air and Climate	Air Quality	Ozone	Ozone	Atmospheric ozone concentration, damage to sensitive vegetation	X	X	X
		Wet and dry deposition	Wet and dry deposition	Wet and dry sulfate and nitrate deposition, concentrations of nitrates, sulfates in high-elevation streams	X	X	X
		Visibility and particulate matter	Visibility and particulate matter	IMPROVE station data, change in visibility deciviews	X	X	X
		Air contaminants	Air contaminants	Aluminum & mercury, especially in high-elevation streams	X	X	X
	Weather and Climate	Weather and Climate	Weather	Rainfall amount, snowfall amount, temperature, relative humidity, wind speed and direction, solar radiation, fog or cloud emersion time, UV-B radiation	X	X	X
Water	Hydrology	Surface water dynamics	Surface water dynamics	Flow rate, annual water level fluctuation	X	X	X
	Water Quality	Water chemistry	Water chemistry	Temperature, specific conductivity, pH, dissolved oxygen, ANC, turbidity,	X	X	X

Level 1 Category	Level 2 Category	Level 3 Category	Network Vital Sign	Measures	BISO	BLRI	OBRI
				major ions			
		WQ Nutrients	Nutrient dynamics	Nitrate, ammonia, total phosphate	X	X	X
		Toxics	Toxics	Heavy metals, coal, aluminum	X	X	X
		Microorganisms	Microorganisms	Fecal coliform, fecal strep	X	X	X
		Aquatic macroinvertebrates and algae	Aquatic macroinvertebrates	Species richness, diversity, IBI of stream macroinvertebrates, relative abundance	X	X	X
Biological Integrity	Invasive species	Invasive exotic plants	Invasive exotic plants	New invasions (early-warning emphasis); occurrence, distribution models of most damaging species	X	X	X
	Focal Species or Communities	Forest vegetation	Forest vegetation	Community structure and demography; species composition, relative abundance, structure, exotic species occurrence (partly remote sensing)	X	X	X
		Riparian communities	Cumberlandian cobblebars	Species composition, structure, distribution, patch size; distribution & trends in rare species occurrence within the community	X		X
		Freshwater invertebrates	Freshwater mussels	Mussel species composition, abundance, age structure	X		X
	At-risk Biota	T&E species and communities	T&E Fish - duskytail darter	Distribution, abundance, age structure	X		
		T&E species and communities	T&E Fish - spotfin chub	Distribution, abundance, age structure			X
Human use	Consumptive Use	Plant poaching	Medicinal and ornamental plant poaching	Population trends and changes in distribution patterns of selected medicinal and ornamental plants		X	
	Visitor and Recreation Use	Visitor usage	Vegetation impacts from recreational rock climbing	Veg community structure, species composition; extent of exposed substrate		X	X
Landscapes	Landscape Dynamics	Landscape Dynamics	Land cover and use	Area of dominant land cover types, patch size distribution, fragmentation (aerial & satellite photos; veg maps; FIA); road density, housing density, other development & resource extraction adjacent to parks;	X	X	X

REPORTING THE RESULTS OF MONITORING

As part of the Service's effort to "improve park management through greater reliance on scientific knowledge", a primary purpose of the Inventory and Monitoring Program is to develop, organize, and make available natural resource data and to contribute to the Service's institutional knowledge by transforming data into information through analysis, synthesis and modeling. The NPS is a highly decentralized agency with complex data requirements. The primary audience for many of the products from the I&M Program is at the park level, where the key role of the I&M Program is to provide park managers and interpreters with the information they need to make better-informed decisions and to work more effectively with other agencies and individuals for the benefit of park resources. However, certain data are also needed at the regional or national level for a variety of purposes, and as stated by the National Park Advisory Board, the findings "must be communicated to the public, for it is the broader public that will decide the fate of these resources". Toward this end, the APHN is developing strategies for effectively sharing information with Network parks, scientists, cooperators, adjacent land managers and other potential collaborators (See Chapters 6 and 7 of this plan). The Network is making a substantial commitment of resources to data management and dissemination.

APHN will be subject to periodic reviews to ensure high program quality and accountability. The Vital Signs Monitoring Plan has been subjected to peer review, as each monitoring protocol will be. In 2010 and every fifth year thereafter, a comprehensive review of program operations will be conducted.

PRIMARY GOALS OF THE APPALACHIAN HIGHLANDS I&M NETWORK

- **DEVELOPING A COORDINATED LONG-TERM ECOLOGICAL MONITORING PROGRAM** to efficiently and effectively monitor ecosystem status and trends over time;
- **CONDUCTING BASELINE INVENTORIES** of natural resources in the parks. Vascular plant and vertebrate surveys will document 90% of the species in each taxonomic group; detailed vegetation cover maps are also being prepared for each park from aerial infrared photos;
- **DEVELOPING DECISION SUPPORT SYSTEMS** (including GIS and other tools) to aid park managers in identifying, implementing, and evaluating management options;
- **INTEGRATING INVENTORY AND MONITORING** programs with park planning, maintenance, interpretation and visitor protection activities to help the parks in their efforts to make natural resource protection even more of an integral part of overall park management, and;
- **COOPERATING WITH OTHER AGENCIES AND ORGANIZATIONS** to share resources, achieve common goals, and avoid unnecessary duplication of effort and expense. A concerted effort is being made to identify and carry out cost-sharing, data sharing, and technology exchange opportunities with other agencies conducting similar inventories or monitoring.

ACKNOWLEDGEMENTS

This monitoring plan was made possible through the National Park Service Natural Resource Challenge. We extend our gratitude to Abby Miller, Gary Williams, Steve Fancy, and Larry West for direction and guidance on developing a Vital Signs Monitoring Program. We are also grateful to the Superintendents and Acting Superintendents of the Big South Fork National River and Recreation Area, Blue Ridge Parkway, Great Smoky Mountains National Park, Obed Wild and Scenic River, and Appalachian National Scenic Trail, who have made time in their busy schedules to participate on our Board of Directors, and shared their advice and enthusiasm for protecting the natural resources of the parks. The APHN Science and Technical Committee, Tom Blount, Keith Langdon, Mike Jenkins, Nancy Keohane, Bambi Teague, and Ray Albright participated in countless meetings and discussions as the monitoring program evolved, and we hope to have their continued assistance. The staff of our Network's prototype park, GRSM, (Janet Rock, Mike Jenkins, Becky Nichols, Keith Langdon, Chuck Parker [USGS], Jim Renfro, and Steve Moore) have been especially generous with their time and advice on long-term monitoring. Numerous others, including all those who participated in our Vital Signs workshops, have assisted us tremendously, in ways far too numerous to mention here. However, we would especially like to thank Dr. Jack Ranney, University of Tennessee, for his invaluable help with facilitating our Vital Signs planning and conceptual modeling workshops. Dr. Robb Turner, Executive Director of Southern Appalachian Man and the Biosphere, was also very helpful in facilitating some of our early workshops and developing ideas about Vital Signs selection.

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1. INTRODUCTION AND BACKGROUND

The National Park Service (NPS) Inventory and Monitoring Program represents a long-term commitment by the Park Service to document the status of natural resources in parks, and the long-term trends in their condition. The National Parks Omnibus Management Act (1998) established a mandate for the NPS to fully integrate natural resources inventories, monitoring and other scientific 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."

The Appalachian Highlands Network (APHN) is one of 32 NPS Inventory and Monitoring (I&M) Networks created to conduct inventories and long-term monitoring of the parks' natural resources. Parks included in the Network are the Appalachian National Scenic Trail (APPA), Big South Fork National River and Recreation Area (BISO), Blue Ridge Parkway (BLRI), Great Smoky Mountains National Park (GRSM), and the Obed Wild and Scenic River (OBRI). As a "prototype" I&M park, GRSM provides input to the network concerning protocol development and sampling design, however, the Smokies' I&M program is operationally distinct from the rest of the network, and will not be covered in detail in this document, except where monitoring results and protocols are potentially applicable to other parks in the network. The southern portion of APPA was incorporated into the early stages of the network's long-term monitoring planning process, but APPA does not currently have monitoring funding from the NPS I&M Program. Therefore, the Appalachian Trail is not included in the detailed site-specific monitoring discussions in this plan.

Natural Resource monitoring is a major component of park stewardship, and a cornerstone of the NPS Natural Resource Challenge, a program developed to revitalize and expand the natural resource program in the Park Service. Monitoring results will be used to assess the efficacy of management and restoration efforts, to provide early warning of impending threats, and to provide a basis for identifying and understanding significant changes in natural systems that are characterized by complexity and variability. Monitoring data may help to determine what constitutes impairment and to identify the need to initiate or change management practices.

GOALS OF THE NATIONAL PARK SERVICE VITAL SIGNS MONITORING PROGRAM

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

As defined by the NPS, **Vital Signs** are a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values. The Vital Signs that are monitored are a subset of the total suite of natural resources that park managers are directed to preserve unimpaired, including water, air, geological resources, plants and animals, and the various ecological, biological, and physical processes that act on those resources.

Because of the need to maximize the use and relevance of monitoring results for making management decisions, Vital Signs selected by parks may include elements that were selected because they have important human values (e.g., harvested or charismatic species) or because of some known or hypothesized threat or stressor/response relationship with a particular park resource. Therefore, every selected Vital Sign may not be an indicator of overall ecosystem condition. Broad-based, scientifically sound information obtained through natural resource monitoring has multiple applications for management decision-making, research, education, and promoting public understanding of park resources.

This chapter provides background information on the Appalachian Highlands Network Inventory and Monitoring (I&M) Program including: the natural resources of the APHN, the importance of park and regional inventory and monitoring programs, the objectives of the Network's monitoring plan, the significant threats and management issues facing the natural resources of the APHN parks, and monitoring work that is already underway.

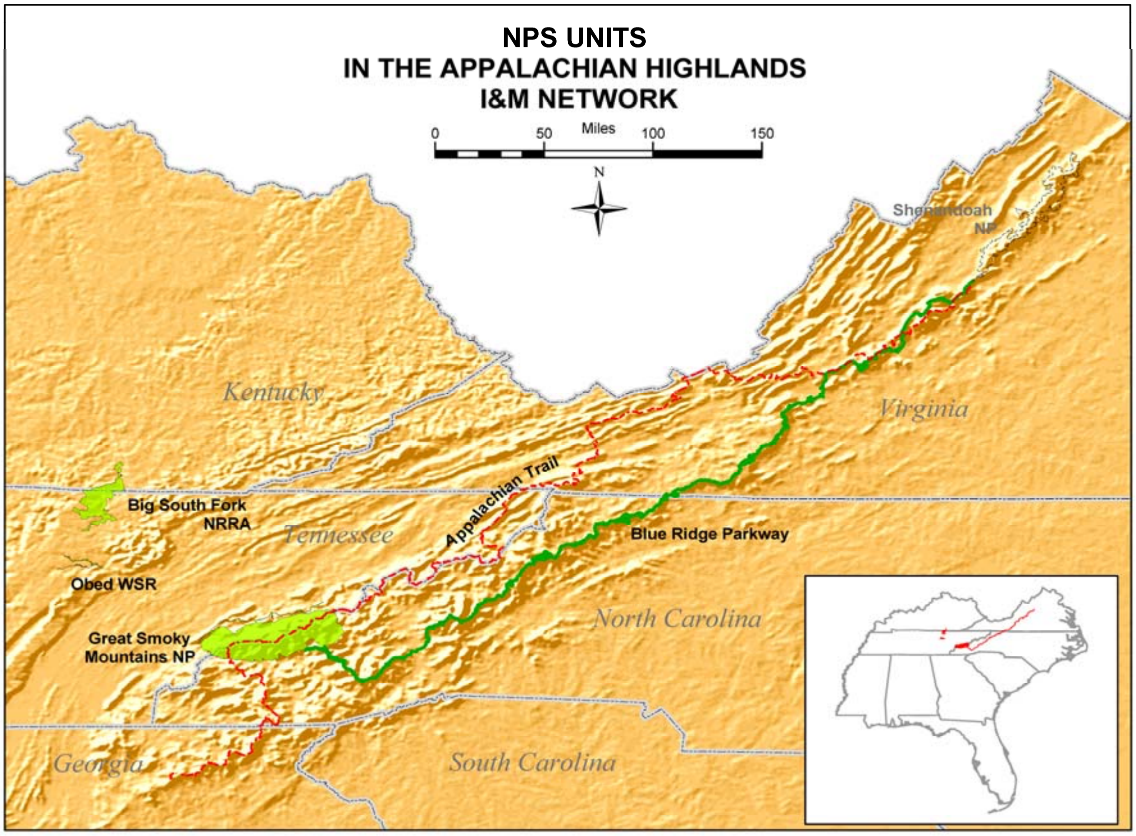


Figure 1.1. The Appalachian Highlands Network parks

(Map by Ron Cornelius, BISO)

Table 1.1. Parks of the Appalachian Highlands Network.

PARK NAME	CODE	Annual Visitation**	SIZE (Acres)	SIZE (Ha)	STATE
Appalachian National Scenic Trail	APPA	Undetermined	7,935* (836 miles of the trail)	3,211	VA, NC, TN, GA
Big South Fork National River and Recreation Area	BISO	851,000	125,000	50,586	KY, TN
Blue Ridge Parkway	BLRI	18,776,000	81,406+	32,944	VA, NC
Great Smoky Mountains National Park	GRSM	9,527,000	521,490	211,040	NC, TN
Obed Wild and Scenic River	OBRI	236,000	5,174	2,094	TN

*Acreage owned by NPS in fee title south of SHEN, exclusive of other NPS-owned land. In addition, approximately 48,450 acres are "influenced by APPA management" (but not owned by NPS) south of SHEN.
** Visitation is the annual average from the most recent 10-year period, rounded to the nearest thousand.
+ 1,700 additional acres of easements are owned by BLRI.

The Appalachian Mountains are among the oldest in the world, having changed relatively little over the past 200 million years. This long stability, combined with great variation in geology, landforms (including the highest elevations in eastern North America), and climate has fostered enormous biological diversity, especially in the south where the land was never covered by glaciers or inundated by oceans. The Southern Blue Ridge Ecoregion is one of the most biologically significant ecoregions in the United States for vascular and nonvascular plants, terrestrial communities, amphibians, snails and neotropical migratory birds, and is one of the most species-rich temperate regions on earth. Network parks protect the largest contiguous stands of old-growth forest remaining in the eastern United States, as well as many of the best remaining examples of globally imperiled species and communities. Of the approximately 4,000 plant species occurring in this ecoregion, 400 are considered rare and over 250 are native only to this region (Stein *et a*l. 2000). This ecoregion has the second highest hardwood and conifer diversity in North America as well as the third highest number of hardwood and conifer endemics (Rickets et al. 1999). The Southern Appalachian Mountains are considered a major world center of evolutionary diversification for Plethodontid salamanders (Tilley and Huheey 2001; Stein et al. 2000). Using the U.S. National Vegetation Classification system (FGDC 1997), 136 distinct terrestrial communities have been described here, with over 90 percent of these considered endemic or limited to the ecoregion. In addition, 66 at-risk aquatic species occur here, 20 of which are Federally-listed as Threatened or Endangered (The Nature Conservancy 2000). Because of their length, BLRI and APPA cross several degrees of latitude, in effect serving as long-distance, high-elevation transects along the crest of the Blue Ridge Mountains. In addition, GRSM contains the largest remaining stands of old-growth forest in the eastern U.S. BLRI is the most visited unit (19 million annual visitors) of the entire National Park system, and GRSM is the most visited National Park (10 million annual visitors) in the system. Significant threats to the natural resources of these parks include atmospheric deposition of nitrates, sulfates, and other air-borne contaminants, as well as invasive exotic pest plants, insects and forest diseases.

The Cumberland Plateau, extending 450 miles from southern West Virginia to northeastern Alabama, is an extensive tableland of sandstone and shale carved by water into a labyrinth of rocky ridges and deep gorges. This is the world's longest expanse of hardwood-forested plateau (The Nature Conservancy 2003); the forests are dominated by oaks, with inclusions of mixed mesophytic forest. In the Cumberland Plateau Parks of the APHN, the primary natural resource management focus is on the Big South Fork and Obed Rivers and their tributaries. These river systems are renowned for their aquatic species diversity (Stein *et al*. 2000), with 80 species of fish, 215 taxa of macroinvertebrates, and 30 species of freshwater mussels. The Cumberland River system historically contained approximately one-third of the United States' freshwater mollusk diversity (more than twice as many species than are found there now). The existing mussel fauna in the Big South Fork represents one of the richest and healthiest remaining in the entire Cumberland River system (Ahlstedt *et al.* 2003). In addition to the tremendous variety of aquatic life, several globally rare plant species associated with cliff, rock shelter, and riparian habitats are in the river gorges. The largest and best remaining populations of two Federally-listed plants (Cumberland rosemary and Cumberland sandwort) are within network parks on the Plateau. Threats to these parks' impressive biological diversity are significant. Both BISO and OBRI have been and are still being impacted by current and past coal mining as well as oil and gas extraction within and outside the parks. Water quality is degraded in many areas by acid mine drainage and other pollutants associated with fossil fuel extraction, as well as industrial and domestic effluent from developed areas adjacent to the parks (NPS 2005). Withdrawal of water to supply municipal drinking water demands is also an issue.

The sections that follow provide a more detailed description of the significant resources and ecological context of the five parks of the Appalachian Highlands Network.

1.1 AN OVERVIEW OF THE APPALACHIAN HIGHLANDS NETWORK

A. APPALACHIAN NATIONAL SCENIC TRAIL (APPA)

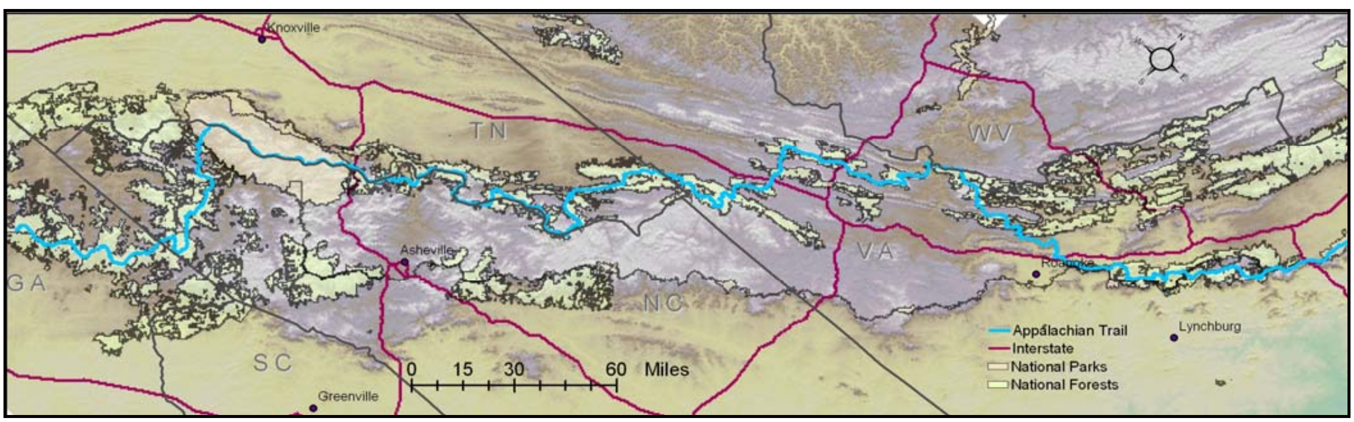


Figure 1.2. Appalachian Trail in the Appalachian Highlands Network
(Map by Patrick Flaherty, APHN)

The Appalachian Trail was designated as the first National Scenic Trail by the National Trails System Act of 1968 (16 USC 1241 *et. seq.*). At 2,174 miles, the AT is the longest unit within the National Park System, stretching from Springer Mountain, Georgia to Mt. Katahdin, Maine. Work on the trail began in 1923; it was completed in 1937. The AT passes through 14 states, 6 National Park Service units, 7 National Forests, numerous state parks and forests, and 5 NPS I&M networks. The trail corridor varies from 50 feet to a mile wide. The land base of the trail is comparable in size to Rocky Mountain National Park, with visitation levels comparable to those of Yosemite. The Appalachian Highlands Network includes the portion of the trail that stretches from the southern end of Shenandoah National Park in Virginia, through North Carolina and Tennessee to the southern terminus of the trail in Georgia, encompassing 48,450 acres over which APPA has management authority (7,935 acres are owned in fee by NPS) and traversing 836 miles.

At least 14 major forest types occur on the Appalachian Trail within the Appalachian Highlands Network (See description for Blue Ridge Parkway and Great Smoky Mountains National Park). Within these are at least 45 distinct ecological communities (Milo Pyne, Natureserve, pers. com. to K. Schwarzkopf, Appalachian Trail Park Office; 2002). Lower elevations are dominated by oak and oak-pine forests with rich cove forest common in topographically sheltered areas. At higher elevations on the trail, northern hardwood species such as American beech, sugar maple, yellow buckeye and yellow birch become common. At the highest elevations, spruce-fir forest dominates, although much of the Fraser fir overstory has been eliminated by an introduced insect pest, the balsam wooly adelgid.

Over 2,000 occurrences of globally rare species and exemplary vegetative communities are found along the trail, with the majority of these being in the southern states of Virginia, North Carolina, Tennessee, and Georgia (within the Appalachian Highlands Network). Of the globally rare species, 9 G1 species (critically imperiled) and 29 G2 species (imperiled) are within the 1,000-foot AT corridor. Rare and exemplary communities of the southern AT include high-elevation grassy balds, red spruce-Fraser fir forests, high-elevation rocky summits & cliffs, boulderfield forests, swamp forest-bog complexes, cranberry bogs, northern hardwood forests, heath balds, rich cove forests, montane white oak forests, high-elevation red oak forests, beech gaps, and Carolina hemlock communities.

Nine Federally-listed Endangered or Threatened species are known to occupy the southern portion of the Trail. (Table 1.6) In addition, nineteen globally rare community types have been identified on the Trail in the Appalachian Highlands Network (K. Schwarzkopf, pers. Com., 2002), including red spruce/Fraser fir forest and Southern Appalachian mountain bogs, identified by Noss *et al*. (1995) as two of the most Endangered ecosystems in the United States.

B. BIG SOUTH FORK NATIONAL RIVER AND RECREATION AREA (BISO)

Big South Fork encompasses approximately 125,000 acres in northeastern Tennessee and southeastern Kentucky. BISO is located in portions of Fentress, Scott, Morgan, and Pickett Counties in Tennessee; and McCreary County in Kentucky. Roughly two-thirds of the park acreage lies in Tennessee; one third in Kentucky. BISO lies within the region broadly known as the Cumberland Plateau, and more specifically, within the highly dissected Cliff Section in the western portion of the Plateau (Braun 1950). Roughly 80 miles of the Big South Fork Cumberland River, and its two major tributaries (Clear Fork and New River), lie within the park boundary. The lower 15 miles of the northward-flowing Big South Fork within the park boundary are impounded backwaters of Lake Cumberland.

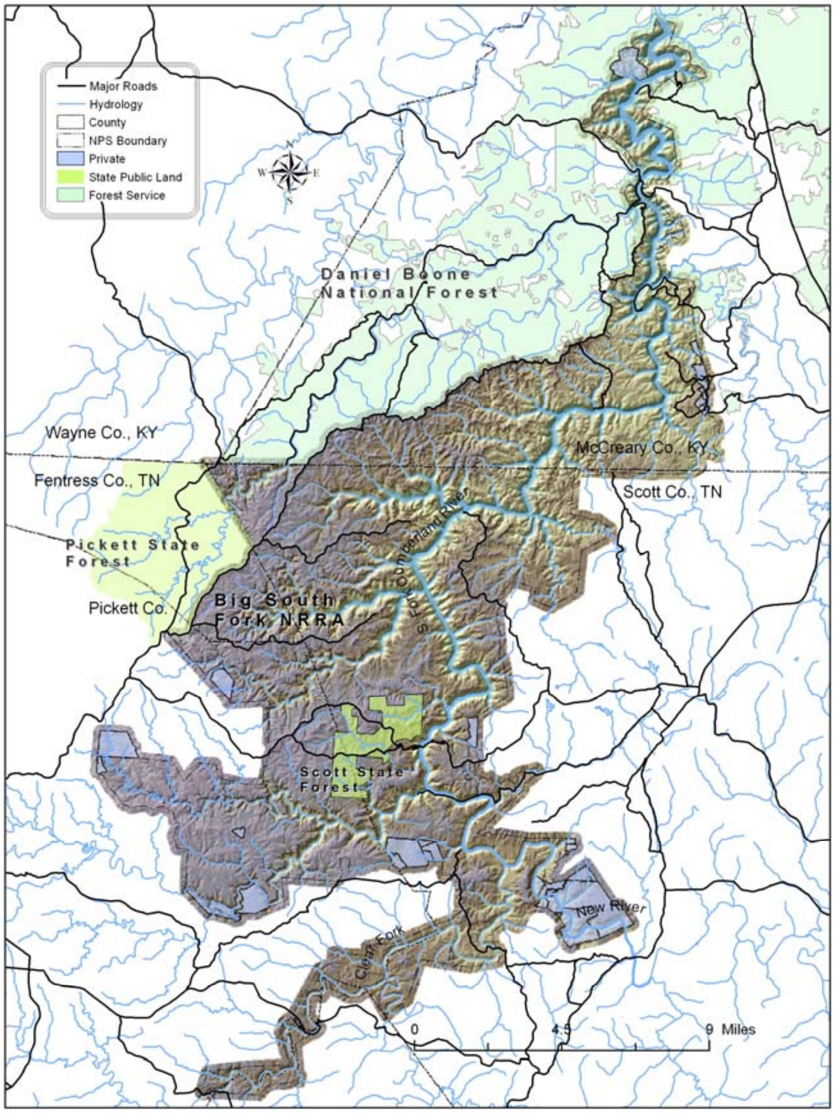


Figure 1.3 Big South Fork National River and Recreation Area
[Map by Patrick Flaherty (APHN)]

In general, the geology of BISO is characterized by parallel, horizontally-bedded sedimentary rocks of Pennsylvanian and Mississippian age. These rocks are predominantly sandstone and shale, and include siltstone, conglomerate, and coal. Most of the park lies within the non-calcareous Pennsylvanian zones of the Cliff Section. Calcareous Mississippian rocks outcrop only occasionally, in narrow bands on lower valley slopes (Beatty, 1982). The pronounced tributary gorges of the Cliff Section are formed by differential erosion of various soft Pennsylvanian formations overlain by the highly resistant Rockcastle Formation. The numerous talus blocks lying at the bottom of the gorge are typically derived from this formation.

The majority of historic and current coal mining in Tennessee occurs within the Big South Fork watershed, particularly in the headwaters of the New River. Coal mining became pivotal in the economic and cultural development of the region after the construction of railroads in the late 1800's. Most of the early mines were "drift mines" – tunnels dug into a hillside, sloped down to a coal seam. After World War II, many areas in the BISO watershed were strip mined - still the dominant method of coal extraction in the area (Kimball 1979). As with coal, the majority of oil and gas production in Tennessee occurs in the BISO watershed (Zurawski 1995). The greatest production of oil and gas has been from Mississippian rocks at depths of less than 2000 feet, although additional reserves are believed to exist at greater depths.

With the exception of pockets of successional old agricultural fields and developed areas, the park is entirely forested. Forests are predominantly second-growth, much of the old-growth having been cut by the mid-twentieth century. Vegetation in the BISO watershed is largely mixed oak, with some mixed mesophytic pockets. These vegetation types fall into two main groups - upland types and ravine types - which reflect variations in climate, topography and soils (Hinkle 1989). Upland vegetation types range from red maple-dominated stands on poorly drained flats to Virginia pine-dominated stands on dry ridges and cliff edges. Broad flats on the shallow slopes of the uplands, are characteristically mixed oak with some hickory. Ravine communities are characterized by more mesic species, with a mixture of sugar maple, black birch, beech, white oak and white pine. Eastern hemlock is prominent along narrow gorges and streams. BISO contains a significant proportion of the best remaining examples of a globally rare plant community (the Cumberlandian Boulder-Cobble Bar).

Perkins (1981), Campbell *et al.* (1990, 1991), and DeSelm (1992) characterized the flora of rock outcrops, cliff edges, and barrens, on the Plateau. These communities are generally disturbance dependent, maintained by weathering on exposed sites, and by fire in more protected locations. DeSelm (1992) noted similarities between dominant elements in these habitats and constituents of the tallgrass prairie in the Midwestern United States. There are 42 globally rare plant taxa known from BISO or immediately adjacent lands. An additional 80 BISO plants are considered rare or endangered by the States of Tennessee and Kentucky.

BISO supports 26 freshwater mussels, including six species Federally-listed as Endangered. These remnant populations survive in a small number of shoals restricted to one river segment. Breeding populations of all seven mesic habitat birds identified by Partners in Flight as priorities for conservation on the Cumberland Plateau occur in the park. The Federally-listed Endangered red-cockaded woodpecker was recorded in the park in the late 1970's, and about 25 colonies formerly occurred within a radius of 20 miles of the park. None are known to remain in the vicinity of the Park.

Comiskey and Etnier (1972) confirmed the presence of 67 species of fish in the Big South Fork and its tributaries, including the Federally Endangered duskytail darter, and several state-listed species. Game fish include channel catfish, muskellunge, walleye, and smallmouth bass. Within the park are 37 species of amphibians, including 15 frogs and toads and 22 salamanders; and 35 Reptiles, including 7 lizards, 22 snakes, and 6 turtles. Over 20 state-listed species are among these groups, including hellbender, green salamander, slender glass lizard, and pine snake.

The park's large mammalian fauna includes white-tailed deer, gray fox, red fox, beaver and coyote. River otter were reintroduced into the park in the mid-1980's and observations of this species have become more frequent in the last decade. In the mid-1990's, fourteen adult female black bears and their cubs were reintroduced into the park during an experimental release. Based on radio-tracking information, and visits to winter dens, this "founder population" appears to be stable. Elk have been recently reintroduced on adjacent lands, and are now being found inside the park boundaries.

C. BLUE RIDGE PARKWAY (BLRI)

Designed as a scenic highway, the 469 mile-long Blue Ridge Parkway encompasses 83,343 acres and ranges in elevation from 649 feet to 6,047 feet as it winds along the crest of the southern Appalachian Mountains. Connecting Shenandoah and Great Smoky Mountains National Parks, the Parkway traverses 29 counties in North Carolina and Virginia, passing through four national forests, one Indian reservation, two state parks, and a dozen municipal watersheds. The Parkway traverses five major mountain ranges along its route – the Blue Ridge, Black, Great Craggy, Great Balsam and Plot Balsam Mountains. Authorized in the 1930's and taking over 50 years to complete, the Parkway provides tremendous scenic vistas for visitors, while also protecting diverse high elevation sites and habitat corridors along an ecological transect spanning 4 ½ degrees of longitude and 2 ½ degrees of latitude (the third-largest geographic range of any unit in the national park system [Teague 2000]). Parkway lands, which include not only the lands adjacent to the road, but also 33,000 acres of backcountry, support a greater diversity of native plant and animal species than most comparably-sized but non-linear NPS units in the Southeast. With over 19 million annual visitors, the Blue Ridge Parkway is the most visited unit of the National Park System.

Geological stability over millennia, coupled with a large variety of soils, landforms, climates and the lack of glaciation, flooding, or volcanic activity has fostered enormous biodiversity in the southern Appalachians. In part because of the complex geomorphology found within the Blue Ridge, and the long time period over which geologic strata have been exposed to erosion, a large variety of soil types (100 different series [Smathers and Pittillo 1978]) have weathered from different parent materials, dramatically affecting distribution of plants and some animal species. The height of the mountains, compared to the surrounding landscape, has influenced local weather patterns. For every 1,000 feet of elevation gained, the temperature drops approximately 3 degrees F (Catlin1984), making the highest mountains on the Parkway an average of 18-20 degrees cooler than the lowest areas. These high-elevation sites are also wetter, because the high ridges intercept warm, rain-bearing winds from the southwest. Some areas in the Southern Appalachians receive 100 inches of rainfall per year, making this the second wettest place on the North American continent (only the Pacific Northwest coast has higher levels of precipitation) (Catlin 1984).

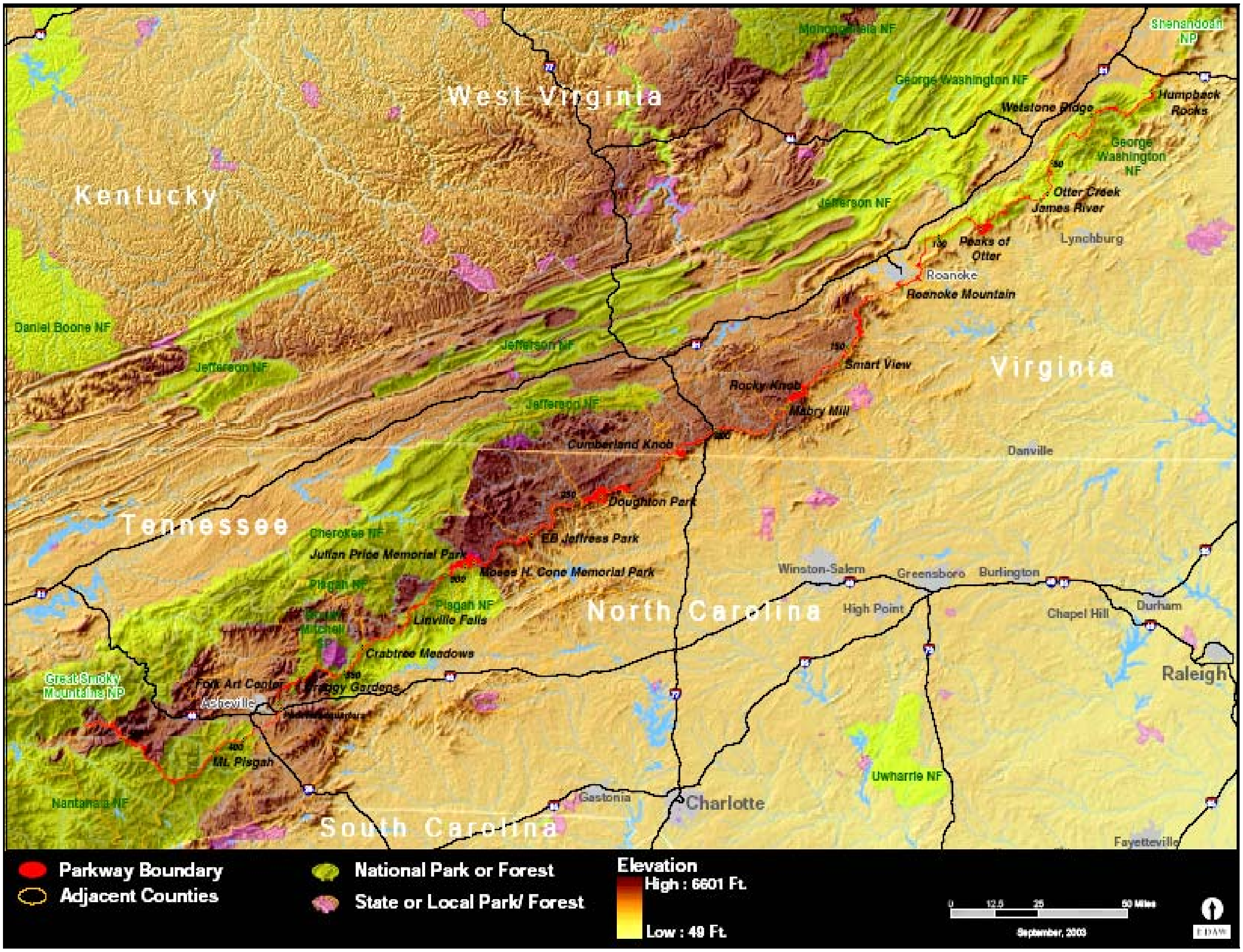


Figure 1.4 Blue Ridge Parkway
(Map by Drew Stoll, EDAW; NPS Denver Service Center)

At least 14 major forest types occur on the Parkway. Within these, 45 distinct ecological communities have been recognized by Schafale and Weakley (1990); vegetation inventories and mapping currently underway may result in the description of additional community types. Lower elevations along the Parkway are dominated by oak and oak-pine forests with rich cove forests common in topographically sheltered areas. As elevation increases, northern hardwood species such as American beech, sugar maple, yellow buckeye and yellow birch become common. At the highest elevations, spruce-fir forest dominates, although much of the Fraser fir overstory has been eliminated by an introduced insect pest, the balsam wooly adelgid. Interspersed among the forests are small unique habitats such as grassy balds, heath balds, mountain bogs, cliffs and rock outcrops, talus slopes and beech gaps. The Parkway also administers some 500 agricultural leases that involve several thousand acres of hayfields, pastures, and some cultivated croplands.

The complexity of the Parkway's geology and topography, including its 5,700-foot elevation change (substantial for an eastern park), has resulted in unusually high vegetative diversity within the forest types described above. There are approximately 1,400 species of vascular plants (including more than 100 kinds of flowering trees and 14 native conifers, 400 species of bryophytes (nearly one-third of the total found in North America), 2,000 species of fungi, and hundreds of species of lichens (Catlin 1984) . There are five Federally-listed Endangered and Threatened plants on the Parkway, along with 111 state-listed plants. There are also 100 species of exotic plants, including some aggressive invaders.

For many of the same reasons described above, the Parkway also supports an exceptional diversity of faunal species. Simpson (1992) documented 319 species of birds from the Parkway, with 159 of these breeding in the park. Because of its north-south orientation on the edge of the 2000+-foot Blue Ridge Escarpment, the Parkway protects a significant migratory corridor for neotropical migratory birds. Fifty-five species of mammals have been documented from the Parkway, along with 38 species of amphibians, 29 species of reptiles, 40 species of fish, more than 150 species of snails, and 500 millipedes (Catlin 1984, Knowles et al. 1989). There are four Federally-listed Endangered and Threatened animals residing on Parkway lands, along with 49 state-listed animals.

Parkway habitats support populations of nine Federally-listed Endangered or Threatened species, 160 State-listed species of plants and animals, and 81 species ranked as globally vulnerable, imperiled or critically imperiled. The Parkway bisects 36 state-designated Natural Heritage Areas (areas recognized for outstanding natural resource value, 11 of which are ranked as being of national significance). All 21 of the highest priority bird species identified in the Southern Blue Ridge Partners in Flight Bird Conservation Plan breed on the Parkway (Hunter et al. 1999). Some of these breeding populations represent a significant percentage of the range-wide total (e.g., two-thirds of the total known breeding Southern Appalachian yellow-bellied sapsuckers are on Parkway lands). Eight globally rare and imperiled (G1 or G2) community types have been identified to date on the Parkway (Schafale and Weakley 1990; Grossman *et al*. 1994), including red spruce/Fraser fir forest and Southern Appalachian mountain bogs, identified by Noss *et al*. (1995) as two of the most Endangered or critically Endangered ecosystems in the United States. The Parkway has 699 acres of high-elevation wetlands (a significant proportion of North Carolina's remaining habitat of this type occurs on the Parkway).

D. GREAT SMOKY MOUNTAINS NATIONAL PARK (GRSM)

Great Smoky Mountains National Park encompasses over 800 square miles (521,490 acres) divided almost equally between the states of North Carolina and Tennessee, and is one of the largest protected areas in the eastern United States. Elevations in the park range from 888 to 6,643 feet, including 16 peaks over 6,000 feet. Precipitation levels are among the highest on the North American continent, with annual averages of 85 inches in parts of the park (Tilley and Huheey 2001). Higher elevations in the park average 69 inches of snow annually. The Park is within easy driving distance of two-thirds of the U.S. population and is the most heavily visited National Park in the system, with nearly 10 million annual visitors.

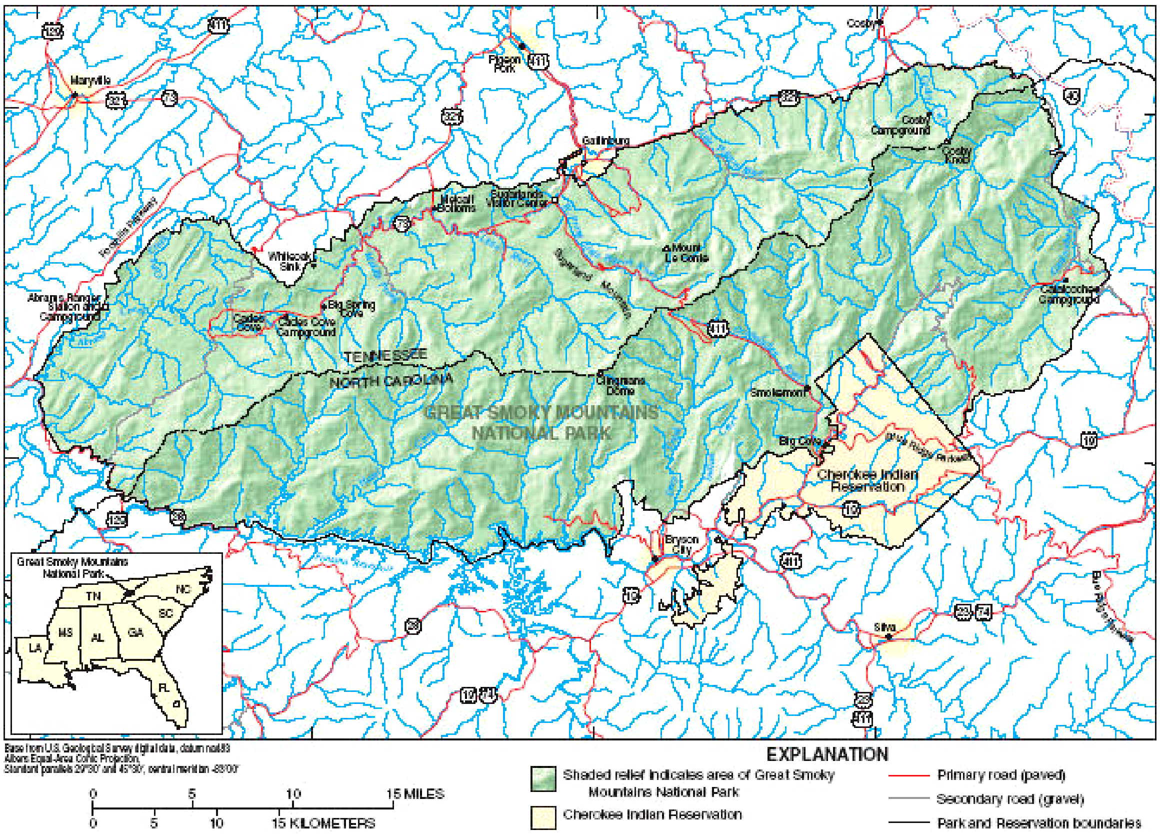


Figure 1.5. Great Smoky Mountains National Park
(From Dodd 2003)

The extraordinary biodiversity of the Great Smokies is world-renowned, as reflected in its designation as an International Biosphere Reserve. Every major eastern forest type can be found within the Park's boundaries. The park's 1,637 vascular plant species include over 130 species of trees, and 60-70 distinct vegetative communities. At lower elevations, forests of tulip poplar dominate large areas that historically were cleared and farmed. In sheltered rich coves (typically with northerly aspects), yellow buckeye, sugar maple, white basswood, and tulip poplar dominate the overstory. In coves with steeper v-shaped drainages, silver bell and hemlock dominate the canopy and rhododendron often forms a thick, impenetrable understory layer. Drier slopes (south and west facing) are dominated by chestnut oak with an understory of mountain laurel. Dry ridges typically have a large component of pine (pitch, shortleaf, Virginia, and table mountain) mixed with dry site oaks (chestnut, scarlet, and black). At higher elevations, the northern hardwood forest is prevalent, which is composed of sugar maple, yellow buckeye, yellow birch, and American beech. At the highest elevations in the Park, red spruce forests (above 5,200 feet) and red spruce-Fraser fir forests (above 6,000 feet) dominate. Scattered throughout the Park are unique communities such as grassy balds, heath balds, beech gaps, caves, vernal pools, and small wetlands, which are significant because they support unique biota, are generally small in aerial extent, and have a limited distribution in the southern Appalachians.

The park supports 70 species of mammals, 243 species of birds (110 of which breed in the park), 44 amphibians, and 40 reptiles (M. Jenkins, pers. com. 2005). GRSM contains one of the highest diversities of breeding Neotropical migratory birds of any area in the United States. In some habitats, over 80 percent of the breeding bird community is made up of Neotropical migrants (Simons and Shriner 1998). In addition, the southern Appalachians, including the park, are a center of evolutionary diversification for lungless salamanders (Plethodontidae) (Tilley and Huheey 2001), harboring 31 of these species (M. Jenkins, pers. com. 2005). Invertebrate diversity in the park is still being documented, but numbers in well-known groups are already impressive, including 1,500 species of beetles and 1,000 species of butterflies and moths.

Six terrestrial vertebrates historically occurring in the park are considered extirpated. Three species have been successfully reintroduced into the park in the last two decades – peregrine falcons, river otters, and elk. The park's black bear population is one of the densest in the East. This core protected population acts to augment other populations in the surrounding region. European wild boar, released on lands adjacent to the park in the 1950's, are now a major threat to the natural resources of the park, causing damage to native ecosystems, particularly to mesic and unique high elevation communities, which contain numerous rare plant and animal species (National Park Service 1991).

Eighty-six species of fish have been documented in the park, including 5 introduced exotic species (Simbeck 1990; M. Jenkins, pers. com. 2005). In the 1950's, thirty species of fish were extirpated from the park in one major park tributary due to reservoir construction, and application of fish toxins to enhance game fish populations. Four of the rarest species have been recently reintroduced (smoky madtom, yellowfin madtom, duskytail darter, and spotfin chub). Regional fisheries studies showed that by the 1980's, brook trout range in the southern Appalachians – and in the Park - had contracted by approximately 75% due to logging and encroachment by non-native salmonids (National Park Service 1991). Genetic research has indicated that these native brook trout populations belong to a distinct southern Appalachian sub-species – separate from northern and hatchery strains (Stoneking 1981; Etnier and Starnes 2001), which makes the reductions in distribution and population size all the more significant.

The park supports 14 Federally-listed Endangered or Threatened species, 25 animal species that are under consideration for Federal listing as Endangered or Threatened, and 194 species of plants and animals ranked as globally vulnerable, imperiled, or critically imperiled by The Nature Conservancy. There are 405 plant species that occur in fewer than five locations in the park; 3 of these are Federally-listed and 74 are state-listed as Threatened or Endangered (National Park Service 2001).

GRSM contains 74 percent of all the Fraser Fir forest that remains in existence (Dull *et al*. 1988), a significant proportion of all remaining Southern Appalachian northern hardwood forest, and the largest contiguous tracts of old-growth forest (all types) remaining in the eastern U.S.

E. OBED WILD AND SCENIC RIVER (OBRI)

OBRI is located within Morgan and Cumberland Counties on the Cumberland Plateau in north-central Tennessee. Its boundaries encompass approximately 5,174 acres, including portions of the waters, stream bed, and land adjoining 45.2 miles of the Emory River, Obed River, and two of the Obed River's tributaries – Clear Creek and Daddy's Creek. The park watershed lies within the Tennessee River drainage. The boundary includes these stream corridors, the gorges which contain them, and an average distance of approximately 200 feet back from the top rim of the gorges. OBRI contains portions of public land owned or managed by the National Park Service (about 3,500 acres) and the Tennessee Wildlife Resources Agency (roughly 1,500 acres of the Catoosa Wildlife Management Area).

The Cumberland Plateau in Tennessee is capped by sedimentary rocks of Pennsylvanian age (280 to 320 million years old), mostly sandstones, shales, siltstones, and coal. It is important to note that all of the strata exposed in the park are Pennsylvanian sandstones and shales; no Mississippian limestones are exposed, although calcareous shale and siltstone is exposed upstream of the park in the headwaters of Daddy's Creek. This geology has a major influence on the distribution, diversity and abundance of many aquatic species, most notably freshwater mussels.

There are no permitted coal mines now operating in the Obed River watershed, however, runoff from abandoned sites continues to affect water quality in the park. There are concentrations of abandoned strip mines in the headwaters of Daddys Creek, the Emory River, and various tributaries of Clear Creek. Oil and gas extraction occurs both within and outside the legislated park boundary. Seven oil and gas wells are located within the boundary. The four that are active within the boundary are situated on private inholdings (National Park Service 1994).

Forest types at OBRI are classified as mixed mesophytic types in tributary gorges, with uplands of mixed oak and pine communities. These include mesic white oak, beech – tulip poplar, river birch, tulip poplar, eastern hemlock, sweet birch – hemlock, chestnut oak – white oak, Virginia pine, white oak – scarlet oak – pine, and white pine – white oak – chestnut oak (Braun 1950; Schmalzer and DeSelm 1982). All of these forest types have been significantly influenced by disturbance, having experienced logging or fire to varying degrees.

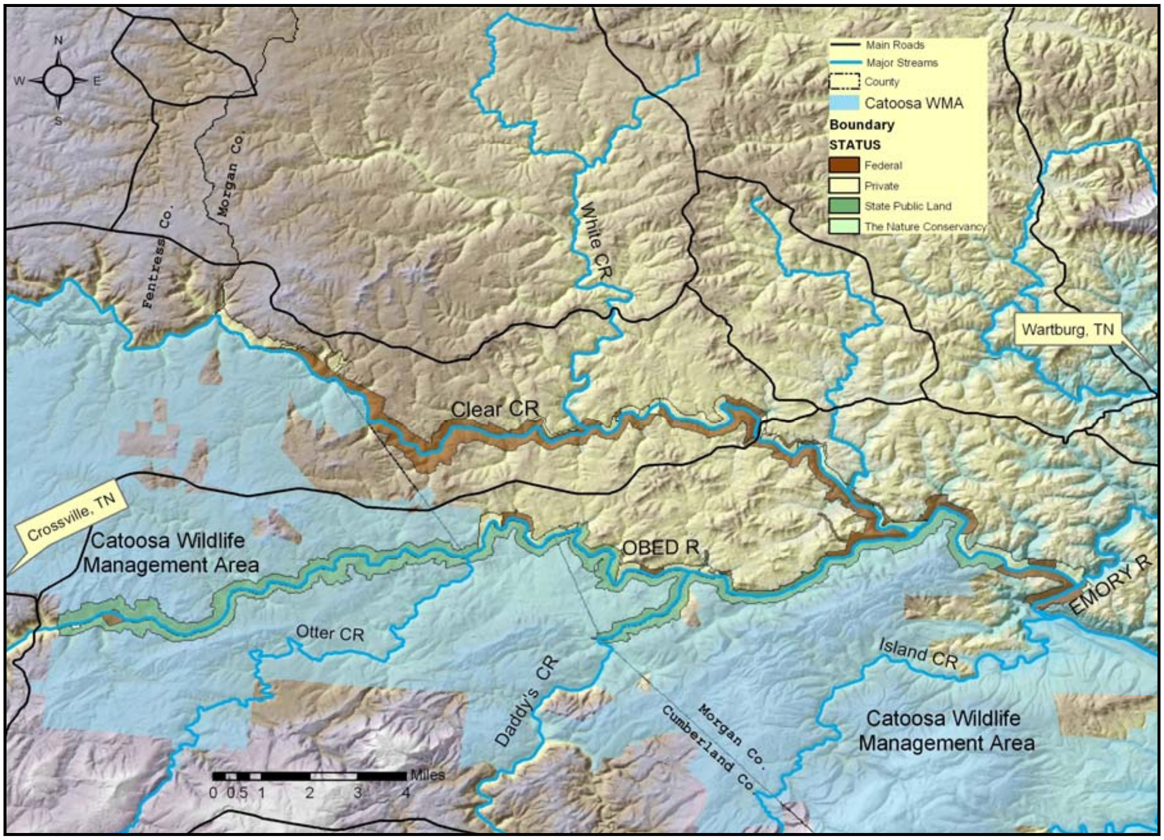


Figure 1.6. Obed Wild and Scenic River
Map by Patrick Flaherty, APHN

Non-forest vegetation types include the riparian shrub – herb type, which is maintained by the flooding regime of the river; sandstone rock outcrops, which have soils too shallow to support a closed forest; cleared areas and abandoned strip mines. Minor vegetation types, which depend on special or restricted habitats, include aquatic types, dry sandstone cliffs, and wet sandstone or shale cliffs (Schmalzer and DeSelm 1982).

The flora of Obed WSR includes 734 taxa in 122 families. Fifty-two (6.8 percent) are introduced taxa. Two are Federally-listed as Threatened and nineteen are considered rare, Threatened or Endangered on state lists. The vast majority of the park's rare plant populations (ca. 90 percent) occur in the riparian shrub-herb community, and are dependent on periodic river scouring to maintain their habitat (Schmalzer and DeSelm 1982).

A terrestrial vertebrate survey conducted by Taylor et al. (1981) identified 31 mammal species, 75 reptiles and amphibians, and 81 species of birds within the park. The non-native European wild boar, introduced into the adjoining Catoosa Wildlife Management Area in the 1960's, is present in the park in small numbers. Two Federally-listed animals - both aquatic – occur in the Obed drainage: the purple bean pearly mussel, and the spotfin chub. Two other Federally-listed species, the Red-cockaded woodpecker and the Alabama lampshell were historically recorded adjacent to the park, but are probably extirpated. There are nine state-listed animals found in the park (National Park Service 1994).

The park's significant resources are concentrated along the main tributaries which comprise the Wild and Scenic River, and along the parallel-trending clifflines which form the stream gorges. In addition to the rare species found within OBRI, there is a globally rare plant community (the Cumberlandian boulder-cobble bar), as well as many other sensitive sites which, although not globally rare, are regionally significant and unique in the park. Most of the best remaining examples of the Cumberlandian boulder-cobble bar community are within OBRI and BISO. Other sensitive or unique habitats include sandstone outcrops, boulderfields, mesic forests, floodplain forests, shoals in the larger tributary streams, and spray cliffs adjacent to waterfalls (Schmalzer and DeSelm 1982).

1.2. WHY UNDERTAKE AN INVENTORY AND MONITORING PROGRAM?

> ***"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."***
>
> ***- National Park Service Management Policies 2001***

A. INVENTORY AND MONITORING MANDATES

The enabling legislation establishing the National Park Service and its individual park units clearly mandates, as the primary objective, the protection, preservation and conservation of park resources unimpaired, in perpetuity, for the enjoyment of future generations (**NPS Organic Act, 1916**). NPS policy and recent legislation require that park managers know the condition of natural resources under their stewardship and monitor long-term trends in those resources in order to fulfill the NPS mission of conserving parks unimpaired. In 1970, Congressional reinforcement of the Organic Act ensured that all parkland units – regardless of title or designation – were united by the common purpose of resource preservation.

Both in 1998 and 2000, Congress gave the NPS explicit direction to inventory and monitor the natural resources under its charge. The 2000 directive shown in Table 1.2 comes from appropriations language for the Natural Resource Challenge, the key mandate driving the NPS Inventory and Monitoring Program. First articulated in 1999, the Natural Resource Challenge is a National Park Service action plan that outlines numerous improvements needed in natural resource stewardship. The Challenge requires that NPS managers know the condition of natural resources under their stewardship, and assure that they are being conserved unimpaired for future generations by monitoring long-term trends in their condition. From the Congressional mandates described in Table 1.2, the Service established policy greatly expanding the NPS I&M program.

Table 1.2. Congressional mandates that direct the National Park Service to inventory and monitor natural resources.

"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."	***FY 2000 Congressional Appropriations Bill***
"The Secretary shall undertake 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 conditions of the National Park System."	***1998 National Parks Omnibus Management Act***
"…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."	***National Park Service Organic Act of 1916***

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."

The **2001 NPS Management Policies** (NPS 2001) updated previous policy and specifically directed the Service to inventory and monitor natural systems.

The NPS Management Policies further state;

"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."

Table 1.3. Federal legislation and Executive Orders that direct or influence NPS I&M programs

- National Park Service Organic Act of 1916
- Clean Air Act of 1955 and 1990
- Fish and Wildlife Coordination Acts of 1958 and 1980
- Wilderness Act of 1964
- National Environmental Policy Act of 1969
- Environmental Quality Improvement Act of 1970
- Clean Water Act of 1972
- Endangered Species act of 1973
- Migratory Bird Treaty Act of 1974
- Forest and Rangeland Renewable Resources Planning Acts of 1974 and 1976
- Mining in the Parks Act of 1976
- Surface Mining Control and Reclamation Act of 1977
- Federal Caves Resources Protection Act of 1988
- Government Performance and Results Act (GPRA) of 1993
- National Parks Omnibus Management Act of 1998
- Executive Orders – including 11987 Exotic Organisms, 11988 Floodplain Management; 11644 and 11989 Off-Road Vehicle Use; 11990 Protection of Wetlands; 13186 Protection of Migratory Birds; 12088 Federal Compliance with Pollution Control Standards; 13112 Invasive Species

More than a dozen other pieces of Federal legislation and Executive Orders influence and direct the NPS Inventory and Monitoring Program. These Acts range broadly in time and scope, as shown in Table 1.3. A more detailed look at legislation driving the National Park Service's I&M Program can be found in Appendix A, and at http://www1.nature.nps.gov/im/monitor/index.htm.

Service-wide mandates, enabling legislation, general management plans and resource management plans for APHN parks commit each park to follow NPS policies for natural resource protection and management, which includes the inventory and monitoring of the condition of those resources (Table 1.4). APHN parks contain a broad spectrum of resources that are protected or regulated to varying degrees by law, or by Park Service policy. These resources include Federally- and state-listed species, air resources, rivers and streams, migratory birds, wetlands, and floodplains, among others.

Table 1.4: Park enabling legislation related to natural resource protection and monitoring

APPA	National Scenic Trails are designated by Act of Congress as "…extended trails so located as to provide for maximum outdoor recreation potential and for the conservation and enjoyment of nationally significant scenic, historic, natural, or cultural qualities of the areas through which such trails may pass." (National Trails System Act of 1968; 16 USC 1241 *et. seq.*) For APPA, the Secretary of the Interior is required to identify all significant natural, historical, and cultural resources to be preserved in the trail corridor, and to identify carrying capacity of the trail and develop a plan for implementation.
BISO	BISO was established for the purpose of "…conserving and interpreting an area containing unique cultural, historic, geologic, fish and wildlife, archeological, scenic and recreational values, preserving as a natural free-flowing stream, the Big South Fork of the Cumberland River"… and major portions of its tributary streams, …"for the benefit and enjoyment of present and future generations…" (P.L. 94-587 as amended by P.L. 101-561). Management mandates include that water quality will be protected and enhanced in cooperation with others, with special emphasis on the New River watershed.
BLRI	BLRI was established as a scenic road connecting GRSM and SHEN to provide a means for leisurely travel and recreation in a variety of significant Southern Appalachian environments (USC Title 16; §460a-2). The Parkway's mission statement reads; "The Blue Ridge Parkway, in linking the Shenandoah and Great Smoky Mountains National Parks, is dedicated to enhancing the outstanding scenic and recreational qualities of the corridor that it traverses, conserving unimpaired its significant natural and cultural resources, and promoting in perpetuity the public enjoyment and appreciation of the Central and Southern Appalachian Mountains".
GRSM	The Park was established by Act of Congress (US Stat. 616) on May 22, 1926, "…for the benefit and enjoyment of the people." In that Act, the Park's purpose was further specified by reference to the Organic Act of 1916 (16 USC 1) which stated that the fundamental purpose of national parks is "…to conserve the scenery and the natural and historic objects and the wildlife 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." Other than this very general statement of purpose, the enabling legislation provided no specific direction to guide park resource management.
OBRI	The Wild and Scenic Rivers Act (P.L. 90-542) states that "…certain selected rivers of the Nation which, with their immediate environment possess outstandingly remarkable scenic, recreational, geologic, fish and wildlife, historic, cultural, or other similar values, shall be preserved in free-flowing condition, and that they and their immediate environments shall be protected for the benefit and enjoyment of future generations…".OBRI's specific purpose is "To preserve and protect the Obed Wild and Scenic river system and the surrounding area in an essentially primitive condition, with unpolluted waters for the benefit and enjoyment of present and future generations." (NPS 1994)

Any legislation or other mandate requiring the protection of natural resources, by implication, also requires monitoring the condition of those resources to determine whether protection goals are being met.

B. I&M AS A BASIS FOR ASSESSING LONG-TERM ECOLOGICAL HEALTH AND FOR ADDRESSING MANAGEMENT ISSUES

To assess, manage, and protect ecosystem health, NPS must understand the condition of the natural features and processes it manages. The first step in gaining this understanding

National parks are part of larger ecosystems and must be managed in that context.

is conducting **inventories – point in time surveys to determine location or condition of a biotic or abiotic resource.** Inventories may involve both the compilation of existing information and the acquisition of new information.

A long-term monitoring program builds on original inventory work through ongoing resource observation, measurement, and analysis. Long-term monitoring provides an excellent means of assessing long-term ecological health, as well as providing information to address long-term management issues and concerns. **Monitoring differs from inventory in that it adds the dimension of time, and that its purpose is to detect changes or trends in the condition of a resource.** Detection of a change or trend may trigger a management action, or it may generate a new line if inquiry. Monitoring is usually done by sampling the same sites over time; some of these sites may be sites that were sampled as part of the initial inventories.

The overall purpose of monitoring, then, is to develop broadly-based, scientifically sound information on the current status and long-term trends in the health, composition, structure, and function of park ecosystems and resources of concern, as well as the reaction of those resources to management actions. Ultimately, monitoring data should facilitate informed decisions, and increase public confidence in NPS resource management.

C. STRATEGIC PLANNING AND PERFORMANCE MANAGEMENT

The National Park Omnibus Management Act mandated that all NPS field units must write Strategic Plans and Annual Performance Plans consistent with the 1993 Government Performance and Results Act (GPRA). GPRA seeks to make Federal agencies more accountable for the money the agencies spend and the results they achieve. The Act requires that agencies plan strategically by setting, measuring and reporting on goals annually.

Following GPRA guidance, the NPS Strategic Plan for 2001-2005 (NPS 2001c) sets goals in four categories:

Category I: Preserve Park Resources
Category II: Provide for the Public Enjoyment and Visitor Experience of Parks
Category III: Strengthen and Preserve Natural and Cultural Resources and Enhance Recreational Opportunities Managed by Partners
Category IV: Ensure Organizational Effectiveness

Category goals are further broken down by time frame into Mission Goals (continue indefinitely), Long-term Goals (five years in duration), and Annual Goals (one year in duration).

Each park is responsible for responding to the overall NPS GPRA goals (e.g., creating Strategic Plans, Annual Performance Plans, and Annual Performance Reports). Local plans are a blend of national and local missions and goals. All five parks in the APHN have prepared five-year strategic goals, and are charged with preparing an annual Performance Plan that tiers from the Service performance goals.

Category I goals – preserve park resources – reflects the NPS Organic Act mandate "to conserve the scenery and the natural and historic objects and the wildlife therein." Category I, 5-year goals for APHN parks are summarized below. A full listing of GPRA Category I goals for each APHN park can be found in Appendix L.

Table 1.5: APHN park GPRA goals

APHN PARK GPRA GOALS RELATED TO NATURAL RESOURCES MONITORING (Goal Target date: September 30, 2005)	**APPA**	**BISO**	**BLRI**	**GRSM**	**OBRI**
Identification of Vital Signs for long-term monitoring	X				X
Long-term monitoring implementation				X	
T&E species stable or improving	X	X	X	X	X
Natural resource inventories	X		X		X
Restoration of disturbed lands	X	X	X	X	
Prescribed fire management		X			
Gypsy moth control		X			
Exotic invasive plant inventory and control	X	X		X	X
Exotic animal control				X	
Water resource inventories	X				
Water quality & quantity		X		X	X
Focal species management (black bear, elk)		X		X	
Land acquisition					X
Focal habitats				X	

This Vital Signs monitoring plan specifically addresses GPRA Goal, "Identification of Vital Signs", but the scientific information collected, analyzed, and reported as part of this integrated monitoring program will also be used to address a number of other key goals related to natural resource stewardship.

D. APHN MONITORING PROGRAM BENEFICIARIES AND TARGET AUDIENCES

Foremost among the I&M program's intended beneficiaries are the park resource managers, who need the ability to (1) detect significant change in resource condition, and (2) evaluate resource response to management actions. In addition, long-term monitoring will contribute fundamental knowledge of park ecosystems to other agencies, private sector cooperators, and academia, which should facilitate the sharing of resources, achievement of common goals and avoid unnecessary duplication of effort and expense. Integrating monitoring activities and information with park planning, maintenance, interpretation and visitor protection activities should help the parks in their efforts to make natural resource protection even more of an integral part of overall park management. By providing park interpretive specialists and the public with information on current studies, management decisions, and trends captured by monitoring programs, the Network hopes to increase pubic awareness of park activities as well as the state of the parks' natural resources.

1.3. RESOURCES AT RISK

A. THREATENED AND ENDANGERED SPECIES

The parks of the Appalachian Highlands Network provide, or historically provided, habitat for 34 species Federally listed as Endangered or Threatened (Table 1.6), as well as 409 species listed by The Nature Conservancy as Critically Imperiled, Imperiled, or Vulnerable (Global ranks of G3 and higher). For some of the Federally-listed species, the APHN parks contain a significant proportion of the best populations remaining in existence (rock gnome lichen, duskytail darter, smoky madtom, yellowfin madtom, spotfin chub, spruce-fir moss spider, Cumberland sandwort, Cumberland rosemary, Littlewing pearlymussel, Cumberlandian combshell, tan riffleshell, Cumberland elktoe, and purple bean). The parks' populations are crucial to the survival and recovery of these species.

The Endangered Species Act (1973) requires all Federal agencies, including the NPS, to conserve Threatened and Endangered species and their critical habitats. NPS policy (NPS 2001) extends this responsibility to state-listed species as well.

Table 1.6: Federally-listed Threatened & Endangered species in APHN parks

SPECIES	STATUS	APHN PARKS				
		APPA	BISO	BLRI	GRSM	OBRI
Carolina northern flying squirrel (*Glaucomys sabrinus coloratus*)	E	X		X	X	
Virginia northern flying squirrel (*Glaucomys sabrinus fuscus*)	T	X				
Eastern cougar (*Puma concolor couguar*)	E	X (historic)	X (historic)	X (historic)	X (historic)	X (historic)
Gray bat (*Myotis grisescens*)	E		X		X	X
Indiana bat (*Myotis sodalis*)	E				X	
Virginia big-eared bat (*Corynorhinus townsendii virginianus*)	E			X		
Red-cockaded woodpecker (*Picoides borealis*)	E		X (historic)		X (historic)	
Bog turtle (*Glyptemys muhlenbergii*)	T (S/A)			X		
Shenandoah salamander (*Plethodon Shenandoah*)	E	X				
Duskytail darter (*Etheostoma percnurum*)	E		X		X	
Spotfin chub (*Cyprinella monacha*)	T				X	X
Smoky madtom (*Noturus baileyi)*	E				X	
Yellowfin madtom (*Noturus flavipinnis*)	T				X	
Spruce-fir moss spider (*Microhexura montivaga*)	E	X			X	
Alabama lampmussel (*Lampsilis virescens*)	E					X (historic)
Purple bean (*Villosa perpurpurea*)	E					X
Cumberland elktoe (*Alasmidonta atropurpurea*)	E		X			
Cumberlandian combshell (*Epioblasma brevidens*)	E		X			
Littlewing pearlymussel (*Pegias fabula*)	E		X			
Oyster mussel (*Epioblasma capsaeformis*)	E		X			
Tan riffleshell (*Epioblasma florentina walkeri*)	E		X			
Cumberland bean (*Villosa trabalis*)	E		X			
Spreading avens (*Geum radiatum*)	E	X		X	X	
Rock gnome lichen (*Gymnoderma lineare*)	E	X		X	X	
American chaffseed (*Schwalbea americana*)	E		X (historic)			
Cumberland sandwort (*Arenaria cumberlandensis*)	E		X			
Cumberland rosemary (*Conradina verticillata*)	T		X			X
Virginia spiraea (*Spiraea virginiana*)	T		X		X	X
Blue Ridge goldenrod (*Solidago spithamaea*)	T	X				
Small-whorled pogonia (*Isotria medeoloides*)	T			X		
Swamp-pink (*Helonias bullata*)	T			X		
Heller's blazing star (*Liatris helleri*)	T			X		
Virginia sneezeweed (*Helianthus brevifolius*)	T			X (historic)		
Roan Mountain bluet (*Houstonia (=Hedyotis) purpurea* var. *montana*)	E	X				

Table 1.7: Numbers of species in Appalachian Highlands Network parks that are ranked as "Critically imperiled", "Imperiled" or "Vulnerable" by The Nature Conservancy.

TNC Global Rank	# APHN Species	Status	APHN Parks				
			APPA	BISO	BLRI	GRSM	OBRI
G1	48	Critically Imperiled	8	7	15	17	1
G2	95	Imperiled	20	12	30	27	6
G3	266	Vulnerable	50	23	36	150	7
TOTALS	**409**		**78**	**42**	**81**	**194**	**14**

B. AQUATIC RESOURCES

Major water quality and quantity issues for the Cumberland Plateau parks (BISO, OBRI) revolve around contaminated drainage from abandoned mines, contaminants and siltation including coal fines (particulate material weathered from coal) associated with current mining operations (including oil and gas extraction), water withdrawals for municipal and industrial use, and erosion-related sedimentation associated with development within and outside the parks. Paradoxically, some of the most pristine streams remaining on the Plateau are in OBRI and BISO, as is reflected by Outstanding Resource Water designations in both parks.

Atmospheric deposition is also related to water quality issues for the three mountain parks (APPA, BLRI, and; GRSM). Most of the headwater streams in the Southern Appalachians are characterized by soils which are derived from materials that have a low buffering capacity; at current deposition levels, these streams are highly susceptible to acidification. Chronic and episodic acidification of streams can lead to elevated levels of aluminum which can reduce survival and diversity of macroinvertebrate and fish populations in sensitive streams (SAMAB 1996c; Robinson *et al.* In Press). Problems with nitrate acidification can also be exacerbated in watersheds where gypsy moths have defoliated the trees, as is occurring on the northern end of the Blue Ridge Parkway and adjacent sections of the Appalachian Trail. Emissions of nitrogen oxides are expected to increase as the human population increases (Southern Appalachian Mountains Initiative 2002).

Table 1.8. Impaired and pristine/outstanding waters of APHN parks

PARK	OUTSTANDING RESOURCE WATERS (ONRW=Outstanding National Resource Water SORW=State-designated Outstanding Resource Water)	IMPAIRED (303d) WATERS (2004 data)	DOCUMENTED PROBLEM PARAMETERS													STATE	COUNTY	RIVER BASIN
			Fecal Colifrom	Temperature	Color	Bacteria,	PCB's	Acid deposition	Mercury	Siltation	Low DO	Organic	Sediment	Contaminated mine drainage, low PH	Oil, Related contaminants			
APPA		Catawba Creek				X										VA	Botetourt	James
		Tinker Creek	X	X												VA	Botetourt, Roanoke	Roanoke, Yadkin
		Kimberling Creek	X													VA	Bland, Giles	New
		Pigeon River			X											TN	Cocke	Upper French Broad
		Nolichucky River				X										TN	Unicoi	Nolichucky
	North Creek-ONRW															VA	Botetourt	James
BISO		Pine Creek				X				X	X	X	X			TN	Scott	Cumberland
		Bear Creek								X				X		TN KY	Scott McCreary	Cumberland
		Roaring Paunch Creek								X				X		TN KY	Scott McCreary	Cumberland
		Rock Creek							X	X				X		KY	McCreary	Cumberland
	Big South Fork of the Cumberland River (within BISO)-ONRW															TN	Scott	Cumberland
	Big South Fork of the Cumberland River (within BISO)-ONRW															KY	McCreary	Cumberland

PARK	OUTSTANDING RESOURCE WATERS (ONRW=Outstanding National Resource Water SORW=State-designated Outstanding Resource Water)	IMPAIRED (303d) WATERS (2004 data)	DOCUMENTED PROBLEM PARAMETERS													STATE	COUNTY	RIVER BASIN
			Fecal Colifrom	Temperature	Color	Bacteria,	PCB's	Acid deposition	Mercury	Siltation	Low DO	Organic	Sediment	Contaminated mine drainage, low PH	Oil, Related contaminants			
BLRI		Dodd Creek		X		X										VA	Floyd	New
		Roanoke River				X	X									VA	Bedford, Roanoke	Roanoke
		Glade Creek		X		X										VA	Botetourt, Roanoke	Roanoke, Yadkin
		Toms Branch						X								VA	Augusta	Potomac, Shenandoah
	Andrews Creek-SORW															NC	Avery	Catawba
	Linn Cove Branch-SORW															NC	Avery	Catawba
	Wilson Creek-SORW															NC	Avery	Catawba
	Clear Branch-SORW															NC	Watauga	Yadkin
	North Creek-ONRW															VA	Botetourt	James
GRSM		West Prong of the Little Pigeon River (.7 mile upstream of Dudley Cr. to Pigeon Forge)				X				X						TN	Sevier	French Broad
	West Prong Little Pigeon River (portion within GRSM upstream of Gatlinburg) - ONRW															TN	Sevier	French Broad
	Little River - ONRW															TN	Blount	Tennessee
	Abrams Creek - ONRW															TN	Blount	Little Tennessee
	Little Pigeon River - ONRW															TN	Sevier	French Broad

PARK	OUTSTANDING RESOURCE WATERS (ONRW=Outstanding National Resource Water SORW=State-designated Outstanding Resource Water)	IMPAIRED (303d) WATERS (2004 data)	DOCUMENTED PROBLEM PARAMETERS													STATE	COUNTY	RIVER BASIN
			Fecal Colifrom	Temperature	Color	Bacteria,	PCB's	Acid deposition	Mercury	Siltation	Low DO	Organic	Sediment	Contaminated mine drainage, low PH	Oil, Related contaminants			
OBRI		Obed River (biodiversity declines, flow alteration)								X						TN	Morgan	Emory
		Clear Creek													X	TN	Morgan	Emory
	Obed River (portion designated as WSR - provisional designation)-ONRW															TN	Morgan	Emory

Maintaining waters in an unimpaired state represents a considerable challenge for APPA, BLRI and OBRI, because of their linear nature, and because most of the threats to their water quality originate outside the parks. This is also true to some extent for BISO. When the Blue Ridge Parkway was constructed, much of the adjacent land was already in agricultural use, particularly as grazing land. In many cases, the use of adjacent lands for livestock grazing has been allowed to continue under land-lease contracts in an effort to preserve the traditional scenic and cultural character for the Blue Ridge Parkway visitor (Maas 1992).

AQUATIC RESOURCES OF THE APPALACHIAN NATIONAL SCENIC TRAIL

AT Hiker on southern trail section (© Victoria Logue)

General descriptions of water resources for the Blue Ridge Parkway and Great Smoky Mountains National Park apply for much of the length of the Appalachian Trail in the APHN, since the Trail traverses or parallels large sections of both parks. Natural lakes are rare to nonexistent in the APHN stretch of the Trail, owing to the lack of Pleistocene glaciation. Watauga Lake in Tennessee and Fontana Lake in North Carolina, are major, man-made impoundments. Small impoundments are common along upper reaches of streams. Good groundwater recharge areas are being impacted by encroaching development (NPS 2004). The surface water drainage pattern is well-established, dendritic to trellis, but primarily the former. Much of the Trail's route through this section is captured by the New River and its tributaries, which eventually drain into the Ohio River to the west. However, the Trail also crosses the headwaters of the Holston River in this section, which drains to the south. Streams are generally more acidic and less productive than in the Northern Ridge and Valley Section. Wetlands (bogs, swamps) are scarce (NPS 2004).

Based upon data compiled by the NPS Water Resources Division and Service-wide I&M Program, using the USGS 1:100,000 scale National Hydrography Dataset (http://nhd.usgs.gov/) and assuming a corridor of land 500 feet on each side of the footpath, APPA contains approximately 196 miles of perennial rivers and streams, 34 miles of intermittent streams, 760 acres of lakes, ponds, and reservoirs, and 38 miles of shoreline. The Water Resources Division is in the process of acquiring the 1:24,000 scale National Hydrography Dataset for the entire Trail, which will significantly refine these hydrographic statistics and provide a more accurate count of springs and seeps. A Baseline Water Quality Data Inventory and Analysis Report specifically for the Trail corridor will be prepared in 2005 (NPS 2004). According to a preliminary compilation by the Water Resources Division, the Trail has approximately 16.45 miles of impaired

(303d designation) rivers, streams, and canals within or adjacent to the Trail corridor. Approximately 18.4 acres of lakes, ponds, and reservoirs within the Trail corridor are also impaired (NPS 2004). Data currently available indicate that there is one designated Outstanding National Resource Water within the APHN section of the Trail, and five stream sections designated as impaired (303d) (Table 1.8).

Maintaining waters in an unimpaired state represents a special challenge for the Appalachian Trail, just as it does for the Blue Ridge Parkway. For the Trail, almost all sources of pollution are offsite, and since much of the land traversed by the Trail in this section is not owned by the NPS, management influence is limited. Water quality is a concern for this park unit because long-distance hikers in remote areas of the Trail are dependent upon springs and creeks for their drinking water. No Federally-listed aquatic species are known from the Trail within the APHN states.

AQUATIC RESOURCES OF BIG SOUTH FORK NATIONAL RIVER AND RECREATION AREA

The Big South Fork is part of the Cumberland River watershed and is the largest free-flowing river entirely contained within the Cumberland Plateau of Kentucky, Tennessee, Alabama and Georgia. The BISO watershed covers approximately 1,120 square miles in seven counties in Tennessee and Kentucky, of which only about 14 percent is inside the boundaries of the National River and Recreation Area. BISO occupies the downstream portion of this large drainage, and therefore, the health of its aquatic systems is dependent to a large degree on external factors.

Freshwater mussel inventory at BISO

The park contains approximately 72 miles of small to medium-sized rivers, including the Big South Fork of the Cumberland River, and its two major tributaries, Clear Fork and New River. In addition, BISO encompasses roughly 10 miles of Lake Cumberland backwaters at the northern end of the park and hundreds of miles of tributary and headwater streams within its 125,000 acres. Some of the streams within BISO are severely polluted, yet the park also contains some of the most biologically diverse and pristine waters on the Cumberland Plateau. Based on their water chemistry, streams within the park fall naturally into categories depending on the degree to which they are limestone or sandstone-influenced. Sandstone-influenced streams are more susceptible to acid contamination because of low buffering capacity and very low alkalinity. In general, streams in the western portion of the BISO watershed are less disturbed than tributaries in the eastern and southern portions of the drainage, which are regularly impacted by activities related to coal mining, forestry and development (Rikard *et al*. 1986). The New River, the largest tributary to the Big South Fork, drains a basin which supplied more than half of Tennessee's coal during the 1970's. Thirty years later, the effects of this mining activity are still evident in large deposits of coal fines on the river bed and banks, and acid mine drainage seeping out of once clear-flowing streams. Portions of the Big South Fork are classified as Outstanding National Resource Waters by the states of Tennessee and Kentucky; portions of four tributaries inside BISO are classified as 303d (impaired) streams by these states. (Table 1.8).

Only two other river systems in the region, the Clinch-Powell (upper Tennessee River tributaries) and the Green River (Ohio River tributary), harbor an equally significant aquatic fauna. BISO has more imperiled aquatic species than any other unit of the National Park system (Ahlstedt *et al.* 2003; NPS 2005). There are six Federally-listed Endangered freshwater mussel species within the park. The Big South Fork's population of the duskytail darter, a Federally-listed Endangered species, is the only occurrence of this fish in the Cumberland River drainage, and appears to represent a unique taxon (Wood *et al.* undated). There are two Federally-listed Threatened floodplain plants within the park that are dependent upon the Big South Fork's natural flood regimes for survival, as well as numerous excellent occurrences of the globally imperiled Cumberlandian boulder/cobblebar community.

Water needs are outgrowing existing water supply systems on the Cumberland Plateau and Highland Rim. Three regional water utility districts have proposed or installed water intakes in the Big South Fork watershed in the last decade to meet increasing water supply demands. The Huntsville Utility District has operated a water supply intake on New River upstream of the park since the early 1990's. In 2001, the McCreary County Utility District installed a water intake on the impounded section of the Big South Fork near the downstream park boundary. The cumulative effects of water withdrawal on the hydrologic cycle, and on the aquatic life supported by the affected tributaries, are unknown.

AQUATIC RESOURCES OF THE BLUE RIDGE PARKWAY

The heavy precipitation received by the Southern Appalachians generates the headwaters of nine major rivers, and the source of drinking water for much of the Southeast (Catlin 1984, SAMAB 1996a). The water resources of the Blue Ridge Parkway include 400 streams, five major rivers (the French Broad, the James, the Roanoke, the Swannanoa and the Linville Rivers), as well as numerous wetlands and lakes. Park boundaries encompass the headwaters of 150 streams (Maas 1992). There are five rivers or streams on the Parkway that are either state- or nationally-designated Outstanding Resource Waters, and four 303d-listed waters (Table 1.8)

Affecting or affected by Parkway waters are 149 industrial/municipal discharges, 40 drinking water intakes, and 78 impoundments. Based upon data from 315 monitoring stations, waters within the Park have exceeded (at least once during the previous 30-year period) EPA criteria (for drinking water, for protection of freshwater aquatic life, or for swimming) for 24 parameters, including pH, dissolved oxygen, turbidity, bacteria, heavy metals and other toxins (arsenic, cyanide, mercury, selenium and phenanthrene) (NPS 1996a), however there are virtually no consistent multi-year data from within the parkway's boundaries (Mary Giorgino, USGS, pers. com. 2004).

Maintaining waters in an unimpaired state represents a challenge for the Blue Ridge Parkway for several reasons. Many streams cross the Parkway which receive pollutant inputs from offsite sources. Also, when the Parkway was constructed, much of the adjacent land was already in agricultural use, particularly as grazing land and this use continues. In many cases, the use of adjacent lands for livestock grazing has been allowed to continue under land-lease contracts in an effort to preserve the traditional scenic and cultural character of the original landscape (Maas 1992). Half of North Carolina's remaining mountain bogs/fens are within BLRI, and some of these are grazed by livestock (NPS 1992). Light to moderate grazing has been found to be beneficial to some of the rare species that occupy these habitats, particularly the Federally-listed bog turtle (Herman 2003), but these mountain wetlands are complex systems and the effects on them from grazing are not entirely understood. Grazing, particularly, at higher intensities, can detrimentally affect wetlands by increasing the amount of nutrients in these naturally nutrient-poor systems, and by causing soil compaction which decreases water filtration and can alter hydrology (Cole et al. 1996, Sutter et al. 1996). Rare plant sites that might be damaged by grazing are not part of the Parkway's agricultural lease program. As noted above, there are some serious problems with water quality on the Parkway at certain locations. These represent problems, not only for the wildlife that are dependent upon the water for parts or all of their life cycles, but also for the health of the Parkway's 20 million human visitors.

Atmospheric deposition is also related to water quality issues. Based upon work conducted in the Great Smoky Mountains and on the adjacent Pisgah and Nantahala National Forests (Southern Appalachian Mountains Initiative 2002), the streams and wetlands most affected by acidic deposition are associated with first-order streams, at higher elevations, in watersheds with low acid-neutralizing capacity. Recent macroinvertebrate collections from high-elevation seeps and other wetlands on BLRI have produced some significant finds, including some species probably new to science, and other species known from fewer than half a dozen sites, worldwide (C. Parker, D. Lenat, pers. com., 2004), emphasizing the importance of monitoring these unique and highly threatened habitats. High-elevation sites here typically have soils derived from materials that have a low buffering capacity. With current nitrate and sulfate deposition levels, streams at high elevations in the Southern Appalachians are highly susceptible to acidification. Chronic and episodic acidification of streams can lead to elevated levels of toxic aluminum which can reduce survival and diversity of macroinvertebrate and fish populations in sensitive streams (SAMAB 1996c). Problems with nitrate acidification can also be exacerbated in watersheds where gypsy moths have defoliated the trees, as is occurring on the northern sections of the Blue Ridge Parkway. Emissions of nitrogen oxides are expected to increase with human population increases.

AQUATIC RESOURCES OF GREAT SMOKY MOUNTAINS NATIONAL PARK

There are more than 2100 miles of streams within the park. Wetlands, which are not common, include high-elevation springs and seeps, and lower-elevation bogs and vernal pools. Portions of four park streams are designated Outstanding Resource Waters, and one park stream is listed on Tennessee's 303(d) list (Table 1.8)

Park streams are subject to runoff from heavy precipitation that deposits some of the highest total nitrate and sulfate levels in the United States. Average pH of rainfall here is 4.3 (Robinson, UT, pers. com. 2004). A single storm may acidify streams at high elevations by more than a full pH unit. Recent research (Robinson *et al*. In Press) demonstrated that the streams in GRSM have very low buffering capacity and are therefore highly susceptible to acidification, with pH levels expected to drop to less than 5.0 during large storms at higher elevations. These pH levels can remain suppressed for several days following a storm event (Robinson *et al*. In Press). Sustained pH levels less than 5.0 can result in decreased nutrient cycling rates, decline in periphyton species richness, declines in benthic invertebrates, reproductive failure of acid-sensitive amphibians, and loss of most or all fish species (Baker et al.1996). The park monitors trends in water quality related to atmospheric deposition, as well as the variation in water quality among ecological communities, and relations between ecosystem processes and water quality (National Park Service 1996a). Native brook trout, believed to be a separate taxon endemic to the Southern Appalachians, have disappeared over the past two decades from the upper elevation reaches of many streams in the park (Culp, pers. com. 2003). Recent fish surveys in the park have shown that 736 miles of park streams now have no fish at all (M. Kulp, pers. com. 2003). Four Federally-listed Endangered or Threatened fish inhabit park streams at lower elevations, and the pH of stream waters, even at lower elevations, is decreasing at GRSM.

AQUATIC RESOURCES OF THE OBED WILD AND SCENIC RIVER

The main natural resource issues facing the park are related to its efforts to preserve the "outstandingly remarkable" character of park waters – the reason it was designated a Wild and Scenic River. Resource management challenges involve not only protecting park waters, but defining baseline conditions, so that the park can more effectively manage potential resource threats. Outstanding National Resource Waters designation also implies that a common understanding of baseline aquatic conditions exists, so that anti-degradation provisions can be applied.

Principal potential impacts to water quality in the park are from high levels of siltation and suspended solids, fecal bacteria contamination, low dissolved oxygen content, high nutrient levels, oil and gas spills, and disturbance of acidic strata. High bacterial counts from sewage effluent, raised sulfate levels and severely reduced biodiversity from coal mining, elevated conductivity from agricultural operations, and high levels of silt from construction sites, have been documented from the main stem of the Obed and several of its major tributaries (Rikard et al. 1986).

Water quantity issues are also a significant concern for OBRI. Water withdrawal or impoundment can alter the quantity, frequency and duration of flows downstream, and threaten associated biological systems. As development pressures around the town of Crossville increase, demand for water in this section of the Plateau has become a high profile issue. Requests for permits to construct large impoundments, for water supply or recreation upstream of the park, have been made several times in the last few years. These proposals have been defeated on principle, but the baseline data needed to define OBRI's unimpaired condition is still lacking. Currently, the park is conducting a historic flow study, and a paired watershed study (highly impounded vs. unimpounded watersheds), to gain a better understanding of how water flows through the system, and the effect of water withdrawals on the flow regime (Jeff Hughes pers. com. 2004).

The park watershed area is about 615 square miles, located in Cumberland, Morgan and Fentress Counties, Tennessee. The park's land base is relatively small compared to the size of its watershed, therefore the quality and quantity of its waters largely reflect conditions upstream of the park boundary, where coal mining, oil and gas operations, agricultural and forestry operations, and water-supply impoundments represent the most significant threats to the park's aquatic systems. The headwaters of the Obed River and Daddy's Creek drain the region around the city of Crossville and flow north and east into the park. Clear Creek flows east through predominantly rural pastureland before entering the park. There are no permitted coal mines now operating in the Obed River watershed, however, runoff from abandoned mines continues to affect water quality in portions of the park. There are concentrations of abandoned strip mines in the headwaters of Daddy's Creek, the Emory River, and various tributaries of Clear Creek. Within the Obed WSR boundary, there are portions of two abandoned strip mines, and one abandoned deep mine, all of which have naturally re-vegetated. Oil and gas extraction occurs both within and outside the park. Seven oil and gas wells are located within the boundary; the four that are active are situated on private inholdings (TVA 1998). Approximately 72 percent of the Obed/Emory River watershed is forested, 25 percent is comprised of pasture, and three percent is in agricultural production for livestock and row

Federally-listed Cumberland rosemary (*Conradina verticillata*) – a cobblebar species dependent upon river flooding
(NCSU photo)

crops (TVA 1998). Runoff from agriculture and livestock operations results in high levels of bacteria and elevated conductivity that threaten water quality conditions at certain places within OBRI (TVA 1998). Increasing residential and commercial development in the watershed presents an external threat to the water quality and quantity in OBRI. In the counties surrounding the park, there are no local zoning or engineering regulations on storm water management for developments; increasing residential development and associated water quality impacts from septic tanks and drain fields are expected to increase in future years (TVA 1998). As is true of the Big South Fork NRRA, there are both severely polluted waters as well as relatively pristine waters within OBRI. Reflecting their exceptional ecological and recreational significance, the streams comprising the Obed WSR were provisionally designated as Outstanding National Resource Waters in 1999. Portions of two park tributaries are classified as 303d (impaired) streams by the state of Tennessee. Interestingly, there is some overlap in designations at the furthest upstream boundary of the park, where a short reach of the main stem of the Obed River is designated as both impaired and ONRW (Table 1.8) .

As with other stream systems on the Cumberland Plateau, the Obed system is characterized by rapid surface runoff and little groundwater storage, creating a wide range of flows. Stream flows at Oakdale, just downstream of the park boundary, have been measured from nearly zero cubic feet per second (cfs) to more than 190,000 cfs (recorded in March 1929) (TVA 1998). Ten floods with peak flows greater than 70,000 cfs were recorded at Oakdale between 1929 and 1977 (*Ibid*). Because the park's aquatic ecosystem is dependent on this widely fluctuating flow regime, there is concern that upstream impoundments may individually and cumulatively impair natural variability of streamflows and water-related resource attributes. Between 1943 and 1994, there were 2,903 impoundments constructed upstream of the park boundary, from farm ponds to large reservoirs (TVA 1998). As of 1997, there were 3,871 impoundments in the Obed watershed (Keller 2004).

Federally-listed spotfin chub (*Cyprinella monacha*) from the Obed River

(Photo by W. T. Russ II)

The Obed WSR is home to a Federally-listed Threatened fish and an Endangered mussel, as well as two Federally-listed Threatened floodplain plants, and a globally imperiled community (the Cumberlandian boulder/cobblebar). National Wetlands Inventory maps indicate that four wetlands are located on the Obed River within the park, and 28 potential wetland areas may exist within the banks of the Obed River, Clear Creek, and Daddy's Creek – all at tributary confluences.

Tables 1.9, 1.10, and 1.11 below summarize trends and available data on sites selected for water quality monitoring in the Network parks. See Chapter 4 for additional detail.

Table 1.9. BLRI water bodies selected for monitoring: Summary of available data, trends (priorities are shown within category)

CATEGORY	RESOURCE	WATER BODY	MILE-POST	JUSTIFICATION	PRIORITY
Impaired (303d)	Stream	Dodd Creek	162	303d-listed; Dodd Cr. and tribs parallel BLRI for approx. 2 miles; West Fork drains Rocky Knob Campground; string of wetlands (about 4) with Fed-listed bog turtle populations.	High #1
	Large river	Roanoke River	114.7	303d-listed; BLRI crosses over it; very little inside park boundary; very large watershed outside Park's control.	Low
	Stream	Glade Creek	107.9	303d-listed; massive streambank collapse inside BLRI; cattle grazing & external development impacts; no resources of concern known; only 2/10 mile on BLRI – very little park control over watershed or impacts.	Low
	Stream	Mills Branch	~19	303d-listed; approx 50 m outside boundary according to map	Low?
	1st–order stream	Toms Branch	6.5 & 6.7	303d-listed; only the headwaters on BLRI; acid deposition	High? #2
Pristine (ONRW, ORW, WSR)	2nd-order stream	Wilson Creek	303	National Wild and Scenic river, State Outstanding Resource Water; high elevation; acid dep?; protected watershed (TNC ownership) above BLRI; state has a long-term monitoring station below the park boundary.	High #2
	Stream	Linn Cove Branch	304	State Outstanding Resource Water (very close to Wilson Cr and Andrews Cr; Wilson is highest priority because of WSR & ORW designations?)	Low?
	Stream	Andrews Creek	304.9	State Outstanding Resource Water (very close to Wilson Cr and Linn Cove Branch; Wilson is highest priority because of WSR & ORW designations?)	Low?
	1st-order stream	Clear Branch	280	State Outstanding Resource Water; crosses BLRI; may be intermittent at the crossing(intermittent on BLRI?)	Low?
	1st-order stream	North Creek (headwaters on boundary)	78	Outstanding National Resource Water (the only one on BLRI and the only one designated in the State of VA); on BLRI & APPA; gypsy moth defoliation; 3472'- one of the higher elevations on BLRI in VA – acid dep?	High? #1
	Stream	Big Pine Creek	225	Relatively pristine; state-designated Natural Heritage Site; State-listed plants, wetlands	High/ Medium? #3
Acid deposition	High-elevation perennial seep	Yellowface Overlook seep	450.2	High elevation; low ANC watershed; rare salamander (G1Q)	High? #1
	Stream	Basin Creek	243	5,500-acre watershed entirely within BLRI boundaries; relatively pristine, forested watershed; acid dep., veg changes predicted from HWA, gypsy moth; the Parkway is at the top of the watershed along with a few ag leases, but watershed is very little impacted overall.	High #4
	High-elevation perennial seep	Graybeard Mountain Overlook seeps	363.4	4 high-elevation (5,450') seeps; pH measured in 1974-75 at 5.0-5.1; water source for Craggy Visitors Center?	High? #3

CATEGORY	RESOURCE	WATER BODY	MILE-POST	JUSTIFICATION	PRIORITY
	Stream	Redbank Branch (dift watershed from Yellowface?)	441.5	High-elevation (4,600'); BLRI owns this small watershed; State-designated Natural Heritage Site ("Redbank Cove"); northern hardwood?	High? #2
Agricultural impacts	Stream	West Fork Chestnut Creek & Chestnut Creek	215-216	Ag impacts; VADGIF fish sampling site; runs through Fishers Peak wetlands (potentially 2 sites)	High #2
	Stream	Glade Creek (see above in 303d category)	107.9		
	Stream	Little Glade Creek	229	BLRI owns a lot of it; Streambank restoration in 1992; NPS Ag lease for pasture; state-designated Wild Trout Water	High? #3
	Stream	Meadow Fork	247	Streambank restoration planned for 2005 (potential before and after data); state Natural Heritage Area close by.	Medium?
	Mountain bog/fen	Coy Wade Bog (see below in Other significant resources/wetlands)	163.7	Rare wetland type; Federally-listed bog turtle; trib to Dodd Cr. (303d); Ag impacts from NPS leases & off-park ag. (maybe co-locate sampling sites to include this and another site on Dodd Creek?)	High #1
	Stream, mountain bog/fen	Cold Prong	297.7	Ag impacts; bog turtles (only 1 found so far); nice stream but not as good as Coy Wade Bog	Low?
Vegetation change	Stream	Sims Creek above Pond	295.9	Old-growth hemlock dominates watershed (imminently Threatened by HWA) – shift from hemlock to hardwood could change hydrology because of increased evapotranspiration; BLRI owns almost all of the watershed; minor disturbance from housing developments and agriculture upstream;	High? #1
	Stream	Rockcastle Creek	169	Relatively pristine watershed; almost all within BLRI boundary; imminent threats to watershed from gypsy moth and HWA; wetland at the bottom with Fed-listed bog turtles; VADGIF may be doing some sampling here. (Bambi: best sampling location is just outside park at bridge crossing near confluence of Rockcastle and Little Rockcastle)	High #2
	Stream	Basin Creek (see above in Acid Dep.)	243		
Development impacts	Stream	Otter Creek	~60	BLRI campground, other in-park development impacts; leach field problems; ~8 miles on BLRI (one of the park's longest stream reaches)	High #1
	Stream	Sims Creek below the Pond	295.9	Reservoir impacts on stream; ag leases, bog turtles, picnic ground; many issues and resources;	Low?
	Stream	Boone Fork above Price Lake	297	Hurricane impacts in 2004 resulted in lots of sediment deposition, spillway and dam blowout; won't stabilize for a long time; potential 300-acre development upstream	Low
	river	Linville River (or Camp Creek at MP 313 – impacts similar but less serious; no in-park development impacts? resources not quite as significant?)	316.6	Impacts from NPS campground; off-park development, nurseries (pesticides); heavy visitor use; acid dep. (USFS found extremely low pH and high aluminum in this watershed); under consideration as Wild and Scenic River?	High #2
	Stream	Crabtree Creek and Falls	339.5	High visitor use; in-park development impacts; BLRI owns almost all of the headwaters; NPS would be the only source of threats;	Medium #3

CATEGORY	RESOURCE	WATER BODY	MILE-POST	JUSTIFICATION	PRIORITY
Other significant resources/wetlands	mountain bog/fen	Coy Wade Bog (see above in ag impacts)			High
	mountain bog/fen	Love Bog	15.6	Rare wetland type; relatively pristine; Federally-listed plant (Helonias bullata); state-listed plants; threats from adjacent lands to water quality and hydrology; ATV's and logging on tributaries above.	High #3
	mountain bog/fen	Saddle Mountain Church Natural Heritage Area	222.2	Probably best bog turtle site on BLRI; State-designated Natural Heritage Area; some ag impacts from cattle grazing, but these were controlled with fencing about 2 yrs ago; easy access.	High? #2
	mountain bog/fen	Flat Laurel Gap Bog (Mt. Pisgah)	407.3	12,000 year-old bog; excellent example of very rare wetland type; state-designated RHA; surrounded by campground and traversed by NPS wastewater line; rare wetland type; high elevation; acid dep?; 4 bird spp. of concern (northern saw whet owl, olive-sided flycatcher, brown creeper; S. Appalachian yellow-bellied sapsucker); state-listed plants (*Lonicera Canadensis, Tofieldia glutinosa, Eriophorum virginicum*) (monitor below bog and above the sewage treatment plant)	High #1

Table 1.10. BISO water bodies selected for monitoring: Summary of available data, trends

PRIORITY	SITE NAME	ACCESS	GAUGE TYPE	PERIOD OF RECORD	JUSTIFICATION & ISSUES FOR SITE SELECTION
1	New River At New River, TN	Bridge	continuous	1934 - present	Represents major water quality contribution concerns in BISO from surface mining, oil and gas exploration and forestry operations.
2	Big South Fork at Leatherwood Ford	Bridge	continuous	1942 to present	Good main stem site that integrates flow from the upper portion of the drainage basin. Significant historic water quality data.
3	Clear Fork Near Robbins, TN	Bridge	continuous	1930 to present	Cleanest major tributary, eight mussel species (one Federally listed) Removed from TN 303d list in 1998, was listed for siltation due to silviculture.
4	White Oak Creek At Rugby, TN	Bridge		1980-1982	Taken off 303d in 1998, was listed for siltation from resource extraction First STP constructed five years ago Six mussel species (one Endangered) Oil and gas exploration and extraction at lower end

PRIORITY	SITE NAME	ACCESS	GAUGE TYPE	PERIOD OF RECORD	JUSTIFICATION & ISSUES FOR SITE SELECTION
5	Mouth Of Bear Creek	4x4 Road			303d listed for Iron, pH and siltation from resource extraction. Mussel population poor just downstream of mouth.. Poor access on 4x4 low maintenance road Possibly most severely degraded stream in the park
6	Near Mouth Of North White Oak Creek	4x4 road	staff plate		Old deep mining. Development along park boundary. Jamestown water supply. Recently became park lands. Oil and gas exploration and extraction. ,Two mussel species (one Federally listed). Was removed from 303d list in 1998, was listed for pH from Abandoned Mining. No bridge access for storm sampling. Possibly cleanest stream in basin.
7	Laurel Fork of Station Camp Creek at horse trail crossing				TDEC eco-region monitoring site for Cumberland Plateau Eco-region. No Bridge access for storm sampling.
8	Roaring Paunch Creek At Barthell, KY	Bridge			Home of rare – ancient crayfish. Poor biological health. Oil and gas exploration and extraction and coal mining. 303-d listed for Siltation and low pH from resource extraction
9	Pine Creek At Toomey Bridge	Bridge	staff plate		8 sections of Pine Creek are on the TN 303d list. Multiple sources of pollution. Better access than at mouth of Pine Creek; state is already monitoring
10	Mouth Of Rock Creek	Good access			Designated a Kentucky Wild River, High Quality Waters TN state line to White Oak Creek 303d listed in KY (2 sections) -- Low pH and Mercury from Resource extraction activities and acid mine drainage (AMD)
11	Bandy Creek at Hwy 297 bridge crossing	Bridge	staff plate		Sewage outfall from NPS campground is here; concern for fecal coliform, nutrients.
12	Williams Creek				Impacts from development on park boundary; monitoring here would also incorporate Puncheon Camp Creek where there is illegal dumping of waste water from septic tank trucks
13	Big South Fork Cumberland River Near Stearns, KY	Condemned cableway	continuous	1942 to present	Down stream integrator site, long term water quality data. Ten years of continuous sediment, and field parameters from 1980 to 1990.

Table 1.11. OBRI water bodies selected for monitoring: Summary of available data, trends

PRIORITY	SITE NAME	ACCESS	GAUGE TYPE	PERIOD OF RECORD	JUSTIFICATION & ISSUES FOR SITE SELECTION
1	Obed River at Alley Ford	Difficult walk; condemned cableway	Continuous		Existing gauging station not currently operational; excellent integrator site for the Obed and Clear Creek, incorporating everything inside the park; immediately downstream of the best biological resources in the Obed R., and immediately upstream of the Emory River which contributes heavy pollutant loads to the Obed R.
2	Clear Creek at Lilly Bridge	Bridge	Continuous	1997-present	Most downstream point on Clear Creek easily accessed, has a gauging station
3	Daddy's Creek at Devils Breakfast Table	Low head Bridge	Staff Plate		Good amount of historic data, new bridge going in (might want to give this site time to stabilize after bridge construction). Most downstream site on Daddy's Creek
4	White Creek at Mouth near Barnett Bridge	Road	Staff plate		Large tributary to Clear Creek, oil and gas exploration and extraction. No bridge for storm water measurements, but water sample may be collected from right side of Barnett bridge during storms. Confluence of White Creek to Clear Creek very close to bridge and is not mixed at bridge.
5	Obed River at Adams Bridge	Bridge	Staff plate		Most upstream site that is accessible, below Crossville, monitor urban influences on the Obed.
6	Otter Creek at Road Crossing in Catoosa WMA	Bridge	Staff plate		Upper end of drainage basin influenced by urbanization including retirement communities and trailer parks. Discharge from bottom of reservoirs may be an issue. Land application of municipal waste. Access limited during periods from Catoosa WMA.
7	Emory River at Nemo Bridge	Bridge	Staff plate		Downstream integrator site of the whole drainage area of OBRI. Recommend stream gage to be installed at this site.
8	Emory River near Lancing	Bridge			Most downstream site in Emory drainage in the park, good bridge access. Emory confluence is at lower end of Park.
9	Rock Creek at mouth nr Nemo Bridge	Bridge	Staff plate		Most heavily impacted of all streams in basin from AMD. Rock Creek is at lower end of Park.

C. AIR QUALITY

(See Table 1.13 and Figures 1.8 and 1.9 for details and graphic representations of ongoing air quality monitoring in and near the network parks; also, air quality information for the APHN is now available at www2.nature.nps.gov/air/Permits/ARIS/networks/aphn.htm and at http://www2.nature.nps.gov/air/Maps/AirAtlas/index.htm).

GRSM is designated as a Class I area under the Clean Air Act, meriting the greatest degree of air quality protection. This legislation also mandates that the Park Service "protect air quality-related values" including visibility, flora, fauna, surface water, ecosystems, and historic resources.

Air-borne pollutants, mostly from emissions outside the Southern Appalachian Mountains, are degrading park resources and visitor enjoyment of scenic vistas. Fossil fuel combustion from power plants, factories, and automobiles is the primary source of these emissions. The height and physical structure of the Southern Appalachians (the highest in eastern North America), combined with predominant weather patterns, tend to trap and concentrate these anthropogenic pollutants in the area occupied by APPA, BLRI, and GRSM. GRSM receives some of the highest depositions of sulfur and nitrogen in North America. Despite declining national trends, sulphur dioxide emissions affecting the Southern Appalachians have increased in the past two decades, deleteriously affecting air quality and visibility. These pollutants are deposited in the form of rainfall, dry particles and cloud water. The average annual pH of rainfall in GRSM is ten times more acidic than natural rainfall. Clouds with acidity as low as pH 2.0 bathe the high elevation forests during much of the growing season. Some high-elevation park streams have the highest nitrate levels of any systems in the U.S. that drain undisturbed watersheds. Research at GRSM has shown that some high-elevation soils in the park are receiving so much airborne nitrogen that they are suffering from advanced nitrogen saturation. This limits the availability of forest nutrients to plants and causes the mobilization of toxic ions such as aluminum that can harm vegetation and aquatic biota. Sensitive mountain streams and forest soils are being acidified to the point that the health of the park's high elevation ecosystems is in jeopardy. Nitrate levels in some streams are approaching the public health standard for drinking water (GRSM Briefing Statement, September 2002).

Ground-level ozone, another air quality problem in the Southern Appalachians, is formed when nitrogen oxides from automobiles and factories mix with hydrocarbons in the presence of sunlight. Most ozone pollution originates outside the park and travels to the Southern Appalachians on prevailing winds. Current ozone exposures are causing significant injury to at least 30 species of native plants in the Southern Appalachians. In general, ozone exposure and related vegetation damage are worse at higher elevations. Ozone monitoring stations in the Great Smoky Mountains, at the southern end of the Blue Ridge Parkway, have documented ozone exposures that are among the highest in the eastern United States, exceeding the National Ambient Air Quality Standard (NAAQS) for the protection of public health (GRSM Briefing Statement, September 2002). Ozone-sensitive species have been identified in all five network parks.

Because of air quality degradation, the standard visual range in the Southern Appalachian Mountains is currently about 22 miles; average natural background visibility is 93 miles (SAMAB 1996c; NPS 1997b). During severe haze episodes at GRSM, visibility has been reduced to less than one mile (J. Renfro, pers. com. 2003). Obviously, reduced visibility negatively affects public enjoyment of scenic mountain vistas, a resource of great importance to visitors to the Blue Ridge Parkway, Appalachian Trail and Great Smoky Mountains National Park, all of which are renowned for their high-elevation views of the surrounding landscape. (GRSM Briefing Statement, September 2002)

Little specific information is available on air quality within the Cumberland Plateau parks, but data from nearby monitoring stations indicate that surface waters at BISO and OBRI are not susceptible to acidification from atmospheric deposition. Ozone is a significant air pollution threat for Network parks, both in terms of human health and impacts to vegetation, but spatial differences in ozone concentrations are unknown for BISO and OBRI, and need to be determined (Maniero 2004).

1.4 KEY MANAGEMENT/SCIENTIFIC ISSUES

Water quality and quantity, air quality, and Threatened and Endangered species are three of the most significant natural resource management issues for the Network parks (see detailed discussion above). In addition to these, there are numerous other issues that threaten the resources of APHN parks. Many of these are common to most parks within the NPS system, including habitat fragmentation, invasive exotic species, introduced forest pests and diseases, unsustainable or inappropriate recreational use, and intensive development or resource extraction adjacent to park boundaries (Table 1.12 and Appendix G).

TABLE 1.12: Major natural resource management issues facing APHN parks in 2004.

	APPA	BISO	BLRI	GRSM	OBRI
ATMOSPHERIC	• Air quality degradation due to transported emissions (acid depsn.) • Visibility declines • Ozone damage to vegetation, human health effects • Impacts to surface waters, soils	• Lack of specific data on air quality	• Air quality degradation due to transported & vehicle emissions (acid depsn.) • Visibility declines • Ozone damage to vegetation, human health effects • Impacts to surface waters, soils, invertebrates, fish	• Air quality degradation due to transported emissions (acid depsn.) • Visibility declines • Ozone damage to vegetation, human health effects • Impacts to surface waters, soils, invertebrates, fish	• Lack of specific data on air quality
TERRESTRIAL	• Invasive exotics • Introduced insect pests, disease • Habitat fragmentation due to adjacent land use change • Unsustainable recreational use • T&E plants and animals, communities • Lack of basic information on invertebrates, non-vascular plants	• Invasive exotics • Introduced insect pests, disease • Fire suppression in fire-adapted habitats • Species and community diversity • Unsustainable harvest of sensitive resources • Unsustainable recreational use • Habitat fragmentation due to adjacent land use change, inholdings • Birds of conservation concern • Lack of basic information on invertebrates, non-vascular plants • Lack of data on rare species distribution, abundance	• Invasive exotics • Introduced insect pests, disease • Fire suppression in fire-adapted habitats • Species and community diversity • Unsustainable harvest of sensitive resources • Habitat fragmentation due to adjacent land use change, inholdings • Unsustainable recreational use • White-tailed deer overpopulation and associated vegetation impacts • Birds of conservation concern • T&E plants and animals, communities • Lack of basic information on invertebrates, non-vascular plants • Lack of data on rare species distribution, abundance	• Invasive exotics • Introduced insect pests, disease • Fire suppression in fire-adapted habitats • Species and community diversity • Poaching of rare plants • Unsustainable recreational use • White-tailed deer overpopulation and associated vegetation impacts • T&E plants and animals, communities	• Invasive exotics • Introduced insect pests, disease • Fire suppression in fire-adapted habitats • Species and community diversity • Habitat fragmentation due to adjacent land use change, inholdings • Unsustainable recreational use • Lack of basic information on invertebrates, non-vascular plants • Lack of data on rare species distribution, abundance
AQUATIC	• Lack of basic aquatic resources inventory • Atmospheric deposition impacts to high-elevation ecosystems	• Water withdrawal for municipal, industrial use • E/T fish, mussels • Contaminated mine drainage • Siltation/erosion from roads & trails, nutrient runoff	• Atmospheric deposition impacts to high-elevation ecosystems • Agricultural impacts, including pesticide drift and runoff, erosion	• Atmospheric deposition impacts to high-elevation ecosystems • E/T fish	• Water withdrawal for municipal, industrial use, impoundments • E/T fish, mussels • Contaminated mine drainage • Lack of species diversity
GEOLOGIC	• Erosion • Calcium loss from high-elevation ecosystems (related to atmospheric deposition)	• Mining, drilling-oil, gas, coal • River channel geomorphology alteration	• Calcium loss from high-elevation ecosystems (atmospheric deposition) • Slope failure/landslides	• Calcium loss from high-elevation ecosystems (related to atmospheric deposition)	• Mining, drilling-oil, gas, coal • River channel geomorphology alteration

A. INVASIVE EXOTIC SPECIES

BLRI, APPA: Because of the narrow corridor occupied by the Appalachian Trail and the Blue Ridge Parkway, invasion by exotic plant species is a constant problem, although the high elevations on the southern end of these parks and the relatively wide corridor through National Forests and National Parks have limited the problem to some extent. At least 15 of the Trail's Endangered species sites and many rare plant populations on the Parkway are threatened by invasive exotic plants. Over 100 exotic plant species have been documented from the Parkway and the Appalachian Trail. Many incursions of exotic plants are near road crossings, utility corridors or agricultural lands. The Parkway crosses more than 300 public highways, and is crossed by over 400 utility rights-of-way, representing unlimited opportunities for invasion and re-invasion by exotic plant species (NPS 1992). The Southeast Exotic Plant Management Team, stationed at BLRI in 2003, is working to control invasive plants in this and 16 other Southeastern parks, including BISO and OBRI.

GRSM: Exotic plants and European wild boar are significant management concerns for this park. Exotic plant management is a long-term commitment for park management, with the first control efforts having started in the mid-1950's. Over 600 exotic-infested sites are monitored annually and re-treated if necessary, sometimes requiring 10 years for complete eradication. From 1995 to 1999, the number of managed sites increased by 35 percent and the number of species under management increased by 20 percent (National Park Service 1999). Some exotic species are capable of extremely rapid growth (kudzu, for instance, can grow 12-15 inches per day) and one year's progress can be lost the following year if treatments are not continued. Every year new sites are identified and new species are added to the control list (National Park Service 1999).

The European wild boar is one of the major resource threats to the park. These animals entered GRSM in the 1950's and have since spread throughout the park. Hogs are causing considerable damage to native ecosystems, with the greatest of these impacts occurring within mesic areas and in unique high elevation ecosystems, both of which contain numerous rare and Endangered flora and fauna and sensitive communities. Wild hogs cause changes in vegetative cover, erosion, diminished water quality, and they compete for mast crops with native wildlife. In the last 50 years, more than 8,800 hogs have been removed from the park. Given current technology and limitations, hogs cannot be completely eradicated; however, with adequate resources, the population can be significantly reduced and resource impacts minimized (National Park Service 1999).

BISO, OBRI: Invasive exotic plants are a significant problem in certain areas within the Cumberland Plateau parks, particularly in floodplain and other riparian habitats. The parks' rarest plants and most Threatened natural communities are in these situations, and are therefore the most Threatened by invasive exotics. The largest concentration of European wild boar in Tennessee and Kentucky occurs in and adjacent to BISO. Hogs expanded quickly after being introduced to this area, and their current range extends throughout the park and into the surrounding region (Mayer and Brisbin 1991). The park is now the source population for the rest of the Cumberland Plateau. Of greatest concern are the destructive effects of hog rooting and wallowing in sensitive wetland areas, where state- and Federally-listed plant and amphibian species are found. In the park, these areas include floodplains, marshes, streamheads, seeps and natural wet depressions. Over half of the park's roughly 110 Federally- and state-listed species are dependent on these areas.

B. FOREST HEALH – INFESTATIONS AND DISEASE

BLRI, GRSM, APPA: During the last century, the forests of the Southern Appalachians and adjacent regions have been subject to an influx of new exotic insects and diseases, which have caused significant declines in several forest community types. The first and most devastating of these was the chestnut blight of the 1930's, which virtually removed the American chestnut (a dominant canopy tree) from the forest landscape of eastern North America. Since it was first discovered in 1954, the balsam wooly adelgid has virtually eliminated mature Fraser fir from high-elevation spruce-fir forests in the Southern Appalachians (GRSM contains 74 percent of the remaining forest of this type) (Dull *et al.* 1988). The decline in Fraser fir has placed other species associated with this community in jeopardy. For example, eight species of mosses and liverworts occur exclusively on the bark of this fir. A small tarantula, Federally-listed as Endangered and endemic to a few sites in the Southern Appalachians, a Federally-listed Endangered lichen, and two salamander species, are among the native species which occur in these red spruce-Fraser fir forests.

The gypsy moth, first detected in network parks in 1988 on BLRI, is becoming a serious threat to the oak forests of the park, in spite of attempts by Park staff and other Federal and state agency personnel to slow the spread. Loss of the canopy as a result of defoliation, and the accompanying decline in oak mast, will impact many terrestrial species, aquatic ecosystems and viewsheds. Since the late 1980's, dogwood anthracnose, a pathogenic fungus, has been killing dogwoods throughout the Southern Appalachians, which may be affecting calcium cycling based upon initial findings from research at GRSM (M. Jenkins pers. com. 2004). The hemlock wooly adelgid, another introduced pest, is also severely affecting hemlock forests in these three parks, to the detriment of many associated species of terrestrial vertebrates, invertebrates, plants and aquatic biota. Most of the hemlocks in Shenandoah National Park on the north end of BLRI are already dead; damage is expected to become severe as this Asian insect advances southward. Currently, beech bark disease, an insect/fungus complex, is killing beech trees in upper elevation hardwood forests (M. Jenkins 2001). In APPA, BLRI, and GRSM, American beech occurs as the dominant species in gaps at high elevations. In some of these areas, it is the only deciduous, hard-mast producing tree. Because soils in beech gaps are less acidic and contain more organic matter than soils in the surrounding spruce-fir forests, a diverse assemblage of herbaceous species is often found in these areas. The presence of the introduced European beech bark scale disease was confirmed in GRSM in 1993. Between 1994 and 1996, the mortality of beeches in areas sampled increased from 71 percent to 87 percent (G. Taylor, pers. com. 2003). Additional forest insects and diseases of concern to park management include: butternut canker, rhododendron die-back (a fungal disease), an American holly fungal disease, and European mountain-ash sawfly.

BISO, OBRI: As of 2004, the hemlock wooly adelgid had not arrived on the Cumberland Plateau, and hemlocks there remain unaffected. Aside from an isolated and quickly controlled outbreak of gypsy moths near BISO, this pest has not affected the oaks of the Plateau at present. Chestnut blight and dogwood anthracnose have affected the forests in BISO and OBRI in a fashion similar to that at BLRI, GRSM and APPA.

C. FIRE

There are several fire-dependent communities in the APHN parks, including native grasslands, oak savannas, pine-oak heaths, and gorge rim communities. These communities, and the rare species they support, are adapted to and dependent upon periodic wildfire to maintain their characteristic vegetation patterns and composition. Without fire to curtail succession, the structure and species composition of these habitats change rapidly, and most of the rare species disappear. Species of concern that are dependent upon this type of disturbance include the timber rattlesnake, northern pine snake, golden-winged warbler, prairie warbler, grasshopper sparrow, Henslow's sparrow, Bachman's sparrow, Bewick's wren, and red-cockaded woodpecker (the latter two species are now extirpated from APHN parks), as well as numerous rare plants including the Federally-listed Threatened Heller's blazing star (a Blue Ridge Mountain endemic), death camas, and turkeybeard.

BLRI: In 2001, the Parkway had 22 wildfires, and provided support to fight 14 additional wildfires on adjacent lands. The park requested a Fire Readiness Review by the regional office, which identified a number of areas for improvement and documented a poor representation of the complexity of fire program needs by the standard analysis tools employed. The park is bordered by several of the highest risk communities identified by state foresters and the national fire plan. A fire management plan has been prepared for the park (NPS 2002), which includes direction for some prescribed burning in fire-adapted communities.

GRSM: Since the early 1930's, lightning fires have accounted for 10 percent (110 of 1,102) of the total fires in Great Smoky Mountains National Park, for an average of 1.6 per year; however, annual totals have fluctuated from zero to 10 natural ignitions. From the establishment of the park in 1934 to 1996, NPS policy was to extinguish all fires. This resulted in biological conditions different from those of a natural fire regime, particularly including the loss or decline of species and communities that are adapted to periodic fire. The use of fire as a management tool is now recognized by NPS Management Policies and fire management guidelines. The GRSM Statement for Management commits the park to: "...where possible, restore natural processes as they would proceed if they had never been influenced by non-Indian society." In 1998, the park managed its first lightning-caused fire under its approved Fire Management Plan - 370 acres were burned over the course of 4 days. In recent years, the Park has managed over two dozen prescribed burns, affecting several thousand acres (National Park Service 1996b; National Park Service 1999; M. Jenkins, pers. com. 2005).

BISO, OBRI: While the role of fire in these parks and how it has influenced their ecosystems is not completely understood, it is known that fire-adapted species and communities in the region are rapidly disappearing. There were formerly 25 colonies of the fire-adapted, Federally-listed Endangered red-cockaded woodpecker on the Plateau within a twenty mile radius of BISO; all had disappeared by the early 1980's. The only population in Tennessee and Kentucky of the Federally Endangered chaffseed, also a fire obligate, was recorded within or adjacent to BISO in the 1930's. Repeated searches for this rare fire remnant have proved unsuccessful. Native, fire-maintained grassland communities, once much more common and greater in size and extent, are now restricted to a few small patches along old backcountry road margins in the Cliff Section of BISO, and will soon be extirpated, unless management intervention with fire occurs. The guild of birds dependent on these habitats is rapidly declining. Roughly fifty state-listed plants occurring in the Big South Fork region, some more common only decades ago, are rare now because of the absence of fire (Campbell et al., 1991). BISO is in the process of completing a Fire Management Plan which will make it possible to restore fire to the ecosystem on a limited basis. Further research will be needed to determine appropriate fire regimes for particular community types. Because of its linear nature, small land base and largely vertical structure, OBRI is not planning for use of prescribed fire at present.

D. LAND USE (within and adjacent to parks)

APPA, BLRI, GRSM: This category includes incompatible land development immediately adjacent to the Parkway and the Appalachian Trail, such as construction of shopping malls, subdivisions, operation of open-pit mines, rock quarries, timber harvest, etc., as well as road-building, and construction of unauthorized trails. These land uses often encroach onto the Blue Ridge parks, compromising natural resources and the landscape qualities the Service is trying to preserve for park visitors. GRSM is somewhat less affected by this, being a large park with most of its resources remote from the developed areas on the boundary. The issue of "slope failure" and accompanying landslides is an issue for BLRI, and occasionally, for GRSM, where roads are built on steep slopes where the underlying geology makes the roadbed less stable. The landslides and subsequent repairs of the roads sometimes encroach upon the resources of the parks, where rare plants occupy adjacent rock outcrops, or where acidic Anakeesta formations are exposed, acidifying streams downslope (Moore 1998).

BISO, OBRI: Changing land use around the parks is an issue mainly in its implications for water resources. The waters of the Obed WSR and Big South Fork NRRA are significantly influenced by impacts from development occurring upstream in the watershed (as described in the Aquatic Resources section above). The major contributors to these impacts are municipal discharges, surface drainage from coal, oil and gas mining operations, and runoff from silviculture, agriculture and construction activities. The parks are participating in the development of a long-term regional water supply strategy that would allow the area's water utility districts to plan for the future without withdrawing unsustainable quantities of water from the parks' watersheds.

Internal and external developments are significant potential sources of water pollution and habitat fragmentation within BISO and its watershed. Currently, there are approximately 300 miles of roads within the park, most of which are unimproved dirt roads. The park also contains roughly 300 miles of horse, hiking and bicycle trails. The park's GMP (in draft) will designate a permanent roads and trails system and propose mitigation strategies for reducing associated environmental impacts. Unmaintained roads are a significant cause of erosion and sedimentation in the watershed (Vaculik et al., 1989). Many of the roads within the watershed are unimproved routes, built for access to mining, logging, and oil and gas operations. These roads were often improperly constructed, and have deteriorated with continued use. Road and trail impacts throughout the watershed are aggravated by:

- highly erodible soils and steep terrain
- improper construction, and lack of erosion control
- inappropriate stream crossings
- increased use by off-road vehicles
- improper location – in floodplains, or in streambeds.

Water quality impacts in park tributaries, resulting from erosion on roads, have been documented in Bear Creek, Roaring Paunch Creek, Laurel Fork of North White Oak Creek, and Williams Creek (Rikard et al., 1986). An inventory of trail conditions within the park is currently under way.

The impacts from abandoned coal mines and their associated contaminated mine drainage (CMD) are as significant in BISO as in any NPS unit. The Big South Fork is particularly vulnerable to CMD because of the prevalence of pyritic shales in the watershed, and sandstone-bedded streams that do not adequately buffer increased acid. There are approximately 100 abandoned deep coal mine openings in the Recreation Area. Thirty-seven of these are known to be causing contaminated mine drainage (National Park Service, 1990). Future deep mining within the park is possible on the 18,900 acres where mineral rights have been retained by private owners, so long as the mine entrances are located outside the boundary.

Water quality impacts from coal mining (discussed in detail above in the Aquatic Resources section) are most noticeable in the park tributaries of Bear Creek, Roaring Paunch Creek and lower Rock Creek, none of which support their state use classifications. Recent surveys of Bear Creek have found that macroinvertebrate and fish populations are nearly non-existent even after several abandoned mines were reclaimed (Stucki, 1995). The park tributaries of New River and Puncheoncamp Branch also exhibit CMD impacts (Rikard et al., 1986), and a large coal reserve in the New River drainage has now been proposed for mining.

BISO is also vulnerable to CMD-related pollution from outside its boundaries. There are approximately 25,000 acres of unreclaimed abandoned coal mines in and adjacent to the park (TN Abandoned Coal Mine Reclamation Committee, no date), and approximately 10 abandoned strip mine sites in the KY county which borders the park (McCreary County) (KY Division of Mines, no date). Approximately 69 permitted coal mines were active in the park's watershed in the mid-1990's (KY Division of Mines, 1995; TN Division of Water Pollution Control, 1996). There are currently no operating coal mines within OBRI, but portions of the park continue to be affected by contaminated mine drainage from abandoned mines (see Aquatic Resources section above).

Major oil well fire on OBRI boundary in 2002

The majority of Tennessee's oil and gas production occurs in the BISO watershed (Zurawski, 1995). There are approximately 300 active or abandoned oil or gas wells within the park. Many of these sites have environmental or health/safety problems. Oil and gas operations continue in the park on the 18,900 acres where mineral rights have been retained by private owners. Water quality impacts from oil and gas operations have been documented within the park on Clear Fork, New River and Pine Creek (Rikard et al., 1986). Four active oil wells are operating on inholdings within OBRI. A large oil well explosion and fire occurred adjacent to the park in 2002; the associated oil spill impacted Clear Creek, a major tributary stream within OBRI, and long-term damages are still being assessed and monitored.

E. UNSUSTAINABLE OR INCOMPATIBLE RECREATIONAL USE

APPA, BLRI, GRSM: With 20 million annual visitors to the Blue Ridge Parkway, management personnel face a considerable challenge in trying to provide public access to highly scenic places, while simultaneously protecting extremely sensitive high-elevation habitats and rare species that are sensitive to trampling. Several vegetation types on the Parkway, especially high-elevation grassy balds and cliff summit communities, have been impacted by heavy recreational use as well as disruption of natural disturbance regimes. These communities, which are themselves ranked as globally rare, are habitat for Federally-listed species, many of which are entirely endemic to the Southern Appalachian Mountains. The Park has initiated rehabilitation at some sites, but many more areas are identified as being in need of restoration. The Appalachian Trail traverses many fragile, high-elevation communities. The challenge for trail managers is to provide a quality recreational experience for hikers, while minimizing damaging impacts to sensitive natural resources. Trail maintenance also can threaten rare species that grow immediately adjacent to the tread. The Trail traverses the entire length of GRSM, occupying high-elevation ridges and passing through rare and sensitive communities.

Unsustainable recreational use problems at GRSM primarily involve trampling impacts to clifftop communities that support Federally- and state-listed plants.

BISO, OBRI: Horseback riding is particularly popular at BISO, and maintenance of horse trails is a continuing challenge for Park staff. Resource impacts have occurred at stream crossings, on steep terrain, and where riders (and other user groups) go off-trail to avoid boggy sites or downed trees. The Park's steep terrain restricts areas where trails can be placed, and concentrated trail use has also resulted in adverse impacts to natural resources. ATV use is legally restricted, but the parks do not have sufficient staff to enforce these restrictions; impacts include severe erosion of trails and impacts to water quality and damage to sensitive communities. Hikers and mountain bikers also use the parks' trails; impacts to resources from backcountry campsites are the main concern with these user groups. OBRI is becoming an ever more popular destination for recreational rock climbers. Climbers construct trails and clear vegetation along bluffs where climbing is taking place. Ladders and fixed routes are periodically installed by climbers, and holes are drilled into rockfaces to install fixed anchor points. Impacts to cliff communities and sensitive species are of concern to the Park (NPS 1994). A recent study of climbing impacts at OBRI (Walker et al. 2004) documented impacts of foot traffic associated with rock climbing activity in the talus slopes of climbed areas on both vascular and non-vascular species. An important incidental find of this study was the discovery of ancient red cedars, in excess of 800 years old, growing on the cliffs.

F. CONSUMPTIVE USE – Poaching, Legal Harvest

APPA, BISO, BLRI, GRSM, OBRI: The very nature of the Blue Ridge Parkway renders many of its resources extremely accessible to poachers – most resources are literally within a stone's throw of the pavement. Although poaching of all types occurs on the Parkway (deer, bear, fish, etc.), impacts are particularly damaging to rare species such as the bog turtle (Federally-listed as Threatened), rare plants and butterflies, and to medicinal and ornamental plants which have been taken in very large quantities from the Park in recent years. The Parkway has a very small law enforcement staff. Logistically it is not possible for this limited staff to handle all the resource violations that occur. Poachers have quickly perceived this situation and taken advantage of it by marking or stashing collected plants and other materials during the day, then returning at night to remove them, in some cases by truck-loads. This is also a threat in the other parks, but the volume of material removed is believed to be significantly less. Ginseng and other valuable medicinal plants have been poached for decades from GRSM, and undoubtedly from the other network parks as well, although specific data is lacking from BISO, OBRI and APPA.

The legislation establishing BISO and OBRI allowed for hunting, fishing, and trapping in accordance with Federal and state laws, in designated zones. However, there is little park-specific information on the condition of wildlife populations upon which to base management decisions. For example, while state regulations allow the hunting of fox squirrels, anecdotal information indicates they may be quite rare in the area. The parks do not have the resources to conduct monitoring related to legal harvest of wildlife.

A breeding population of black bears was re-established at BISO with an experimental release in the mid-1990's involving 14 adult female bears and their cubs from GRSM. Prior to this release, black bears had been essentially extirpated from the Cumberland Plateau; no evidence of reproduction in the few that remained had been documented in many years. The release was to test whether habitat in the park was sufficient to support these animals and to determine whether summer or winter relocation techniques were more likely to reduce post-release "homing" behavior. The winter releases, which involved placing mothers and their cubs into dens in BISO, proved to be far more successful. Based on radio-tracking and other ongoing monitoring, it appears that this protected, "founder" bear population is now stable.

No public hunting is allowed in GRSM, BLRI, or APPA. Primary wildlife management issues involve overpopulation of certain areas by white-tailed deer, with resulting impacts to vegetation composition and structure. Problems with white-tailed deer over-browsing are concentrated in certain sections of GRSM (Cades Cove) and BLRI (Peaks of Otter). Four previously extirpated species – river otters, peregrine falcons, red wolves and elk – have been recently reintroduced into GRSM. The otters and falcons appear to be established (the peregrine falcon was recently removed from the Federal list of Threatened and Endangered species). The red wolf reintroduction was not successful and the project was terminated in 1999. Fifty elk were released in 2000-2001, as part of a five-year experimental reintroduction to determine whether a permanent reintroduction is feasible.

1.5 PAST AND PRESENT NATURAL RESOURCE MONITORING

Long-term monitoring of natural resources in the APHN will officially begin following acceptance of the Network's monitoring plan in 2005. Past and current monitoring by NPS and adjacent land managers, although not coordinated into a holistic long-term monitoring program, provide valuable baseline information for some natural resources within the APHN parks (Tables 1.13 and 1.14). Additional data from US Forest Service Forest Inventory plots in the parks may provide further insights, but those data are currently unavailable.

Table 1.13: Summary of current (C, data collected within last 5 years) and historical (H, data collected more than 5 years ago) monitoring efforts within parks of the Appalachian Highlands Network. Shaded cells indicate monitoring work funded by NPS.

Monitoring Categories	APPA	BISO	BLRI	GRSM	OBRI	TOTAL
Air Quality:						
Acid Deposition						1
Ozone		C	C	C		3
Visibility				C		1
Fine Particulates				C		1
Mercury Deposition				C		1
Other Toxics						
Meterology:						
Temperature, Relative Humidity		C		C		2
Precipitation		C		C		2
Visual landscape:	C		C	C		3
Water Quality:						
Core Elements (Temp, pH, Cond, DO)	C	H		C	H	4
Turbidity and Siltation		H			H	2
Contaminants		H		C	H	3
Bacteria		H		C	H	3
Aquatic Macroinvertebrates		C		C	H	3
Water Quantity:						
Ground Water Levels			C			1
Surface Water Flow		C	C	C	C	4
Faunal Characteristics:						
Mammals		C	C	C		3
Birds		C	C	C	C	4
Amphibians			C	C		2
Reptiles			C			1
Fish				C	C	2
Exotic Animals		C		C		2
Vegetation:						
Rare Natural Communities			C	C		2
Rare Plants	C		C	C		3
Fire Effects		C		C		2
Plant Community/Population Changes			C	C		2
Exotic Plants	C	C	C	C	C	5
Forest Insects and Diseases	C	C	C	C	C	5

Table 1.14: Principal topics for past and present multi-year monitoring efforts in APHN parks, broken down by broad ecological resource categories - To date, over 200 park projects have been initiated that include some kind of multi-year observations or analyses to determine the condition of a biotic or abiotic resource (Appendix B); (almost all of these were short-term projects).

	APPA	BISO	BLRI	GRSM	OBRI
ATMOSPHERIC		-weather -ozone	-ozone	-weather -ozone -trace gases -deposition of N, S, Hg, wet deposition, base cations -particulates/visibility -CASTNet, NADP/NTN, IMPROVE	
TERRESTRIAL	-rare plants -invasive exotic plants -forest insects/disease	-breeding birds -wintering birds -fire effects -recreation effects from trail use -gypsy moth	-vernal pool amphibians -bog turtle -breeding birds -peregrine falcon -northern flying squirrel -rare plants -invasive exotic plants -recreation effects on rare plants -gypsy moth -beech bark disease -hemlock	-vernal pool amphibians -birds -peregrine falcon -black bear -white-tailed deer -northern flying squirrel -European wild boar -bats -vegetation composition, structure -rare plants -invasive exotic plants -fire effects -gypsy moth -mountain ash sawfly -southern pine beetle -beech bark disease -hemlock -Fraser fir -introduced diseases of rhododendron, butternut, and holly	-breeding birds -wintering birds -recreation effects on cliff-face plant communities
AQUATIC	-water quality	-aquatic macroinvertebrates -freshwater mussel baseline surveys -water quality (contaminated mine drainage, sewage effluent, siltation, effects of oil and gas extraction) -water quantity/hydrology	-water quality (various parameters)	-aquatic macroinvertebrates -brook trout -fish communities -rare fish -water quality (effects of atmospheric deposition)	-fish (NAWQA) -spotfin chub -freshwater mussel baseline surveys -water quality (contaminated mine drainage, sewage effluent, siltation, effects of oil and gas extraction) -water quantity/hydrology
GEOLOGIC			-Seismic activity (earthquakes)		

A. ATMOSPHERIC RESOURCE MONITORING

Great Smoky Mountains National Park is designated a Class 1 area under the Clean Air Act, and this park operates the most intensive air quality monitoring program in the Network, monitoring ozone and trace gases, deposition (N, S, Hg, wet deposition, base cations), and particulates/visibility. GRSM is one of approximately 70 CASTNet (Clean Air Status and Trends Network) monitoring stations in the U.S. Established in 1987, CASTNet is considered the nation's primary source for atmospheric data to estimate dry acidic deposition. GRSM monitors weekly atmospheric concentrations of sulfate, nitrate, ammonium, sulfur dioxide, and nitric acid; hourly concentrations of ambient ozone; and meteorological conditions required for calculating dry deposition rates. Dry deposition rates are calculated using atmospheric concentrations, meteorological data, and information on land use, vegetation, and surface conditions. Because of the interdependence of wet and dry deposition, NADP/NTN wet deposition data are collected at or near all CASTNet sites, including GRSM. Together, these two long-term databases provide the necessary data to estimate trends and spatial patterns in total atmospheric deposition. All of the other NPS units in the Appalachian Highlands Network have an NADP/NTN wet deposition monitor within 60 km, and a CASTNet dry deposition monitor within 70 km.

As part of its atmospheric deposition effects monitoring, GRSM monitors surface water chemistry with an intensive weekly water quality monitoring program at the Noland Divide watershed. In addition, GRSM conducts bi-monthly water quality sampling at 46 locations throughout the Park. Monitoring data indicate that some streams in the park are susceptible to acidification from atmospheric deposition, and some are currently experiencing either episodic or chronic acidification. In general, the sensitive streams tend to be at higher elevations (Maniero 2004; Robinson *et al*. In Press).

There are no indications that surface waters in Big South Fork NRRA or Obed WSR are susceptible to acidification from atmospheric deposition. Data indicate some streams on the Blue Ridge Parkway may be acid-sensitive; additional water chemistry monitoring is needed in this park. The sensitivity of surface waters on the Appalachian Trail is not known; characterization surveys could help determine if sensitive surface waters occur on the Trail. Given the high levels of nitrogen and sulfur deposition monitored in the region and the sensitivity of park surface waters, atmospheric deposition and surface water acidification are concerns, especially for higher elevation ecosystems in the Appalachian Highlands Network.

In 1985, in response to the mandates of the Clean Air Act, the Interagency Monitoring of Protected Visual Environments (IMPROVE) Program was established to protect visibility in Class I air quality areas. The objectives of this monitoring program are to establish current visibility conditions in all Class I areas, to identify pollutants (particles and gases) and emission sources responsible for existing man-made visibility impairment, and to document long-term trends in visibility. Fine particles in the air, typically those less than 2.5 microns in diameter ($PM_{2.5}$) are a leading cause of human respiratory illness. These fine particles are also the main contributor to visibility impairment. The particles not only decrease the distance one can see, they also reduce the colors and clarity of scenic vistas. Moisture in the air enhances the impact, so areas in the eastern U.S., having higher relative humidity, have worse visibility than areas in the arid West. Since 1988, GRSM has monitored particulate matter through an IMPROVE station that tracks atmospheric concentrations of particles 2.5 microns or less in size. All of the other NPS units in the Appalachian Highlands Network have an IMPROVE visibility monitor within 140 km and a PM_{10} monitor within 35 km. IMPROVE monitoring documents regional visibility impairment and trends; it does not capture localized "hot spots" of visibility impairment. (Maniero 2004; Renfro, pers. com. 2004).

Historic visual range: 113 miles

Current average visual range: 25 miles

Figure 1.7: Air pollution at Look Rock, GRSM

Visibility in the southern Appalachians has been seriously degraded over the past 50 years by anthropogenic pollution; based on regional airport records, average annual visibility in the region has decreased by 80 percent in summer, and 40 percent in winter. The current average visual range at GRSM is 25 miles, compared with the average natural background visibility of 113 miles. Declining visibility is well correlated with emissions of sulfur dioxide. Fine sulfate particles, from the transformation of sulfur dioxide emissions, cause light to be scattered, and are responsible for 83 percent of chronic visibility impairment during summer months in GRSM (NPS 1997).

Ozone is a significant air pollution threat for Network parks, both in terms of human health and vegetation. GRSM and BLRI have several ozone monitors onsite, and GRSM has been conducting surveys of sensitive plant species in recent years, documenting both high ozone levels and substantial injury to vegetation (Maniero 2004; NPS 1997b). All other Network parks have an ozone monitor on-site or within 30 km. Nevertheless, because ozone concentrations are heavily influenced by elevation and location of pollution sources, it is desirable to confirm the adequacy of nearby off-site monitoring for the Appalachian NST, Big South Fork NRRA and sections of the Blue Ridge Parkway. It is also desirable to document any spatial differences in ozone concentrations at Big South Fork NRRA and Obed WSR. Ozone-sensitive species have been identified for all five NPS units in the Appalachian Highlands Network. Vegetation surveys to document ozone-induced foliar injury are warranted at all Network parks. GRSM monitors three planted “ozone gardens” to measure the effects of ozone on four native species of herbaceous plants.

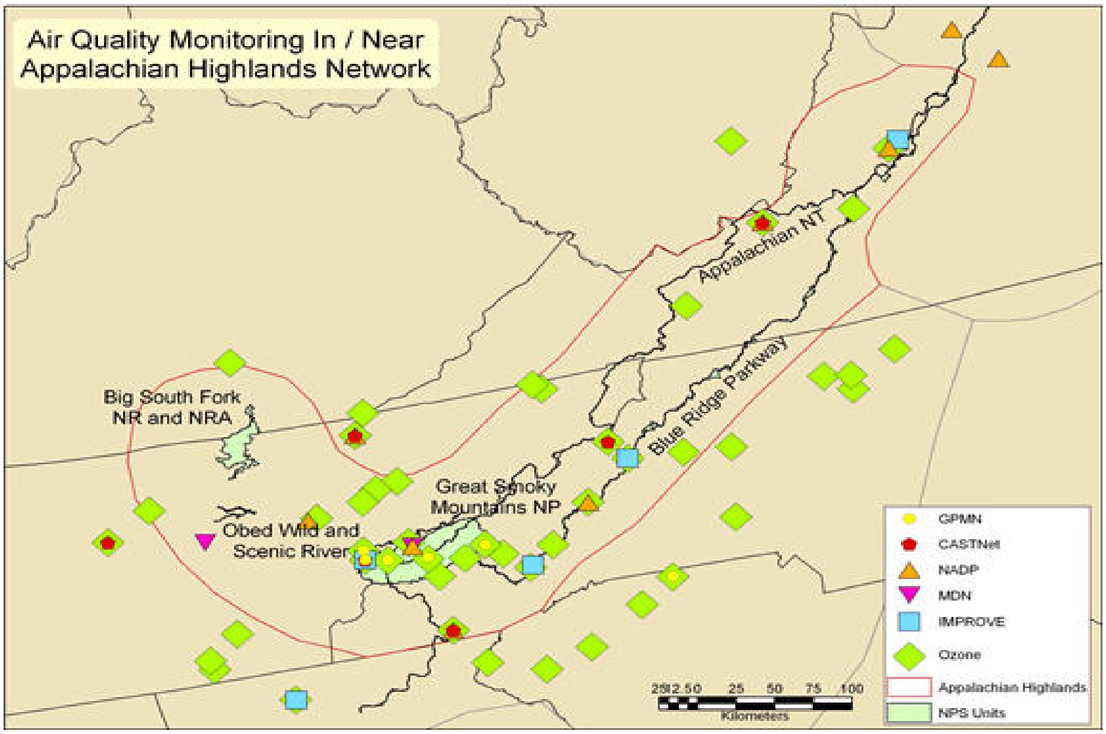


Figure 1.8: Existing air quality monitoring stations in or near APHN parks

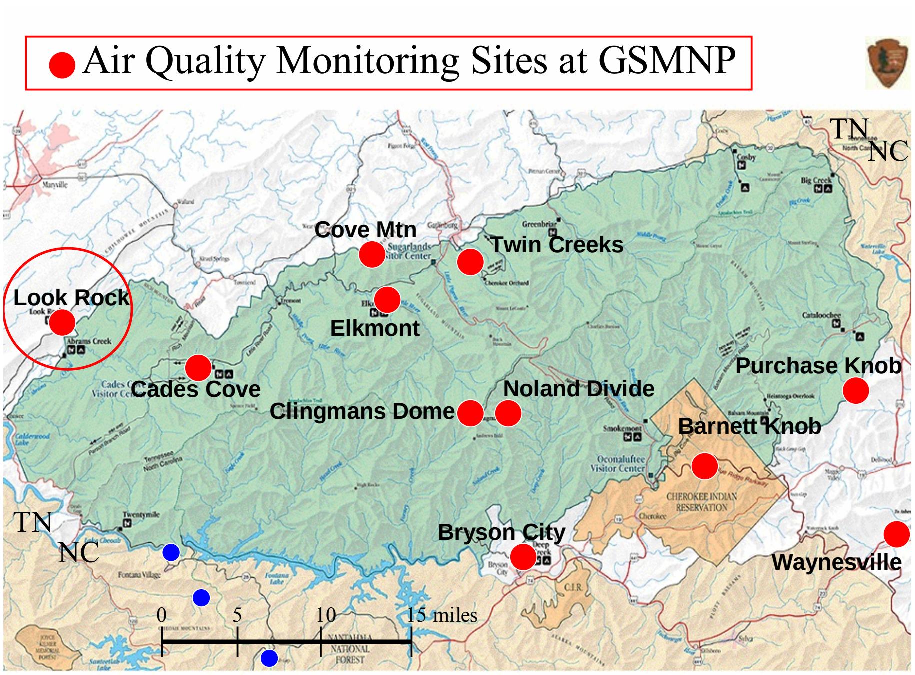


Figure 1.9: Existing air quality monitoring sites at GRSM (red circle indicates location of real-time AirCam source of photographs in Figure 1.7)

Table 1.15: Summary of Ambient Air Quality Data Collected in and near National Park Service Units in the Appalachian Highlands Network

PARK	NADP/NTN		CASTNet		IMPROVE		OZONE	
	LOCATION	SITE #	LOCATION	SITE #	LOCATION	SITE #	LOCATION	SITE #
APPA	Otto, NC 15 km E	NC25	Otto, NC 15 km E	COW137	Cohutta WA, GA 50 km N	COHU	Dawsonville, GA 25 km S	130850001
	GRSM – Elkmont, TN Within 10 km	TN11	GRSM - Look Rock, TN Within 15 km	GRS420	GRSM - Look Rock, TN Within 15 km	GRSM	BLRI - Yancey County, NC 35 km SE	371990003
	Mt. Mitchell, NC 30 km SE	NC45	Cranberry NC Within 10 km	PNF126	Shining Rock WA, NC 50 km SE	SHRO	BLRI - Avery County, NC 15 km SE	370110002
	Eggleston, VA 10 km SE	VA13	Eggleston. VA 10 km SE	VPI120	Linville Gorge WA, NC 15 km E	LIGO	GRSM - Cades Cove, TN Within 10 km	470090102
	Natural Bridge, VA 15 km NE	VA99			James River Face WA, VA Within 5 km	JARI	GRSM - Clingmans Dome, TN Within 5 km	471550102
	Charlottesville, VA 30 km E	VA00					GRSM - Cove Mtn. Within 15 km	471550101
							GRSM - Look Rock, TN Within 15 km	470090101
							Kingsport, TN 45 km W	471632003
							Wythe County, VA Within 10 km	511970002
							Vinton, VA 35 km SE	511611004
							Rockbridge County, VA Within 5 km	511630003

PARK	NADP/NTN		CASTNet		IMPROVE		OZONE	
	LOCATION	**SITE #**	**LOCATION**	**SITE #**	**LOCATION**	**SITE #**	**LOCATION**	**SITE #**
BISO	Oak Ridge National Lab 60 km SE	TN00	Speedwell TN 60 km E	SPD111	GRSM 140 km SE	GRSM	Somerset KY 30 km N	211990003
	Speedwell TN 60 km E	TN04	Edger Evins Park TN 110 km SW	ESP127	MACA 140 km NW	MACA	Oak Ridge National Lab 60 km SE	471451020
							Middlesboro KY 75 km NE	210130002
							Cookeville TN 75 km SW	471410004
BLRI	GRSM 20 km NW	TN11	GRSM 20 km NW	GRS420	GRSM 15 km NW	GRSM	Haywood County NC Within 20 km	370870035
	Mt. Mitchell NC Within 10 km	NC45	Cranberry NC 15 km NW	PNF126	Shining Rock WA, NC Within 5 km	SHRO	Asheville NC 10 km NW	370210030
	Eggleston VA 55 km NW	VA13	Eggleston VA 55 km NW	VPI120	Linville Gorge WA, NC Within 5 km	LIGO	Yancey County NC Within 20 km	371990003
	Natural Bridge, VA 15 km NE	VA99	SHEN 45 km NE	SHN418	James River Face WA, VA Within 5 km	JARI	On-site Avery County NC	370110002
	Charlottesville VA 25 km E	VA00			SHEN 45 km NE	SHEN	Wythe County VA 50 km NW	511970002
	SHEN 45 km NE	VA28					Figsboro VA 45 km SE	510890006
							Vinton VA 5 km NW	511611004
							Rockbridge County VA, 5 km W	511630003
							SHEN 45 km NE	511130003

PARK	NADP/NTN		CASTNet		IMPROVE		OZONE	
	LOCATION	SITE #	LOCATION	SITE #	LOCATION	SITE #	LOCATION	SITE #
GRSM	On-site	TN11	On-site	GRS420	On-site	GRSM	On-site Cades Cove	470090102
							On-site Clingmans Dome	471550102
							On-site Cove Mountain	471550101
							On-site Look Rock	470090101
							On-site Purchase Knob	370870036
OBRI	Oak Ridge National Lab 30 km E	TN00	Speedwell TN 70 km NE	SPD111	GRSM 110 km SE	GRSM	Oak Ridge National Lab 30 km E	471451020
			GRSM 110 km SE	GRS420				
			Edger Evins Park TN 110 km W	ESP127				

NADP/NTN = National Atmospheric Deposition Program/National Trends Network
CASTNet = Clean Air Status and Trends Network
IMPROVE = Interagency Monitoring of Protected Visual Environments
APPA = Appalachian National Scenic Trail
BISO = Big South Fork National River and Recreation Area
BLRI = Blue Ridge Parkway
GRSM = Great Smoky Mountains National Park
OBRI = Obed Wild and Scenic River
MACA = Mammoth Cave National Park
SHEN = Shenandoah National Park

(See Appendix D for further detail on air quality monitoring in the APHN)

B. TERRESTRIAL RESOURCE MONITORING

1. Amphibians and Reptiles

BLRI – Several populations of the Federally-listed Threatened bog turtle are on BLRI, and have been monitored since the mid-1990's (some longer) by park personnel, North Carolina Wildlife Resources Commission, Virginia Department of Game and Inland Fisheries, and amateur and professional herpetologists associated with Project Bog Turtle – a volunteer-based organization in NC. Captured turtles are weighed, sexed, aged, and each is uniquely marked.

BLRI and GRSM - Since 1993, University of North Carolina researchers have been conducting long-term monitoring of population dynamics of wood frogs and spotted salamanders at selected pools on BLRI and GRSM (as well as CUGA in the neighboring Cumberland Piedmont Network). Goals are to document population cycles, dynamics and trends; to identify the smallest demographic unit that should be used in monitoring programs; and to examine genetic variation at different spatial scales. Trends to date suggest a gradual decline in the overall population sizes of these two species at BLRI. Investigators estimate that 12-15 years of data will be necessary to differentiate long-term trends from annual fluctuations due to extrinsic factors such as weather conditions (Petranka 2004).

GRSM – One of the longest-term studies of amphibians in the world, a terrestrial salamander monitoring project has been ongoing in GRSM since 1976. Identical observations, conducted 1-4 times per year for the first 20 years of the study, yielded quantitative data on populations of six species of salamanders. Although population numbers have fluctuated for various reasons during the period of the study, there has been no trend in the numbers for any of the six species. (Hairston and Wiley 1993).

2. Birds

BISO – Since 1994, breeding bird monitoring has been conducted using BBS point count methodology at 100 roadside points and along seven hiking transects (totaling 40.5 miles) in the park's backcountry. Fall surveys have also been conducted along the same hiking transects, and less structured breeding season surveys have been conducted by canoe on all navigable water courses within the park boundaries.

BLRI – Park staff, in cooperation with Appalachian State University, operated a MAPS (Monitoring Avian Productivity and Survivorship) station for six years (1996-2001) in the central portion of the Parkway. Birds were mist-netted and banded during the breeding season to monitor reproductive success and winter survival rates. This work was discontinued after the 2001 season.

Peregrine falcons nest on one cliff within BLRI, and are monitored each year by the NC Wildlife Resources Commission or by volunteers.

The largest known breeding population of Southern Appalachian yellow-bellied sapsuckers is being monitored annually by the NC State Museum of Natural Sciences, which documents the number of nests and reproductive success at the site.

One of the largest cerulean warbler populations in NC occurs on BLRI and has been monitored by volunteers for approximately 10 years, via counts of singing males and active nests.

GRSM – Park staff and volunteers have operated two MAPS stations for the past 5 years and 3 years, respectively. Ten mist nets are run at each site, for six hours, eight mornings during the summer. Birds are identified to species, aged, sexed, banded and released. Fecal samples, ectoparasites, blood smears, and feather samples have been collected from some species as part of other research on parasites and population genetics. Data is sent to the Institute for Bird Populations in California as part of a continent-wide effort to monitor bird population trends.

Peregrine falcons have reoccupied two nest sites in the park (P. Super, pers. com. 2005), after an absence of half a century caused by DDT. Volunteers monitor the nest sites, documenting the time of nesting and the number of young fledged from the nests each year.

Three Breeding Bird Survey routes include parts of the park, and have been monitored since the 1960's, although there was a break of many years in coverage for two of the three BBS routes that enter GRSM (P. Super, pers. com. 2005). Two National Audubon Society Christmas Bird Count circles include parts of the park, and have been monitored since the 1930's.

OBRI – Since 1998, breeding bird monitoring has been conducted using BBS protocols at 50 roadside points, and less structured surveys have been conducted by canoe on all watercourses within the park's boundary.

3. <u>Mammals</u>

BISO - A black bear bait station survey was begun in 1998, and has been continued each July since that time. A hard mast survey is also conducted annually in the fall, according to protocols developed at GRSM.

BLRI – Three of the remaining eight populations of the Federally-listed Endangered Carolina northern flying squirrel are on BLRI. These populations have been monitored, more or less continuously, by the North Carolina Wildlife Resources Commission, US Fish and Wildlife Service and Wake Forest University since 1986. The squirrels are captured in live-traps or nest boxes, weighed, sexed, aged, and marked with numbered ear tags. Large fluctuations within populations have been observed over the course of the monitoring; therefore additional annual monitoring is needed to assess the relative stability of the BLRI populations (Weigl et al. 1992).

GRSM – European wild boar invaded the park in the mid-1950's, causing significant resource damage. The park has been continuously monitoring and removing these animals ever since, with more than 8,800 removed from the park to date.

GRSM provides refuge for a significant portion of the black bear population in the southern Appalachian region. Black bears in the park are monitored using bait station surveys to determine changes in relative densities and distribution, and by a hard mast survey to determine the availability of important fall foods. The University of Tennessee is in its 36th year (as of 2004) of a mark-recapture monitoring study of park bears – the longest ongoing monitoring of bears in the world. For the study, information is collected on sex and age structures, mortality, and natality, in order to acquire an annual population estimate. Trends in the population have generally been upward since the study began. The 1998 park population was estimated at 1,700 individuals, a 160 percent increase from the 1972 level. The increase is attributed to maturing forests (increasing hard mast availability), decreased numbers of European wild boars (reducing food competition), and better overall management of bears in the region (National Park Service 1999).

Bat populations, including Endangered Indiana bats, are monitored at hibernacula and maternity sites in the park in cooperation with the US Fish and Wildlife Service and Tennessee Technological University. Objectives of the project are to monitor and determine distribution of bats in the park, to collect genetic material from Indiana bats, and to monitor temperature and humidity in Whiteoak Blowhole Cave via wireless sensors. Censuses are conducted in hibernacula every other winter.

The Endangered Carolina northern flying squirrel has been monitored since 1998, by NC Wildlife Resources Commission personnel and park staff, using live traps and nest boxes. Squirrels are weighed, sexed, ear-tagged, and reproductive condition is assessed.

Endangered Carolina northern flying squirrel (*Glaucomys sabrinus coloratus*)

White-tailed deer density at GRSM is highest in Cades Cove, a large, open cultural landscape which is maintained by haying and prescribed fire. Deer are monitored, formerly using nocturnal spotlight counts (in 2004, the park began employing distance sampling), to insure that the size of the herd remains within the carrying capacity of the natural communities surrounding the Cove. Excessive browsing could damage rare plant populations, and alter vegetative community composition and structure. The health of the herd is also monitored. During the early 1990's, the size of the herd continued to decline, likely in response to coyote predation (coyote occurrence in the park is relatively recent) (National Park Service 1997a).

4. <u>Flora</u>

APPA – Selected rare plant populations along the Trail are monitored by ATC club volunteers, using protocols developed by the AT Park Office (K. Schwarzkopf pers. com. 2003).

As part of a Southern Appalachian Man and the Biosphere Foundation project, volunteer monitoring has been initiated on the Trail within the APHN area for invasive exotic plants. This monitoring is focused on four main project areas on and around AT lands with the larger objective of protecting significant natural heritage sites on the Trail and adjacent National Forest lands. Currently, the volunteers are only recording the presence or absence of 12 "Primary Plants of Concern" that have been identified by Forest Service and Park Service botanists, exotic pest plant councils, etc. Only established corridors (roads, trails, riparian corridors, and utility rights of way) are being monitored; no plot surveys are involved.

BLRI – Park staff monitor the status and condition of five Federally-listed plants – Heller's blazing star, spreading avens, small-whorled pogonia, swamp pink, and rock gnome lichen – on the Parkway. Past and current cooperators on these projects have included the US Fish and Wildlife Service, the NC Plant Conservation Program, The Nature Conservancy and various university personnel. This monitoring has also documented the effects of trampling and recreational rock climbing on these species.

Park staff are inventorying and monitoring invasive exotic plant populations in the park, following a hierarchical priority system that begins with areas of highest ecological concern (rare species, communities of concern). Exotics are treated, and sites are periodically monitored for reinvasion.

GRSM - Long-term monitoring of vegetation in GRSM has been undertaken to better understand changes that are occurring as a result of past disturbance and ongoing threats, such as air pollution, exotic species invasions, and the alteration of natural fire regimes. The vegetation monitoring program consists of re-sampling the 400 existing permanent vegetation plots established between 1977 and 1985, mostly in the west end of the park, and adding additional permanent plots in vegetation strata not adequately represented in the original sampling design. Sampling protocols are designed to integrate information on structure, composition, and ecosystem processes, in order to best capture the effects of important biotic or abiotic influences (Jenkins 2001).

The park initiated the monitoring of rare plants in 1989, and is monitoring 37 species in 55 populations. Populations are monitored at varying time intervals and levels of intensity. Five of these populations are treated with fire, and monitoring includes parameters related to fire effects. Included in this effort is long-term monitoring of 16 populations of American ginseng, a species which is highly sought-after by poachers for sale in Asian markets. This is part of a multi-park effort to monitor poaching pressure on this long-lived perennial, which currently sells for $300-$400 per pound of dried root. GRSM contains the largest known "protected" population of this increasingly rare species, but illegal collection is difficult to stop and has been shown to occur routinely in the park.

Treatment of exotic invasive plants began in the park in the 1950's, with a project to eliminate kudzu. More systematic monitoring and treatment of all invasive species began in the mid-1980's; 818 sites are now monitored annually (as of 2004), and treated to eliminate invasive species. All inactive exotic species locations are monitored every 3-5 years, and treated where necessary, to ensure they do not become re-occupied.

For the past eight years, park staff and personnel from Michigan Technological University have been monitoring the effects of white-tailed deer herbivory on vegetation in the Cades Cove area of the park. Thirty plots throughout the cove were sampled to measure vegetative diversity, richness and density, comparing deer exclosures to browsed areas. Preliminary analyses of the data suggest that recovery of flora within the exclosures is limited to plant species that can persist under intense deer herbivory. Overall numbers of species do not appear to differ significantly between browsed and unbrowsed plots. However, some species, such as trilliums, were absent or severely reduced in numbers in the browsed areas compared with areas of the park where deer herbivory is much less intense. Forest tree seedlings in exclosures have significantly increased in height and number after deer were excluded from the plots.

The US Forest Service monitors 90 FIA (Forest Inventory Analysis) and Forest Health plots throughout the park, on 3-mile centers. Data are currently unavailable.

5. <u>Fire Effects</u>

BISO – Fire effects monitoring was initiated in 2005, when the park began its prescribed fire program. Pre-burn vegetation/fuels plots have been established.

GRSM – The park's Fire Effects Crew works in multiple parks throughout the Southeast, establishing vegetation/fuels monitoring plots to measure the effects of prescribed burns. Within the APHN network, the crew has established plots at GRSM and BISO.

6. <u>Recreation Effects</u>

BISO – A recent project was completed by Virginia Polytechnic Institute and State University to document baseline conditions of trails in the park, and to develop protocols for long-term monitoring of trail condition and associated resource impacts (Marion In Draft).

BLRI - Park staff monitor the effects of trampling and recreational rock climbing on plant communities and rare species (including three Federally-listed species).

OBRI – A multi-year study was recently completed by Appalachian State University to gauge the effects of recreational climbing on cliff-face plant communities.

7. <u>Forest Pests/Diseases</u>

APPA – Protocols are being developed with the US Forest Service for a volunteer-based forest health monitoring project on and around the Trail in the APHN region. This work is funded by the Appalachian Trail Park Office, the National Forest Foundation, and the Tennessee Valley Authority. The project is in the early developmental stages.

BISO - The park conducts annual gypsy moth monitoring at roughly 15 sites in conjunction with the Tennessee Department of Forestry.

BLRI – Park staff monitor and treat gypsy moth infestations on the north end of the Parkway annually. Hemlock wooly adelgid infestations are being monitored at several sites, along with the change in vegetation structure in one old-growth stand.

The US Forest Service is carrying out a monitoring project for beech bark disease on BLRI. Objectives are to identify current and potential American beech stands affected by the disease, identify apparently resistant beech, and propose minimum impact methods for control of the disease.

GRSM - Monitoring of high-elevation beech-dominated forests in GRSM over the course of 20 plus years has revealed a drastic decrease in the number of beech stems in the eastern half of the park (up to 100 percent) due to the introduced European beech bark scale disease. This monitoring also revealed declines in high-elevation mixed species forests, with oaks, beech, birch and buckeye all declining, and maples increasing. Some evidence points to soil acidification; of the 40 plots monitored, all but three had a soil pH below 4.5 in recent years. The Smokies are known to receive high amounts of acid deposition, and when soil pH drops below 4.5, nutrients such as calcium, potassium, and magnesium are leached and root-toxic aluminum is mobilized.

Park staff and Clemson University personnel are monitoring successional changes in hemlock-dominated forests over the past two decades, as well as physiographic characteristics related to hemlock dominance. This information will form the basis for comparison in future years to assess the impacts of the recently introduced hemlock wooly adelgid on forest composition and structure. In 2004, park staff conducted surveys throughout the park for hemlock wooly adelgids, concentrating on the nearly 800 acres of old-growth hemlock and 18,000 acres of hemlock-dominated forests. Infestations were identified in all areas of the park. Park staff are attempting to treat these infestations with the release of biological control agents, foliar treatments with insecticidal soap and systemic insecticides. However continued monitoring is expected to document large-scale hemlock mortality in the park in future years.

GRSM is also monitoring the effects of dogwood anthracnose. While dogwood is not monitored as an individual species, its loss from long-term vegetation monitoring plots has been documented and the effects examined. Park personnel have been working with the University of Florida to look at the potential use of fire in controlling anthracnose, the ecological role of the species in nutrient cycling, and site characteristics that influence survival of dogwood trees (M. Jenkins, pers. com. 2005).

Annual surveys for southern pine beetles have been conducted since the 1970's, in cooperation with the US Forest Service, to monitor for outbreaks. GRSM has been monitoring for gypsy moths for the past fifteen years, in cooperation with the US Forest Service, using pheromone-baited traps. Thus far, there have been no outbreaks of this introduced forest pest in the park. The park also participates in the US Forest Service's Rapid Detection program for new introductions.

High elevation Fraser fir forests are being monitored in GRSM at 36 plots on three mountaintops, every 10 years. Large, old trees have been eliminated by the introduced balsam wooly adelgid, but regeneration of young trees in these stands is vigorous. Ongoing monitoring by park staff discovered what may be the emergence of natural resistance in some of the young trees. Investigations are continuing.

Park staff are also monitoring rhododendron decline, mountain ash sawfly, butternut canker, and holly decline.

C. AQUATIC RESOURCE MONITORING

1. Biotic

BISO - In 1998, the park began a long-term aquatic macro-invertebrate monitoring program. Annual sampling was conducted at 10 sites, with an additional five sites sampled on a rotating basis in intermittent years. The sampling stations were co-located with water quality monitoring stations when feasible. The samples are collected by park staff and identified by a contract lab.

GRSM - Long-term aquatic macro-invertebrate monitoring has been underway in the park since 1992. Annual samples are taken at 25 permanent sites, and an additional 15 sites are sampled on a rotating basis to provide wider coverage of park streams. When possible, the sites are co-located with water quality monitoring and fish sampling sites, in order to gain a better understanding of ecosystem functioning. The status of a site is determined with a biotic index which combines information on species abundance with individual species tolerance values. Over 500 species of aquatic macro-invertebrates have been documented in park streams and the species accumulation curve is still increasing (National Park Service 1996a).

The GRSM long-term fisheries monitoring program includes:

- Evaluation of long term natural variation in stream fish communities (density and biomass measurements). Large stream surveys were initiated in 1985 in four streams, and annual monitoring continues in two of these streams (one or both of the other streams are sampled if funding allows). Data have provided valuable information on the effects of drought and flood on coldwater fish communities, and indicate considerable variation in fish population characteristics between watersheds in response to abiotic events.
- Brook trout monitoring at 25 sites in 11 streams in 7 watersheds. Monitoring sites were chosen so that population variations could be attributed to either biotic or abiotic factors, or to the presence of non-native salmonids.
- Monitoring of four reintroduced Federally-listed fish species in one park tributary. Annual monitoring consists of timed surveys to collect relative abundance information on total numbers of fish, young-of-the-year, and nests (National Park Service 1996a).

OBRI – Tennessee Valley Authority (TVA) biologists monitor fish at two sites on Clear Creek as part of the National Water Quality Assessment Program (NAWQA). The Federally-listed spotfin chub is known from this reach, so incidental monitoring of that species is done as part of the overall sampling.

USGS recently completed a two-year project to develop a preliminary monitoring design for freshwater mussels in the park (Ahlstedt *et al.* 2001), which designed sampling techniques and identified potential sampling sites. Current plans are to use this preliminary information to design a long-term monitoring protocol, to be carried out jointly by park and Network staff.

2. <u>Water Quality</u>

APPA – As part of the Southern Appalachian Man and the Biosphere Foundation project, a volunteer-based water quality monitoring program has been initiated on the Trail in the Southern Appalachians. Volunteers are collecting biological, limited chemistry and limited bacteriological data in and around gateway communities. Biological health is being measured in the form of benthic macro-invertebrate tallies. Water chemistry parameters being measured include total suspended solids, turbidity, nitrates, ammonia, orthophosphate, pH, alkalinity, and conductivity (A. Brown pers. com. 2004).

BLRI - There are 32 USGS or US National Weather Service water gauges (including stream, lake, well and climate) located on or near BLRI. Most of the monitoring stations represent either one-time or intensive single-year sampling efforts by the collecting agencies. Based on the NPS Water Resources Division’s Baseline Water Quality Data Inventory and Analysis for BLRI, 104 stations within the area (five within the park boundary) yielded longer-term (period of record = 1945-1994 for the five inside the park) records consisting of multiple observations for several important water quality parameters. Screening criteria consisting of published EPA water quality criteria and instantaneous concentration values selected by the WRD were used to identify potential water quality problems within the park. Although there are caveats for interpreting the results, the BLRI water quality screen found 24 groups of parameters that exceeded screening criteria at least once within the study area. Dissolved oxygen, pH, chlorine, cyanide, cadmium, copper, lead, mercury, nickel, selenium, silver, zinc, and phenanthrene exceeded their respective EPA criteria for the protection of freshwater aquatic life. Nitrate, nitrite, nitrite plus nitrate, chloride, cyanide, arsenic, beryllium, cadmium, chromium, lead, mercury, nickel, selenium, silver, and zinc exceeded their respective EPA drinking water criteria. Bacteria concentrations (total coliform and fecal coliform) and turbidity exceeded the WRD screening limits for freshwater bathing and aquatic life, respectively. Alkalinity was below the threshold used by the NPS Air Resources Division for determining potential sensitivity to acid deposition (buffering capacity) (NPS 1996a).

BISO - The park's water quality monitoring program operated from 1982 to 1998. Monthly samples were taken at 26 stations, and 14 parameters were measured. Parameters were designed to monitor for impacts associated with contaminated mine drainage, oil and gas mining, and sewage effluent. Samples were analyzed in a park lab, which did not have EPA certification. Early data were analyzed and reported by Rikard et al. (1986). Based on their water chemistry, streams within the park fall naturally into categories depending on the degree to which they are limestone or sandstone-influenced. Sandstone-influenced streams are more susceptible to acid contamination because of low buffering capacity and very low alkalinity. In general, streams in the western portion of the BISO watershed are less disturbed than tributaries in the eastern and southern portions of the drainage, which are regularly impacted by activities related to coal mining, forestry and development (Rikard *et al.* 1986). The program was suspended in 1998 due to concerns over quality control and lack of staff.

GRSM - Park streams are subject to runoff from precipitation that deposits some of the highest total nitrate and sulfate levels in the nation. A single storm may acidify streams at high elevations by more than a full pH unit. Studies during the 1990's demonstrated that the streams in GRSM have very low solute concentrations and are therefore highly susceptible to acidification. The park monitors the trends in water quality related to atmospheric deposition, as well as the variation in water quality among ecological communities, and relationships between ecosystem processes and water quality (National Park Service 1996a).

Physical and chemical characteristics of streams are monitored bimonthly at 46 sites that represent the entire range of ecosystem conditions in the park. Sulfate concentrations in streams show no trend in relation to elevation, and are relatively low except where geologic sources of sulfate are present. Across the elevation gradient, pH and acid neutralizing capacity decrease with increasing elevation while stream nitrate concentrations increase (Robinson, et al. 2002; S. Moore pers. com. 2004).

OBRI - The park's long-term monitoring program is focused on defining the physical and biological characteristics of its component rivers and streams. In conjunction with BISO, the park operated a water quality monitoring program from 1982 to 1998. Monthly samples were taken at 10 stations. Fourteen parameters were measured, designed mainly to detect impacts from contaminated mine drainage, oil and gas mining, and sewage effluent. Samples were analyzed in the BISO water quality lab (Rikard et al. 1986). The program was suspended in 1998 due to concerns over quality control, and lack of staff.

3. <u>Hydrology</u>

BISO - Long-term monitoring at BISO primarily consists of several programs aimed at establishing baseline conditions in the park's stream systems. To measure flow, there are four stream gauges located within the park, operated jointly by USGS and NPS. Flow measurements are transmitted via satellite, along with measurements of dissolved oxygen and temperature. Several water quality monitoring stations also have staff plates established so that flow data can be taken when water quality samples are collected.

OBRI - There are three stream gauges located within the park operated jointly by USGS and NPS. Flow, temperature and dissolved oxygen information is collected and uploaded to a satellite for dissemination on the USGS web site. In addition, staff plates have been installed at all of the park's water quality monitoring stations so that flow data can be collected when water quality samples are taken (Bakaletz pers. com. 2004).

D. GEOLOGIC RESOURCE MONITORING

BLRI – The Cooperative Central and Southeast U.S. Seismic Network (CUSSN) operates seismograph stations on BLRI as part of a 130-station, 10-state regional seismic network. The CUSSN is affiliated with the Mid-America region of the Advanced National Seismic System of the National Earthquake Hazards Reduction Program. CUSSN monitors earthquake activity in the Southern Appalachian Mountains for the purpose of seismic hazards evaluation. Twenty-two earthquakes were recorded in 2003, including one of magnitude 4.3 (Withers 2003).

1.6 MONITORING GOALS AND OBJECTIVES

(See Chapters 3 and 5 for more detail)

The overall purpose of natural resource monitoring in parks is to develop scientifically sound information on the current status and long term trends in the composition, structure, and function of park ecosystems, and to determine how well current management practices are sustaining those ecosystems. Use of long-term monitoring information will increase confidence in managers' decisions and improve their ability to manage park resources. Monitoring will also allow managers to confront and mitigate threats to the park and operate more effectively in legal and political arenas. To be effective, the monitoring program must be relevant to current management issues as well as anticipate future issues based on current and potential threats to park resources. The program must be scientifically credible, produce data of known quality that are accessible to managers and researchers in a timely manner, and be linked explicitly to management decision-making processes.

The monitoring program of the Appalachian Highlands Network is designed around the five, broad, service-wide goals. The task of selecting a few ecological indicators for a national park or network of parks that "represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values" is extremely difficult. It is relatively easy to generate a list of potential monitoring projects to address a park's most critical current data needs, but the process of paring the list down to a few "Vital Signs" that can be effectively and affordably monitored, and that best represent the composition, structure, and function of the larger ecosystem is very challenging.

NPS Service-wide Vital Signs Monitoring Goals:

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

In order to develop Network monitoring objectives, we began the process by soliciting information from the network parks' management about their most important natural resource monitoring/information needs. We compiled information on past and ongoing monitoring in the parks, conducted literature reviews, and identified monitoring programs ongoing in areas adjacent to the parks that could be applied to or combined with NPS monitoring efforts (Appendix C). Workshops were held with parks' staff, scientists from universities, other agencies and organizations to identify and discuss significant resource concerns and information needs. This information was synthesized into conceptual models, including detailed models of major ecosystems in each park. A framework was developed for evaluating ecosystem components (drivers, stressors, attributes, and measures for monitoring those components). We developed criteria for evaluating conceptual models and the attributes within each model; criteria were related to management significance, ecological significance, threats to ecosystem integrity, and monitoring efficacy and feasibility (see Figures 3.2 and 3.3). During Vital Signs workshops, we applied the evaluation criteria to identify the highest priority Vital Signs for long-term monitoring within each park and across the Network. In the Executive Summary and in Table 3.1 are summaries of the "short list" of priority long-term monitoring objectives, agreed upon by the APHN Science and Technical Committee and Board of Directors.

Below is the list of the highest priority resource monitoring questions, by category, that generated the list and objectives in Table 5.1:

AIR QUALITY

- What are trends in air quality affecting the parks, and how do these correlate to observed effects on natural resources, particularly in high-elevation ecosystems, including acidification and related water quality impacts to streams and wetlands?

- Are specific vulnerable terrestrial or aquatic communities changing as a result of air pollution? For example: acid deposition in soils (in the form of nitrogen and sulfur) causes the release of aluminum, which is not only toxic to plants, but displaces calcium from exchange sites causing it to be leached from the soil. How are aluminum toxicity, calcium availability, and nitrogen saturation varying with acid deposition across high-elevation forests, where the deposition of N and S are greatest? How does the relative abundance of these two cations influence the distribution of plant species across high-elevation forests?

- What are the trends in fine particulates and visibility impairment?

- What are the trends in ground-level ozone, especially at high elevations, and how are ozone-sensitive species being affected?

WEATHER

- What are the trends in precipitation (including storm events), temperature, relative humidity, wind speed and direction, solar radiation, fog and cloud immersion time, and UV-B radiation, and how do these affect other resources being monitored? How does annual rainfall/snowfall and temperature in a given year compare to historic averages; how many storm events and of what magnitude occur each year; etc.?

WATER

- Is water quality and quantity improving or declining in the parks, and what is the effect on park aquatic and riparian resources?

- Are water withdrawals or impoundments affecting the flow and quality of park surface waters or the survival of organisms of concern?

- What are the trends in major water pollutants of concern?

BIOLOGICAL INTEGRITY (Focal species or communities and at-risk biota)

- How is canopy composition changing in hemlock dominated communities (related to the recent invasion of the APHN area by the exotic hemlock wooly adelgid)? Where, and at what rates, is hemlock being lost? Where hemlock is being eliminated, what species are invading and at what rate? Are any of these invasive exotics, and if so, what is the timing of invasion after the hemlocks die?

- What are the changes and in canopy composition in beech-dominated forests that have been invaded by the exotic beech bark disease? Are there elevational differences in the rate or severity of beech die-off? How is the loss of beech as a canopy dominant affecting understory composition in these communities which contain many rare plants and animals?

- Are gypsy moth infestations eliminating oaks as a dominant species from formerly oak-dominated stands? How is the repeated defoliation of oaks affecting understory composition?

- How are populations of rare species of cobblebars and clifflines changing over time? How are these changes correlated to hydrological changes and changes in water quality in the rivers? Are these globally imperiled habitats being invaded by exotic species, and if so, at what rate, and by which species? Which exotic species represent the most significant threat to these communities? Is recreational use of these areas affecting rare species or overall species composition?

- Which exotic plants are present within one mile beyond the park boundary and how is this changing over time? Which vectors do exotic plants use and how easily/rapidly can they invade a new area inside the park? What is the rate of expansion of selected exotic species?

- What are the trends in the relative abundance of the Federally-listed duskytail darter (*Etheostoma percnurum*) and spotfin chub (*Cyprinella monacha*), and how do these correlate with water quality/quantity trends?

- What are the trends in relative abundance, distribution and age class structure in rare freshwater mussels, and how do these correlate with water quality/quantity trends?

HUMAN USE

- How is poaching of medicinal/ornamental plants (removal of massive amounts of galax, orchids, trilliums, lilies, black cohosh, bloodroot, moss, etc. from particular areas and habitat types) affecting species composition and community structure?

ECOSYSTEM PATTERNS AND PROCESSES

- Are oak-dominated stands gradually converting to dominance by red maple in the absence of periodic fire?

- How is the spatial extent and structure of communities of concern (spruce-fir forests, boreal relict communities, grassy balds, fire-adapted communities, high-elevation northern hardwood forests, hemlock forests, oak forest, beech gap forests) changing over time?

- Is habitat fragmentation on adjacent lands affecting vulnerable species within the parks?

- Are vegetation patterns adjacent to the parks benefiting area-sensitive habitat specialist species inside the park (grassland birds, for example)?

- What are the effects of severe outbreaks of southern pine beetle (in combination with fire suppression) on ecosystem patterns and processes in the region?

- How, and at what rate, are land use and development patterns changing adjacent to and upstream of the parks? Which external land use changes are the best predictors of changes in park resources? Is surrounding land-use change affecting exotic species distribution in the parks?

1.7 I&M PROGRAM TIMELINE AND PEER REVIEW

Under the direction of the National I&M Program, Vital Signs monitoring plans are being created in three phases. In Phase I, background material and conceptual models were prepared to build a foundation for Phase II, the selection and prioritization of Vital Signs. Phase III entails the detailed design work needed to implement monitoring, including the development of sampling protocols, detailed statistical sampling designs, a plan for data management and analysis, and information on the type and content of various products of the monitoring effort. Throughout the production of the monitoring plan, APHN has solicited regular peer review of its direction and progress. These reviews covered both the Vital Signs proposed and selected, as well as the process the Network employed to make those selections. Peer review has been provided by the Network's Board of Directors, its Technical and Science Committee, and subject matter experts. The Phase III Report (draft monitoring plan) was peer-reviewed at the NPS Washington Office level in 2004 and 2005. Final approved monitoring plans will be released in September 2005, after which the monitoring programs will be implemented.

Table 1.17: Timeline for the Appalachian Highlands Network to complete the 3-phase planning and design process for developing a monitoring program.

	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
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					Phase 1 Oct 02		Phase 2 Oct 02		Phase 3 Dec 04

The ultimate goal of the long-term monitoring program is the acquisition of better knowledge and understanding of resource change that leads to more effective preservation of the parks' natural resources. The APHN Vital Signs Monitoring Plan will always be a work in progress, with new information being incorporated, and adaptations being made accordingly. Vital Signs selection has been an iterative, multi-stage process, as illustrated in the chapters that follow. Chapter 2 describes the development and use of ecosystem conceptual models to focus Vital Signs discussions, and Chapter 3 details the prioritization process used to produce the highest priority, "short list" and the longer, set-aside list that will have to await additional resources (Table 3.1).

2. CONCEPTUAL ECOLOGICAL MODELS

2.1 INTRODUCTION AND APPROACH

A conceptual model is a structure to organize complex information – a visual or narrative summary that describes the important components of the ecosystem and the interactions among them. These interactions include how agents of change (drivers and stressors) influence the structure or function of natural systems. Workshops to construct conceptual models are brainstorming sessions that promote integration and communication among scientists and managers from different disciplines, as they explore alternative ways to compress a complex system into a small set of variables and functions. Early in the process, simple conceptual models provide a framework that relates information in issue-specific discussions and literature reviews to a broader context. Investigations and discussions that accompany the design, construction, and revision of the models contribute to a shared understanding of complex system dynamics and appreciation of the diversity of information needed to identify an appropriate suite of ecosystem indicators. Throughout the life of a monitoring program, conceptual models can contribute to communication. Once the program is underway, articulation of explicit key linkages in conceptual models is essential to justifying and interpreting ecological measurements and monitoring data (Kurtz et al. 2001).

Well-designed conceptual models:

- **Formalize current understanding of system processes and dynamics**
- **Identify linkages of processes across disciplinary boundaries**
- **Identify the bounds and scope of the system of interest**
- **Contribute to communication among scientists & program staff**

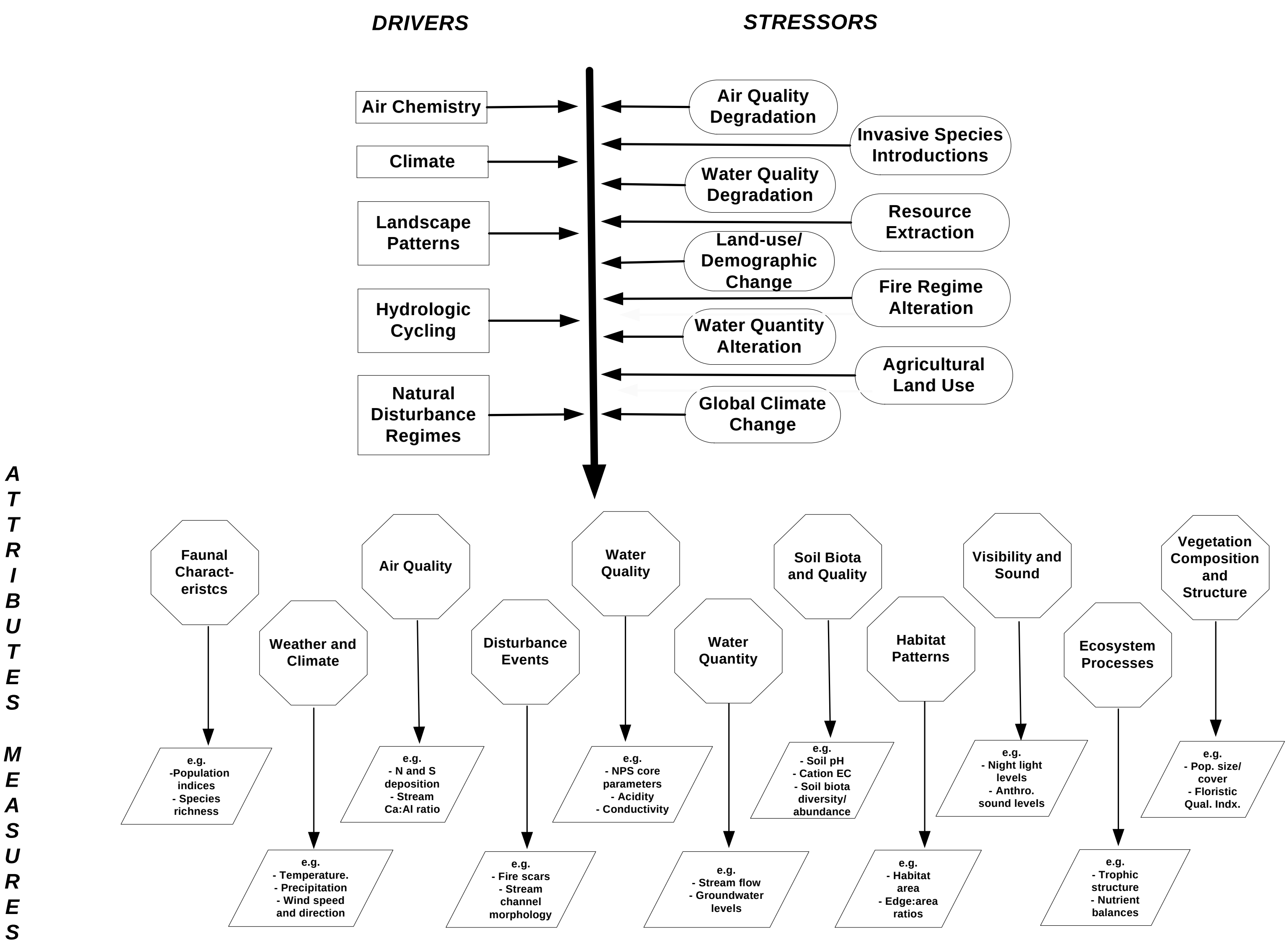
Conceptual models do not represent finished products; the process of thinking about, developing, discussing and revising conceptual models provides the greatest benefit to the users. Conceptual models are based on concepts that can and will change as monitoring provides new knowledge about ecosystem interactions. The purpose of this chapter is to explain our current understanding of ecological interactions, and how stressors and other drivers of change affect selected natural resource components and processes in APHN parks. The models serve as pictorial illustrations of the conceptual foundation for monitoring presented in Chapter 1 and support the identification and selection of ecological Vital Signs for long-term monitoring (Chapter 3).

2.2 CONCEPTUAL MODELING METHODS

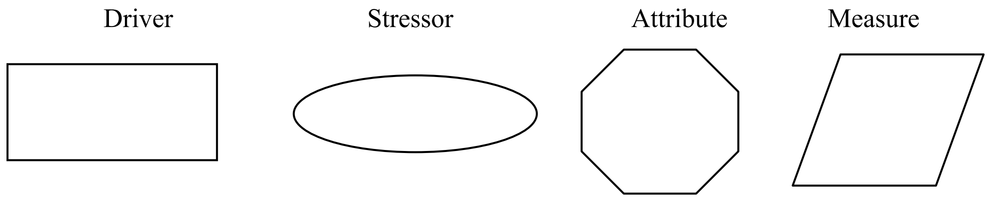
The conceptual models developed for the APHN are not intended to explain all possible relationships or all factors that influence the ecosystems; they are intended to simplify and highlight the most relevant, influential, and important components and processes of the systems. We chose to use a combination of tabular matrices and hierarchical box-and-arrow models, along with narrative explanations.

Step 1: A general theoretical framework (Figure 2.1) model was designed and used to guide the development of system- and issue-specific conceptual models, and to provide insights applicable to the prioritization and selection of Vital Signs. Major drivers, stressors, and ecosystem attributes were identified for the APHN parks, as shown in Figure 2.1 and further described and discussed in part 2.3 of this chapter.

Figure 2.1. Generalized ecosystem model for the Appalachian Highlands Network



Definitions of Conceptual Model Components



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**.

Attributes are any living or nonliving features or processes 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 2002).

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.

Measures are the specific feature(s) used to quantify an indicator, as specified in a sampling protocol. For example, stream acidity may be the indicator, while pH units are the measure.

Step 2: Major ecosystem types were identified for all the network parks (Figure 2.2) and divided into two intuitive levels of ecological organization – terrestrial and aquatic. Numerous terrestrial communities were considered, and then lumped into more general categories. Ecosystems were chosen for their overall significance to the parks and to regional biodiversity, as well as for the potentially different attributes or processes that characterize them. More inclusive general ecosystem categories were used for this process than the highly specific community descriptions used by such systems as the National Vegetation Classification Standards (Federal Geographic Data Committee 1997). Additional ecosystem types that were originally considered were dropped during the process because the indicators that applied to them were duplicative of those already represented in other models.

Major Ecosystems Selected for Model Development

1 Big River Ecosystem
2 Bogs and Fens
3 Clifflines and Rock Outcrops
4 Cobblebars
5 Cove Hardwoods
6 Grassy Balds
7 Grasslands
8 Hemlock/Acid Cove Forests
9 Northern Hardwoods & Beech Gaps
10 Oak Savannas
11 Pine-Oak Forests
12 Pine-Oak Heath (incl. table mountain pine)
13 Riparian Forests
14 Spruce-Fir Forests
15 Tributary Streams, Stream Heads, and Seeps
16 Vernal Pools

Figure 2.2. Major Ecosystems of the APHN used for Conceptual Modeling

Step 3: For each ecosystem, a detailed matrix was developed comparing attributes (potential Vital Signs) with stressors and drivers for the purpose of understanding linkages within the system, and to ensure that all important components, processes, and relationships were considered in developing the conceptual models. Narrative summaries explaining the details of these relationships, as well as lists of rare and special interest species associated with these communities were developed to aid discussions in the ranking process (Appendix H with all models, matrices, and narratives). These matrices and narratives were based upon information drawn from literature reviews, discussions with outside experts, and input from parks' staff. (Table 2.1 shows the matrix developed for the oak savanna ecosystem, as an example.)

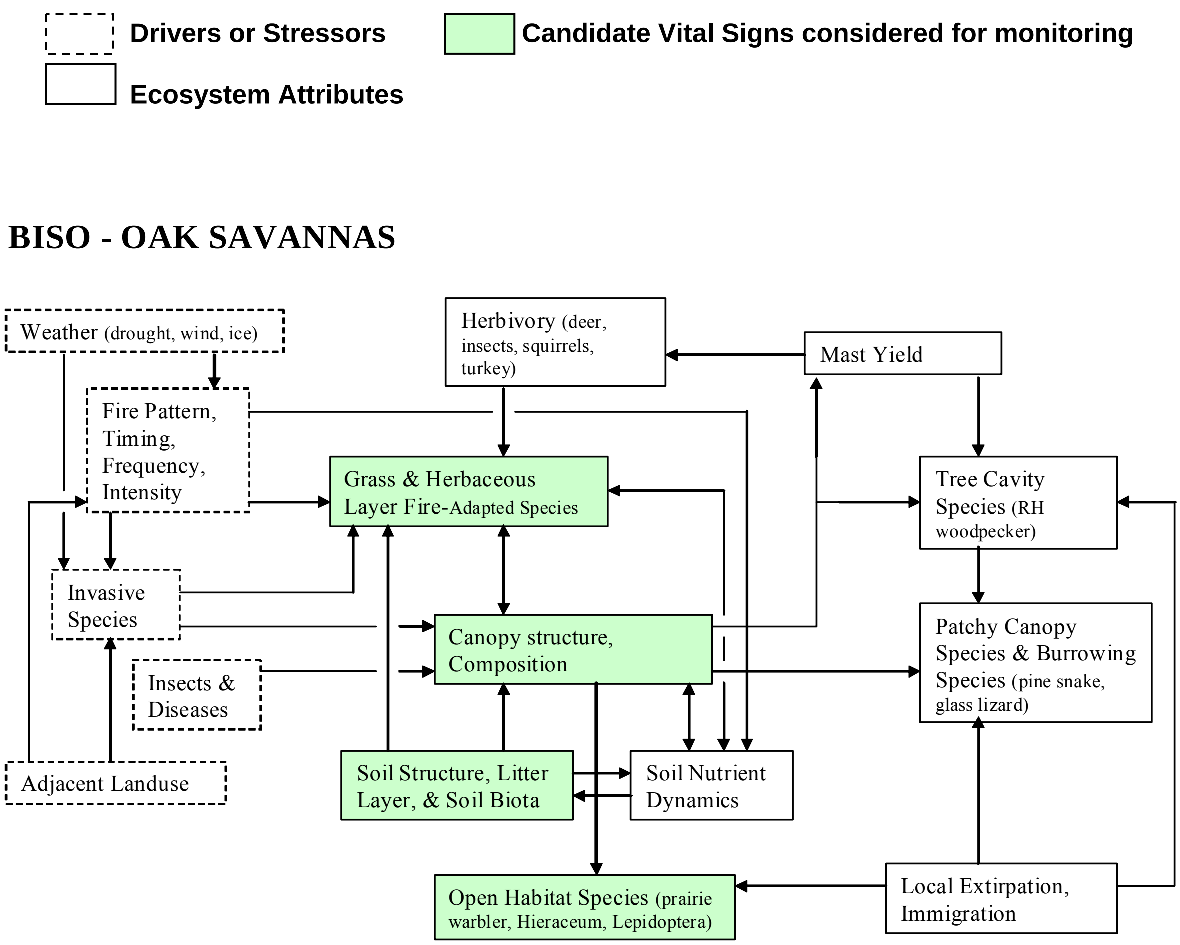
Table 2.1. Matrix showing relationship of drivers and stressors to ecosystem components in oak savanna ecosystem

Ecosystem Components	Possible Monitoring Attributes [incl. indicators of ecosystem integrity (or disruption thereof)]	Agents of Resource Change (drivers and stressors)																
		Climate		Landscape Patterns						Air Chemistry		Hydrologic Cycling			Disturbance Regimes			
		Weather patterns	Global climate change	Natural Landscape Patterns	External Land Use (incl. ext. res. Extctn. /demographic change)	Agricultural Land Use	Unsustainable recreational use/ facility development	Internal Resource extraction (oil, gas, coal)	Harvest (legal and poaching)	Air Chemistry (excl. global climate change)	Air Quality Degradation	Hydrologic cycling (Aquifer recharge, natrl flood regimes)	Water Quality Degradation	Water Quantity Alteration (flood regime alteration)	Natural Disturbance regimes (not incl. flooding)	Fire Regime Alteration	Altered disturbance regimes other than fire & flood (windthrow, drought, loss of large native browsers, beaver effects, native insects; etc.)	Exotic/Alien Species (including disease)
Air Chemistry	ozone																	
	Contaminants (persistent organic pollutants (POP's), mercury, lead, zinc, and cadmium)																	
	Nitrogen/sulfur deposition																	
Air Physics	Fine particles (human health, visibility concerns)																	
	Carbon dioxide, methane, UV-B	X?	X?	X?														X
Ecosystem processes	Productivity	X	X	X	X					X	X?				X	X	X	X
	Nutrient dynamics	X	X	X	X					X?	X?				X?	X	X	X
	Bioaccumulation & biomagnification																	
	Succession	X	X	X	X	X				X?	X?				X	X	X (pine beetle)	X
Faunal characteristics	Native spp. of special interest (presence, population size or trend of selected species; species richness and diversity)	X	X	X	X	X			X						X	X	X (pine beetle)	X
	Species at risk (presence, population size or trend of selected species, genetic diversity)	X	X	X	X	X			X						X	X	X	X
	Exotic spp. (#, area covered, rate of spread of selected exotic species)			X	X				X							X		X
	Interspecific interactions for selected species (herbivory, predation, competition)			X	X	X			X						X	X	X (pine beetle)	X
Habitat patterns	Stream substrate and physical habitat changes; channel and drainage morphology																	
	Land use patterns (e.g., area in different land use types, urban, agriculture, etc.)			X	X	X									X	X	X	
	Fragmentation and connectedness of ecosystem components (e.g., patch size, patch proximity)	X	X	X	X	X									X	X	X	X

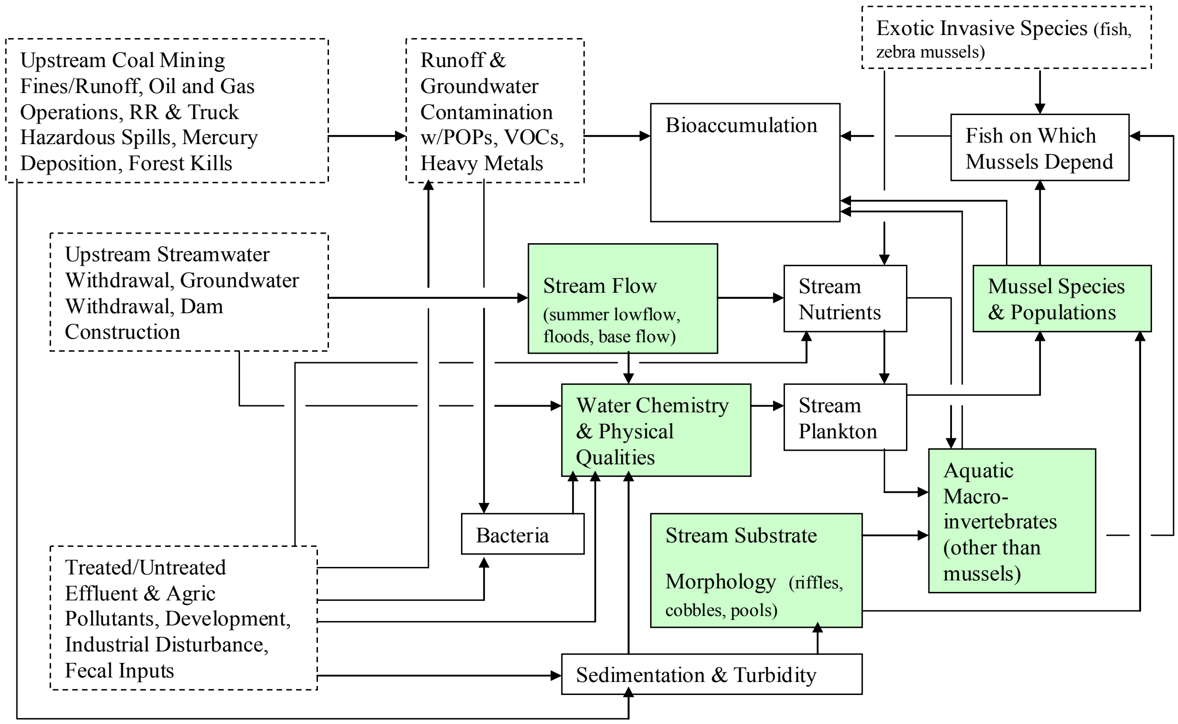
Ecosystem Components	Possible Monitoring Attributes [incl. indicators of ecosystem integrity (or disruption thereof)]	Agents of Resource Change (drivers and stressors)																
		Climate		Landscape Patterns						Air Chemistry		Hydrologic Cycling			Disturbance Regimes			
		Weather patterns	Global climate change	Natural Landscape Patterns	External Land Use (incl. ext. res. Extctn. /demographic change)	Agricultural Land Use	Unsustainable recreational use/ facility development	Internal Resource extraction (oil, gas, coal)	Harvest (legal and poaching)	Air Chemistry (excl. global climate change)	Air Quality Degradation	Hydrologic cycling (Aquifer recharge, natrl flood regimes)	Water Quality Degradation	Water Quantity Alteration (flood regime alteration)	Natural Disturbance regimes (not incl. flooding)	Fire Regime Alteration	Altered disturbance regimes other than fire & flood (windthrow, drought, loss of large native browsers, beaver effects, native insects; etc.)	Exotic/Alien Species (including disease)
Soil biota and quality	Soil structure and chemistry	X	X	X	X					X?	X?					X		X
	Soil erosion and deposition																	
	Soil flora and fauna	X	X	X	X					X	X?					X		X
Vegetation composition and structure	Native species & communities of special interest (presence, population size, trend of selected species; species richness and diversity	X	X	X	X (as it affects use of fire)	X				X?	X?				X	X	X (pine beetle)	X
	Species at risk (presence, population size/trend of selected species, genetic diversity)	X	X	X	X	X				X?	X?				X	X	X (pine beetle)	X
	Exotic species (#, area covered, rate of spread of selected exotic species)	X	X	X	X	X				X?	X?				X	X	X (pine beetle)	X
	Vegetation structure (aquatic, terrestrial and riparian)	X	X	X	X (thru fire)										X	X	X (pine beetle)	X
Visibility & sound	Visibility/viewsheds			X	X	X				X	X					X		
	Dark night sky			X	X													
	Natural sound levels			X	X	X												
Water quality	Water chemistry core elements (temperature, specific conductance, pH, DO)																	
	Water clarity-turbidity & siltation																	
	Contaminants (organic & inorganic nutrients/ contaminants, metals)																	
	Fecal coliform/fecal strep																	
Water quantity	Flow/discharge																	
	Groundwater dynamics																	

Step 4: Based upon the relationships defined in Step 3 matrices, and following the general hierarchical framework in Figure 2.1, we developed 24 conceptual models for the 16 major ecosystems of the parks (Appendix H). More than one model was necessary for some ecosystems because of differences in ecosystem dynamics among parks (for instance, although all network parks have cliff communities, some are adapted to periodic fire and others are not).

Figure 2.3. Two examples of conceptual models - terrestrial Oak Savanna ecosystem and aquatic Big River ecosystem



BIG RIVER ECOSYSTEM



2.3 SUMMARY OF APHN ECOSYSTEM DRIVERS & STRESSORS

ECOSYSTEM DRIVERS are 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. Following is a summary of major drivers for APHN parks. (Table 2.2 shows a summary of the relationships of drivers and stressors to ecosystem conceptual models.)

Air Chemistry

Atmospheric deposition of suspended particulates, nitrogen, and even pulses of background contaminants from wildfires, eruptions, and dust storms provide important ecosystem inputs. Natural drivers in the ecology of the region include the presence of forest-produced volatile organic compounds (VOC's), seasonal and longer term variations in carbon dioxide concentrations, and cloud chemistry that affects precipitation acidity and ozone formation.

Climate

Not surprisingly, climate operates as a driver in every ecosystem modeled, across all parks in the network. Weather patterns, particularly the magnitude and timing of temperature changes and precipitation, have a major influence on all ecosystems, dictating patterns of distribution and species composition. Climate/weather drives ecosystems at various geographic scales including sites (microclimates), landscapes (topographic position), and regional physiography (e.g., mountainous terrain) (Stohlgren *et al*. 1997). The Southern Appalachians, like many mountainous areas, are distinguished by steep moisture and temperature gradients resulting in substantially different environments over relatively short distances. In the Smokies, for example, cool and moist forests of spruce and fir grow on mountaintops within sight of much hotter, drier ridge and valley forests, each of which has a significantly different species composition. This region is characterized by exceptionally high precipitation, being second in North America only to the Pacific Northwest in annual rainfall. Snow, ice, wind and rain, along with temperature fluctuations, all profoundly influence the biotic communities of the Appalachians and the Cumberland Plateau. Precipitation is a major driver in both terrestrial and aquatic systems, influencing soil and fuel moisture (and thereby, fire regimes), primary production, stream flow, pollutant concentrations, and oxygen carrying capacity in riverine systems. Extended drought profoundly affects succession patterns in bogs and other wetlands, as well as forest composition on thin-soiled sites that are prone to desiccation.

Landscape Patterns

The organization and relationships of habitats, acted on by processes of succession and disturbance, tend to follow patterns of geology, topography, temperature, moisture availability, and other variables. These naturally occurring patterns are features to which species and ecosystem linkages are adapted. Landscape scale variation in plant species distributions is dictated primarily by elevation, topographic position and related moisture gradients (Whittaker 1956; McLeod 1988; McNabb 1993), and by soil nutrient status (Newell *et al*. 1999; Newell and Peet 1996). Variability in the distribution of vegetation classes results from the complex interplay of climate, geology, topographic complexity, land-use history and natural disturbance regimes (Newell *et al*.1999; Pearson *et al*. 1999a; Turner *et al*. 2003). Soil type, moisture, and nutrient content has also been found to dictate the distribution of many rare herbaceous plants (Weakley 2000), as well as the abundance of Plethodontid salamanders (Hyde and Simons 2001) at sites in the Great Smoky Mountains.

Hydrologic Cycling

Precipitation, evaporation, and the movement of moisture (including cloud moisture at higher elevations) through the biotic and abiotic components of the ecosystem are major drivers of many important ecological processes and many ecosystem attributes. The availability, quality, movement, and distribution of water influence productivity, water quantity/quality, biogeochemical cycling, microclimate, habitat types, successional patterns, and biodiversity. The Southern Appalachian Mountains are generally characterized by the highest annual precipitation in the eastern United States, which produces and maintains water flow through a vast network of perennial streams, including part or all of the watersheds of 73 rivers (SAMAB 1996b). Annual rainfall in this region ranges from 35 to 100 inches, with considerable variation imposed by orographic rain shadow effects in certain areas. Soil water storage and release characteristics are extremely important to the distribution and persistence of many organisms, both plant and animal. These characteristics are also the major determining factors for atmospheric deposition impacts in a watershed. Contact time of water in the soil mantle and the flowpaths that the water follows are the two most important hydrologic factors influencing the alteration of acidic rainfall as it moves through a catchment (Peters and Driscoll 1987; Vose and Swank 1992).

Hydrologic cycles on the Cumberland Plateau are fed by an annual average precipitation of 52 inches, most of which comes in winter and early spring rains. Flooding typically occurs due to long, wet periods in winter and spring. Low flow periods normally occur in summer and early autumn, when upper reaches of the river system resemble intermittent streams in which pools form with little or no flow between them. However, rainfall associated with severe summer thunderstorms can be heavy for short periods of time, causing tremendous flow fluctuations (0-190,000 cfs) over periods of a week or less (TVA 1998; USGS 1996). These “flashy” systems are characterized by sandstone geology, which has a very short water retention time, and by steep topographic relief including miles of vertical cliff walls bordering the main river channels. At least one riparian community of concern, the globally-imperiled Cumberlandian boulder/cobblebar (and its associated rare species), is dependent upon these periodic flash floods for control of succession by woody species and for nutrient input.

Natural Disturbance Regimes

Ecosystems are in a continuous state of flux and adjustment as a result of a set of naturally occurring environmental disturbances including lightning-caused fires, landslides, and severe weather events such as ice storms, droughts, hurricanes, floods, and unusual heat waves or cold temperatures. Biotic disturbances, such as unusually severe insect outbreaks, can substantially alter structure and composition of these habitats. This, in turn, can alter microclimate, biodiversity, mineral cycling, carbon inventories, productivity, and habitat patterns. Many of the species and communities of the APHN region are dependent upon natural disturbance, including fire-adapted table mountain-pitch pine (pine-oak-heath) communities, remnant native grasslands and oak savannas (Campbell *et al*. 1991). Some riparian communities such as boulder/cobblebars are dependent upon the disturbance of periodic scouring floods (Schmalzer and DeSelm 1982).

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). Stressors cause significant changes in the ecological components, patterns and processes in natural systems out of their natural range of variation. Identification of stressors provides important insight about which ecosystem components may be most important to monitor.

Air Quality Degradation

As described in detail in Chapter 1, air quality degradation is a major problem within the APHN region involving high rates of acid deposition, deposition of heavy metals and other toxic compounds, significantly decreased visibility, as well as extremely high ozone levels at higher elevations. Pollutants of major concern include nitrogen compounds, sulfur oxides, mercury, organic compounds and ozone. Impacts of concern are effects on vegetation, water quality, nutrient cycling, and unique habitats/species (Chappelka *et al*. 1999; Eager *et a*l. 1996).

Damaging atmospheric deposition in this region results from the combination of industrial pollution originating in the Midwest, regional power generation from coal-fired plants, and local transportation-related emissions (Southern Appalachian Mountains Initiative 2002). Haze and high ozone levels are amplified by topography and summer air movement patterns in this mountainous region (*Ibid*).

Ecological concerns include the leaching of nitrogen and calcium from ecosystems, which affects productivity, soil chemistry, water quality, and resistance/tolerance of biota to other stresses (Eager et al. 1996). Acidification of soils and streams, and the associated release of toxic elements such as aluminum, strongly affects biodiversity, productivity, and habitat patterns (Swank and Vose 2001; Eager et al. 1996; Richter et al. 1992; Bondietti and McLaughlin 1992). Increased deposition of heavy metals, especially mercury, may result in bioaccumulation and bioconcentration with potential toxic effects to species higher in the food chain. Direct effects of elevated levels of carbon dioxide, UV-B radiation, and ozone on native biota, include adverse changes in their competitive ability, distribution and survival, resulting in adverse changes in overall biodiversity (Southern Appalachian Mountains Initiative 2002; Herlihy, *et al.* 1996; Fenn *et al.*, 1998).

Acid deposition affects various ecosystems in this region differently, depending primarily upon their buffering capacity. The highest elevation systems and those areas underlain by non-limestone geology are the most vulnerable to change. Therefore, elevation and buffering capacities are important factors in risk assessment.

Increased concentrations of atmospheric carbon dioxide affect plant growth processes, favoring some species guilds (e.g., grasses, and some exotics) while discriminating against others. This could alter reproductive success, successional patterns, and the structure and distribution of ecological communities. (Owensby, et al, 1999; Ziska, et al, 1999)

Water Quality Degradation

Specific water quality stressors include dissolved oxygen depletion, water temperature changes, pollution from wastes, toxins, and sediments, unsustainable visitor use, and atmospheric deposition (stream acidification, aluminum mobilization, and mercury contamination). In the APHN, the two primary ecological concerns with water quality degradation are (1) adverse alteration of habitat and substrate for aquatic and riparian biota of concern, including fish, freshwater mussels, other macroinvertebrates, amphibians and riparian nesting birds; and (2) alteration of high-elevation terrestrial ecosystem functions (nutrient cycling) from soil and water acidification caused by atmospheric deposition (Rosenberg and Resh 1993; Bondietti and McLaughlin 1992; Richter *et al.* 1992; Ahlstedt *et al.* 2003).

Water quality stressors threaten native aquatic species diversity, populations/productivity, and interspecies linkages. Because aquatic and riparian habitats are especially productive and diverse in the APHN, the exceptional biodiversity supported by these habitats is particularly vulnerable to declining water quality (Herlihy *et al.*, 1996; Rosenberg and Resh, 1993; Reidel and Vose, 2002; Grossman and Ratajezak, 1998). (See Chapter 1 for more detail.)

Water Quantity Alteration

Adverse hydrologic changes in the APHN include altered stream flow regimes, depletion of surface and groundwater, and the impact of land clearing (principally outside parks) and conversion of native vegetation to impermeable surfaces that alters runoff patterns and groundwater recharge processes. The role of impoundments, water withdrawals, and changes in evapotranspiration rates are also factors which may alter hydrologic regimes.

Ecological effects of greatest concern are loss of native aquatic biodiversity, loss of stable wetlands, decline in amphibians, change in stream substrate and morphology (as habitat loss for native species), change in water quality as a result of low and high discharge events, and decline in riparian habitat quality as a result of sedimentation and stream channelization (Harding *et al.*, 1998).

Land Use Change/Demographic Change

Although land use change can cause many different, often interrelated, effects, the primary ecological issues are habitat loss, habitat fragmentation, altered nutrient cycles, various types of pollution (air, water, noise, light), major hydrologic changes, siltation of streams, and increases in invasive and nuisance species associated with increasing urbanization (SAMAB 1996a; Wear and Greis 2001; Pearson *et al.* 1999a). Changes in hydrology (storm water diversion, impoundments, water withdrawals and other practices that alter sreamflows and water tables) affect aquatic and terrestrial ecological resources (e.g., wetlands, riparian and stream habitats). The dividing of existing native habitats into smaller and more isolated patches drastically affects native species dispersal patterns and reproductive success. All of these impacts are of particular concern because of rapid population expansion and second home development in the APHN region (SAMAB 1996a).

For the APHN parks, which are within easy driving distance of two-thirds of the U.S. population, this stressor includes pressures from adjacent lands, as well as activities inside parks, such as increased road and trail construction, and other recreation-related development (SAMAB 1996a; Wear and Greis, 2001; Pearson *et al.*, 1999a). As stated earlier, this network contains the most-visited unit in the National Park system (BLRI – 19 million visitors per year) as well as the most-visited National Park (GRSM – 10 million annual visitors). Unsustainable or inappropriate recreational activities are adversely affecting water quality, trail corridors, soil structure and composition, fragile vegetation, and other sensitive resources in the APHN parks. Some of the activities of major concern are social trails (unofficially constructed) on park lands, erosion and related water quality problems caused by overuse (ATV's, horses, mountain bikes), damage to sensitive cliff and rock outcrop communities from recreational climbing, and resource damage caused by looters of archaeological artifacts in rock shelters.

Invasive Exotic Species/Disease Introductions

Invasive exotic species in the APHN region include invasive plants (kudzu, oriental bittersweet, garlic mustard, Japanese knotweed, Chinese and European privet, tree-of-heaven, princess tree, multiflora rose, porcelainberry, bush honeysuckle (several species), winged burningbush, and Japanese stiltgrass are a few of the worst), invasive insects (e.g., hemlock and balsam wooly adelgids, fire ant, and gypsy moth), invasive pathogens (e.g., dogwood anthracnose, beech bark scale disease, chestnut blight, and west Nile virus), and invasive animals (e.g., European wild boar and zebra mussels). Other exotic species, such as rainbow and brown trout, although perhaps not technically invasive, are displacing native species (brook trout) from the streams where the non-native salmonids have been introduced.

Natural areas in the APHN region are heavily impacted by invasive exotic plants along rights-of-way, near population centers, along riparian corridors, and often on private land adjacent to parks. This region is known for its high rate of endemism and native biodiversity, much of which is threatened by invasive exotic species and pathogens. Other stressors interact with this one to exacerbate these threats.

Principal ecological impacts of invasive exotic species and introduced pathogens include the elimination, or severe reduction of native species (particularly rare species), the alteration of natural disturbance regimes and landscape patterns, and the interruption of ecosystem processes (Williamson 1996; Ferguson and Bowman1994; Moony and Hobbs 2000; Corn *et al.* 1999; Miller 1997; Leibold *et al.* 1995).

Resource Extraction

Resource extraction stresses, both inside and outside parks, include mining, timber harvesting, withdrawal of limited water resources, hunting (or the lack thereof), and poaching of plants and animals. Mining impacts include acidic contamination from tailings, escape of hydrocarbons, release of brine and heavy metals, alteration of water tables, erosion and siltation.

Park aquatic habitats as well as terrestrial biota are impacted. Negative effects of water withdrawal include life cycle interruption or loss of aquatic species, alteration of hydrodynamics important to sensitive aquatic ecosystems, and the bioconcentration of toxins. These stresses may be chronic or acute (hazardous substance spills from mine operations or spills along railroads and highways). Legal and illegal taking of plants and animals affects population levels in and near parks, and may also result in local extirpations of rare species. Unsustainable harvest of medicinal plants and ornamental plants has become a concern in recent years. Overpopulation by white-tailed deer (in the absence of hunting, or with overly restrictive regulations) has resulted in severe alterations of native plant communities, and in some cases local species extirpations. Unregulated take of certain species by collectors (bog turtles, butterflies, timber rattlesnakes, etc.), can severely deplete local populations.

Alteration of Natural Disturbance Regimes

Natural disturbance regimes, which are crucial to ecosystem integrity and function, include fire, storms, landslides, floods, drought, and native pest outbreaks. The frequency, intensity and distribution of these disturbances are constantly being altered by human actions, including anthropogenic forest fires, the suppression of naturally ignited fires, and the alteration of natural hydrologic cycles with impoundments and water withdrawal. Because of past alterations of native ecosystems in this region, including the removal of dominant trees such as the American chestnut, as well as species declines and community alterations caused by many decades of fire-suppression in fire-dependent ecosystems (table mountain pine, pitch pine, oak savannas, native grasslands), it is difficult now to establish a baseline for disturbance-dependent ecosystems. Any assessment of ecosystems in this area must accurately characterize system alterations within the context of natural disturbance, including frequency and severity of naturally-occurring fires, landslides, ice storms, droughts, pest outbreaks, spikes in animal populations, floods, torrential storms, and other episodic events. Landscape pattern analyses, geologic pollen records, tree ring and sediment analyses, and soil patterns may help define historic patterns for these natural disturbance regimes. Climate change may alter disturbance patterns by changing the distribution and intensity of flooding, drought, and other weather extremes, exacerbating exotic species invasions (plants, insects, diseases, animals, etc.), and causing extreme fluctuations in native species populations (e.g., southern pine bark beetles). Alterations of hydrologic patterns can disrupt the frequency and intensity of periodic flooding, which is essential for the perpetuation of the rarest species and communities in the river gorges of the Cumberland Plateau parks (BISO and OBRI).

Altered disturbance regimes change ecosystem processes, including nutrient cycling, productivity, and succession. They also influence species and natural community diversity and distribution. These changes may amplify the effects of other stressors on native species, communities, and ecosystem processes. The ecological concerns are loss of biotic diversity, stress to soils and aquatic systems, loss or fragmentation of habitat and animal ranges, and changes in ecosystem structure and function. Unfortunately, natural disturbance regimes are often not well understood, making detection of anthropogenic changes difficult. In fact, the effect of disturbance on diversity (and on the population dynamics of various species) can be completely opposite in different environments; an increase in mortality caused by disturbance generally decreases diversity in environments with low productivity (e.g., poor soils, dry conditions, oligotrophic waters), but increases diversity in high productivity environments. This information is particularly important for resource managers, who need to understand and accurately predict the effects of management activities such as prescribed fire, thinning, etc., as well as of natural disturbances such as fires, ice storms, droughts, etc. This information is also critical for interpreting the results of monitoring, because in some cases an increase in species diversity is the expected result, while in other cases a decrease is expected (Szaro et al. 1999; Scott et al. 2002; Huston *et al.* 2000).

Agricultural Land Use

Agricultural land use adjoining parks can be a significant stressor with respect to agrichemical movement, water withdrawals, animal waste and nutrient concentration, physical and bacterial impacts of livestock on streams, erosion, siltation, use of genetically modified organisms, draining of wetlands, alteration of habitat corridors, and potential introductions of new pests.

The primary ecological effects are water quality and quantity changes that stress aquatic systems, the potential effects of genetically modified organisms on native populations and pollinators, changes in the geographic distribution and interconnectedness of small wetlands, decreased habitat corridor connections, and effects on native species from new insect pest invasions.

Climate Change

Rising seasonal temperatures, altered dates for first and last frost, increased drought occurrences, increased storm/flooding severity and frequency, and other changes in weather patterns directly affect ecosystems. These changes may also alter natural ecosystem disturbance regimes (including fire), and can facilitate exotic species invasions. Effects of climate change are amplified at higher elevations, especially where relict boreal communities occupy mountaintop sites.

Climate change is difficult to separate from natural variations in weather and climate. Sources of climate change originate with increased atmospheric concentrations of greenhouse gases including carbon dioxide, methane, chloroflorocarbons, and carbon monoxide. These are primarily caused by energy generation from fossil fuels, forest clearing, transportation-related emissions, use of CFC-based aerosols, and decreased carbon absorption by oceans. Whether natural or anthropogenically influenced, climate change is a major driver of ecosystem change because it affects all the lower level elements of the conceptual models, including microclimate, soil chemistry, and geographic distribution of species and habitat types. Climate change may result in altered particulate concentrations, cloud cover, and atmospheric moisture levels (Burkett *et al.* 2001; U.S. Global Change Research Program 2000).

High elevation boreal relict communities and associated rare species in the Southern Appalachian Mountains are unique and important resources that may be adversely impacted by significant climate warming trends. Other issues relate to changes in weather events, hydrology, avian nesting success, growing season changes, and aspects of natural disturbance regimes that alter natural communities and cause changes in species/habitat distributions (Melillo *et al.*, 2001; Burkett *et al.*, 2001).

2.4 SUMMARY

Conceptual modeling is a valuable tool for identifying the important components of an ecosystem, the interactions among those components, how drivers and stressors impact the ecosystem, and what are the most important and integrative attributes for monitoring. In addition, conceptual modeling provided the network:

- Multiple ecological frameworks as a basis for vital sign integration discussions;
- Literature-based context for continued deliberations;
- Information legacy, charting the basis for the Vital Signs selection process;
- Assessments of relevant spatial and temporal scales.

The APHN conceptual modeling efforts described in this chapter and in Appendix H revealed several potential Vital Signs and relationships among ecosystem components that did not emerge in discussions with subject matter experts and parks' staff. The graphic comparisons were useful in associating stressors and management actions with ecological responses, as well as the selection of attributes that are central to the functioning of the ecosystems. The conceptual models and related documentation provided a guide for discussing the ranking of each potential vital sign within the context of its linkages with other resources and agents of change in the ecosystem, and with other ecosystems in the parks. A description of those potential Vital Signs and the structured, decision-making process used to identify, prioritize, and select the final list for the Network are the subject of Chapter 3.

Table 2.2 Ecosystem drivers and stressors represented in ecosystem conceptual models

		TERRESTRIAL													AQUATIC			
Category	Driver/Stressor	low-mid-elevation grasslands	oak savanna	hemlock	pine-oak heath	spruce-fir	cliffs & rock outcrops (BLRI,APPA)	cliffs, rock outcrops, rock shelters (BISO, OBRI)	grassy balds	northern hardwood/ beech gaps	pine-oak forest	cove hardwood	cobblebars	riparian forest	big rivers	streamheads, springs, seeps, tributary streams	vernal pools	bogs & fens
Atmospheric	Weather	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Climate change					X			X	X								X
	Air quality degradation					X	X			X								X
Landscape/Land use patterns	External land use	X	X		X		X						X		X	X	X	X
	Agricultural land use														X	X	X	X
	Unsustainable recreational use						X	X										
	Internal resource extraction (oil, gas, coal)												X		X	X		
	Harvest (legal & poaching)																	
Altered disturbance regimes	Fire	X	X		X		X				X							
	Flooding												X	X	X	X	X	X
	Drought, ice, windthrow, native insects	X	X			X	X			X	X	X					X	X
	Beaver, large native browsers	X	X						X								X	X
Exotic/alien species, including disease	Invasive plants	X	X		X						X	X	X	X		X		X
	Exotic animals									X				X		X	X	X
	Forest pests, disease		X	X	X	X				X	X	X		X				
Hydrologic cycling	Aquifer recharge															X	X	X
	Natural flood regimes												X	X	X			
	Water quality degradation												X	X	X	X	X	X
	Water quantity alteration												X	X	X	X	X	X

3. VITAL SIGNS

Designing a long-term ecological monitoring program for multiple parks with disparate resources and management mandates is a difficult, iterative process. Our goal in selecting Vital Signs was to address the five national program goals for long-term monitoring (Chapter 1), and to consider elements in each of four broad categories: (1) ecosystem drivers, (2) stressors and their ecological effects, (3) focal resources, and (4) key properties and processes of ecosystem integrity. From the conceptual modeling process described in Chapter 2, a large, initial list of potential Vital Signs (Appendix F) was produced and refined. This list, in turn, had to be narrowed to a short, practical list of ecosystem attributes that would best reflect the overall health of the parks' ecosystems, regardless of what new stressors enter the systems in the future, while addressing the parks' most important long-term resource management issues. Given this complexity, selecting the best Vital Signs subset for monitoring requires a logical, step-wise process. This chapter describes the selection process followed by the APHN, and then presents the Network's final list of Vital Signs for protocol development.

> **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.

3.1 IDENTIFYING AND PRIORITIZING CANDIDATE VITAL SIGNS

Figure 3.1 illustrates the process used by the APHN to select the Vital Signs, and the relationship of the conceptual models to Vital Signs identification and prioritization. Initial discussions and conceptual modeling produced a preliminary list of 91 possible Vital Signs for further consideration (Appendix F). The highest priority Vital Signs were selected from the larger list through the following step-wise process (this is a brief summary; see Appendix G for complete details):

1. Identify highest priority monitoring questions related to management issues in each park - Network staff worked with the parks' staff to identify the highest priority monitoring questions. Park responses (Appendix E) were used to guide discussions in monitoring meetings and Vital Signs workshops, and as an important aid, along with meeting results and other park input, in developing Network Vital Signs priorities.

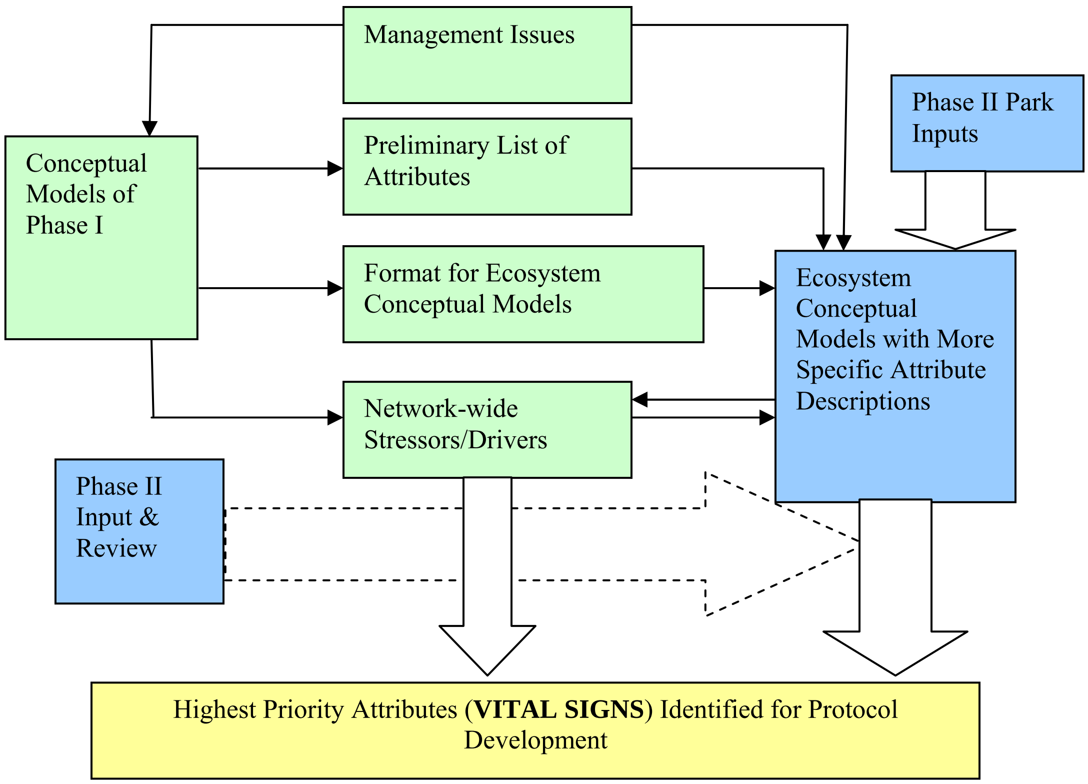


Figure 3.1. Conceptual model relationship to Vital Signs prioritization

2. Develop criteria for evaluation of conceptual models and attributes – Two sets of criteria were developed for the purpose of prioritizing (1) ecosystem models and (2) the attributes contained within each model. Criteria were related to: management significance, ecological significance, threats to ecosystem integrity (applied to ecosystem models only), monitoring efficacy and feasibility (applied to attributes only). Ecosystem model and attribute ranking criteria, with their accompanying point scales, are shown in Figures 3.2 and 3.3.

Ecosystem Conceptual Model Ranking Criteria

Overall Ecological Significance

What is the overall significance of the ecosystem/community protected by the park for overall landscape conservation? [3=highly significant, 2=moderately significant, 1=low significance, 0=no significance]

Threats to Ecosystem Integrity

What is the magnitude (considering immediacy, intensity and scale) of the threat to the ecosystem/community? [3=ecosystem is imminently threatened, 2=threats are not imminent, but could be significant in the long term, 1=major ecosystem impacts are not likely, 0=no threat]

Management Significance

How central is the protection of the ecosystem/community to the park's mission and mandates, and are there management actions that could be taken to adequately protect the ecosystem within the park? [3=high importance; protection could be effectively accomplished, 2=moderate importance; protection may be possible, 1=low importance; protection is doubtful, 0=no importance]

Figure 3.2. Conceptual model ranking criteria and point scores

3. Hold Vital Signs workshops to prioritize and revise (as needed) ecosystem conceptual models – Pairs of parks worked together in two separate workshops to rank the ecosystem conceptual models (using the criteria in Fig. 3.2), to review the models, and to make revisions as needed. Each two-day workshop involved about 25 specialists from universities, conservation organizations, state and Federal agencies, and the NPS. Once the conceptual models were ranked, each model was reviewed to assure that appropriate attributes and relationships were represented and to obtain agreement on their particular meaning with respect to each park's circumstances. This review greatly facilitated the discussions during application of attribute evaluation criteria.

Attribute Ranking Criteria

Management Significance

1. Legal/Policy Mandate: How important is monitoring this resource/attribute for satisfying legal or policy mandates? [3=high importance (required), 2=moderate importance (specifically identified), 1=low importance (generally identified), 0=not important (no mandate)]
2. Potential to Support Management Decisions: Is there a direct linkage between monitoring this attribute and the information needed for carrying out a key management decision, or evaluating the outcome of a management decision? [3=strong application, 2=moderate application, 1=weak application, 0=no potential for supporting management decisions]
3. Importance of Resource Management: How important (for management) is the resource or issue represented by the attribute relative to other resources or issues in the park? [3=high importance, 2=moderate importance, 1=low importance, 0=not important]
4. Potential to Influence External Decisions: If the attribute/resource is threatened from activities outside the park, how great is the potential for the park to influence those activities? [3=high potential, 2=moderate potential, 1=minimum potential, 0=no potential]

Ecological Significance

1. Importance as a controller or integrator: How important is the attribute in controlling the ecosystem model, or how central is it in linking to other attributes in the model? [3=high importance, 2=moderate importance, 1=low importance, 0=no importance]
2. Usefulness as an Indicator: How useful is the attribute in explaining the condition of the ecosystem model; that is, how sensitive would it be as an indicator of ecosystem change? [3=extremely useful, 2=moderately useful, 1=minimally useful, 0=not useful]
3. Linkage: How closely linked is the attribute with attributes in other ecosystems in the park; or is the attribute linked to important resources regionally? [3=many strong links, 2=few strong links or many weak links, 1=few weak links, 0=no linkage]
4. Regional Significance: For biological resources, how important for conservation is/are the population(s) protected by the park, in relation to the range-wide distribution and condition of the taxon? [3=high importance, 2=moderate importance, 1=low importance, 0=no importance, No Entry=not applicable]

Monitoring Efficacy/Feasibility

1. Current Knowledge: How much is currently known about the attribute (do protocols already exist; are baseline conditions already known)? [3=much information, 2=moderate information, 1=little information, 0=nothing known]
2. Natural Variability/Early Warning: Does the attribute/resource have low natural variability (a high "signal-to-noise" ratio); and will this resource respond quickly and measurably to a change in a stressor (will monitoring this attribute provide early warning of undesirable changes to important resources)? [3=low variability/quick response, 2=low variability/slow response, 1=high variability/quick response, 0=high variability/slow response]
3. Ease of Sampling/Impact of Sampling: Are measurements for this attribute easy and repeatable: can it be monitored non-destructively, without impacting resources? [3=easy to measure/low impact, 1=easy to measure/high impact or difficult to measure/low impact, 0=difficult to measure/high impact; no "2" rating included]
4. Possibility for Multi-tasking: Can field data collection for this attribute be accomplished concurrently with data collection for one or more additional attributes? [3=many concurrent datasets possible, 2=two or three concurrent datasets possible, 1=one concurrent dataset possible, 0=no concurrent datasets possible]

Figure 3.3. Attribute (potential Vital Sign) ranking criteria and point scores

4. Select attributes for scoring/ranking and apply evaluation criteria – Within each ecosystem model, only the most significant attributes were chosen for scoring and ranking. Those with minor importance to management and with a minor role in ecosystem function were not evaluated further. Attributes that were chosen for evaluation tended to be either significant drivers or stressors, to have a central role in controlling ecosystem processes, to be integrators of many different ecosystem processes, or to be significant resources associated with that particular ecosystem. Attributes were scored and ranked by applying the criteria in Figure 3.3, after extensive discussion.

5. Compile evaluations (both quantitative and qualitative) and analyze results – Ecosystem models and attribute scores were tabulated and ranked. Then the results were analyzed in several ways: by examining the unweighted mean scores of the attributes; by assigning greater weight to either management significance criteria or ecological significance criteria; by examining the frequency of attributes in ecosystem models; by comparing attribute scoring results with high priority monitoring questions identified by the parks; and by comparing scoring results to previous information gathered from the parks concerning their significant resources and management issues.

6. Select the highest priority Vital Signs for the Network, choosing those which offer the best combination of management significance, ecological significance and feasibility - Evaluation results were used to sort attribute priorities into high, medium and low categories, by park. This was a subjective, though intuitive grouping, because the results of the attribute ranking process and the parks' prioritized monitoring questions tended to mirror one another. The "highest priority" Vital Signs were selected for the Network after extensive review and discussion by the Science and Technical Committee, and approval by the Board of Directors. Table 3.1 presents these Vital Signs in the context of monitoring already ongoing in and near the parks.

3.2 DISCUSSION

Following is a discussion of the potential Vital Signs that were considered in workshop discussions, their applicability to Network parks' high priority management issues, and their relative importance for monitoring:

CLIMATIC FACTORS

Climate patterns over various time scales (ranging from days to centuries) are a primary influencing factor on habitat patterns and species composition of regional ecosystems. Natural variations in weather and climate may be as significant in their ecosystem effects as climatic/weather averages. Climate/weather also drives ecosystems at various geographic scales including sites (microclimates), landscapes (topographic position), and regional physiography (e.g., mountainous terrain). Albedo and heat load dynamics are important components that must also be considered. As indicators of ecosystem health, weather measures are highly important because of their direct implications for the health of regional biota, and because of their value as supporting information for determining the possible causes of ecosystem changes.

AIR QUALITY

Ozone – Ozone is a significant stressor at APPA, BLRI, and GRSM. It is an important indicator of air quality impacts in the southern Appalachians, which can be monitored effectively and relatively inexpensively. Ozone effects are somewhat dependent on elevation, topography and summer air movement patterns, and are of particular concern in high elevation communities in this region. Ozone damage to a small number of plant species has been documented during controlled studies at GRSM; and through anecdotal evidence, damage to many more plant species is suspected. Many plants (including rare plants) have not been studied for potential ozone effects. Ozone is a human health concern, and can exacerbate respiratory conditions, particularly in children and elderly people. Management and ecological concerns are considered to be highly significant at BLRI, GRSM and APPA because of potential damage to biota in high elevation communities, and effects on human health (Southern Appalachian Mountains Initiative 2002). Both BLRI and GRSM are designated "non-attainment" for the eight-hour ozone standard. Increased ozone levels may be a concern at BISO and OBRI, however the problem is considered less severe than in the southern Blue Ridge parks (Maniero 2004). Final Ozone Injury Risk Assessments for APHN network parks are available at http://www2.nature.nps.gov/air/Pubs/ozonerisk.htm.

Contaminants – This category includes deposition of air-borne heavy metals, agricultural and industrial chemicals. Atmospheric deposition of contaminants is of greatest concern at high elevations, in part because those areas are subject to higher levels of wet deposition than low elevation sites. GRSM and MACA have recently installed mercury monitors to establish baseline levels of atmospheric mercury deposition. Air-borne contaminants are suspected to be a significant concern at high elevations in BLRI and APPA, and somewhat less of a problem at BISO and OBRI, although much remains to be learned about the types and levels of deposition throughout the region (Southern Appalachian Mountains Initiative 2002).

Nitrogen and Sulfur Deposition – The southern Appalachian region is subject to high levels of nitrate and sulfate deposition from the burning of fossil fuels (coal, oil and gas) both locally, and from distant sources in the industrial Midwest. Roughly half of total nitrogen and sulfur deposition in the region occurs through wet deposition. At high elevations, acidification of soils and streams, and the associated release of toxic elements such as aluminum, strongly affects biodiversity, productivity, and habitat patterns. Other ecological concerns involve leaching of calcium from ecosystems - affecting productivity, soil chemistry, water quality, and resistance/tolerance of biota to other stresses (*Ibid*).

Because of ecological impacts to biota, soils and streams at high elevations, nitrogen and sulfur deposition are considered to be significant concerns at APPA and BLRI. BISO and OBRI are subject to a lesser degree of atmospheric nitrate and sulfate loading, and inputs from acid deposition have a relatively minor influence on soil and water chemistry *(Ibid)*.

Fine Particles – Ammonium sulfates are a major component of atmospheric particulates in the region, and deposition levels are very high at high elevation sites. Sulfur dioxide particles from coal-fired power plants are responsible for 83% of chronic visibility impairment in the southern Blue Ridge mountains during summer months. Overall, agriculture operations adjacent to the parks constitute a relatively minor fraction of overall total fine particulates. Fires contribute particulates to the atmosphere in the form of organic carbon, elemental carbon, nitrate and sulfate, for a short period of time (days), and are generally a minor impact over longer time scales. Because of impacts to visibility, fine particles are an important concern at BLRI, GRSM and APPA, and relatively less so for BISO and OBRI (*Ibid;* SAMAB 1996c). In addition, the same atmospheric conditions that lead to particulate formation will also lead to ozone formation.

CO_2, Methane, UV-B – Direct effects of elevated levels of carbon dioxide, methane, and UV-B radiation on native and exotic biota include potential changes in their competitive ability, distribution, and survival. At high elevations, UV-B radiation may have an adverse effect on early amphibian life stages, however the impacts remain uncertain. These stressors are of relatively low importance as indicators, based on current knowledge, and they are a low concern for management at all Network parks (*Ibid;* SAMAB 1996c).

ECOSYSTEM PROCESSES

Productivity – Productivity is moderately important as an indicator in all Network parks, but likely would be used as ancillary information, and not be the primary means of measuring changes brought about by anthropogenic stressors. Patterns of species distribution and diversity cannot be understood without taking productivity and disturbance effects into account (Huston *et al*. 2000; Szaro *et al*. 1999). Altered disturbance regimes potentially affecting productivity include:

- transport of air-borne compounds (e.g. nitrates, sulfates, mercury, other toxins);
- forest insects and diseases, such as pine beetle, gypsy moth and hemlock wooly adelgid, which can change vegetative cover, organic inputs, and habitat characteristics (for example, by elevating stream temperatures, changing successional patterns, or altering fuel loading patterns);
- fire regime alteration, which can change vegetation patterns, cause sedimentation, and release pulses of nitrogen into soil and water;
- exotic species – in addition to exotic insects and diseases, introduction of exotic plants and animals (European wild boar, zebra mussels, oriental bittersweet) has a significant impact on native species populations.

Nutrient Dynamics – Nutrient cycling is generally a moderately important potential indicator in Network parks, particularly in relation to aquatic communities, communities at high elevations, and fire-adapted habitats. In aquatic communities, internal land use (within the parks) potentially affecting nutrient dynamics in surface waters (particularly nitrogen concentrations) includes inputs from untreated wastewater and inappropriate recreational use (through sedimentation impacts). External land-use affecting nutrient dynamics in rivers includes inputs of untreated sewage from "straight-piping" and municipal sewage treatment facilities (inputs from Crossville, for example), as well as sedimentation and pollution generated by many kinds of development and extractive activities. Upstream impoundments and water withdrawal affect nutrient dynamics by altering the amount, timing, temperature and chemistry of surface water flows. Also, changes in vegetation patterns influence inputs of organic material into streams.

In high elevation communities, nutrient cycles are unnaturally altered through air pollution impacts. Acid deposition acts to release aluminum into soil and water, leach calcium (and potentially other cations) from the soil, and lower pH levels in soils and water bodies. Quantities of nitrogen in high elevation communities are also elevated as a result of atmospheric inputs of nitrogen compounds. In fire-adapted communities (grasslands, oak savannas, pine-oak heath), burning plays a role in releasing periodic pulses of nutrients into the soil and raising soil pH (Johnson and Lindberg 1992).

***Bioaccumulation/Biomagnification* –** This is another moderately important indicator which applies mostly to aquatic and high elevation communities. At BISO and OBRI, contaminated mine drainage is a source of heavy metals which may accumulate in tissues of aquatic organisms, particularly mussels and fish. Certain industrial and agricultural chemicals may also be retained in the tissues of plants and animals. At high elevations (APPA, BLRI), the release of aluminum from soils caused by acid deposition, and the influx of mercury and pesticides from the atmosphere may be measured by studying bioaccumulation of these substances in tissues. With this in mind, GRSM is currently undertaking a study to determine mercury levels in salamanders at high elevations.

Succession – In Network parks, the maintenance of certain successional stages and patterns is especially important as it relates to bogs and fens, grassy balds (APPA, BLRI), cobblebars (BISO, OBRI), cliffs and outcrops, and fire dependent communities (all Network parks). Community composition on cliffs and outcrops is dependent on the open habitat conditions maintained by wind, rain and freeze/thaw cycles. Bogs and fens are open canopy habitats, whose community makeup is dependent on high groundwater levels. Drawdown of groundwater in these habitats can set in motion an irreversible chain of successional events by allowing the invasion of upland species which in turn consume soil water, to the point where the original wetland species cannot survive. Successional patterns in high elevation grassy balds have radically changed due to the loss of natural disturbance factors, particularly the loss of large ungulates. These balds are habitat for a large number of rare and endemic plant species which are dependent on the balds' open condition for survival. Efforts to restore and maintain grassy balds are underway in some Network parks. Cobblebars along the main stream channels at BISO and OBRI, also support a disproportionately large number of rare plants which require the open canopy conditions created by periodic scouring. Should the amount, timing or duration of water flows change, cobblebar communities would not survive in their present form. Fire dependent communities (e.g. oak savannas, pine-oak heaths), and the unique species they support, depend on a particular disturbance regime to maintain their characteristic vegetation patterns and composition. Without natural fire, succession would soon change the makeup and structure of these habitats.

FAUNAL CHARACTERISTICS

***Freshwater Mussels* –** BISO supports at least 25 species of freshwater mussels, including six species Federally listed as Endangered. Much of the remnant mussel fauna (estimated to be less than one-half of the species that occurred here historically) survive in a small number of shoals restricted to one 14-mile river segment bracketed by upstream and downstream reaches made uninhabitable because of pollution. The BISO mussel fauna are considered the best populations remaining in the Cumberland River system, and appear to be showing signs of recovery from past pollution which decimated the historic fauna here. However, TVA is currently assessing the feasibility of mining 82 million tons of coal from the Royal Blue/Koppers Coal Reserve; much of this mining would potentially occur in the New River watershed, a major source of the Big South Fork's water. Most of the sediment load in the Big South Fork originates in this watershed. Nine species of mussels inhabit OBRI, including one that is Federally-listed as Endangered. Unlike the Big South Fork, the Obed River may never have had a much more diverse mussel fauna because of the biologically non-productive nature of the underlying shale and sandstone geology. BLRI and APPA are not known to support any significant freshwater mussel populations.

Freshwater mussels are adapted to live in gravel shoals in free-flowing rivers and streams, and have been eliminated from much of their historical ranges by impoundments, sedimentation and pollution. Being extremely long-lived under normal circumstances, they are vulnerable to bioaccumulation of contaminants. Contaminated mine drainage originating within BISO is a potential source of heavy metals which can bioaccumulate. Internal activities (e.g., construction, maintenance) which disturb acidic strata or deposits can release constituents of contaminated mine drainage (CMD). External land uses are also potential sources of contaminants from CMD (aluminum, sulfate, iron, manganese), as well as pesticides, all of which can adversely affect mussels. Other external land-use affecting mussels include inputs of untreated sewage from "straight-piping" and sewage treatment facilities (effluent from the Crossville plant, for example, constitutes over 50% of the Obed's flow during summer months), as well as sedimentation and pollution generated by many kinds of development and extractive activities – the most important being coal mining, oil and gas extraction, small industry, residential development, agriculture, and logging. Upstream impoundments and water withdrawal affect aquatic animal populations by altering the amount, timing, temperature and chemistry of surface water flows. Increased development of retirement communities adjacent to OBRI has resulted in increasing demand for water withdrawal from the river, and increasing numbers of small impoundments in the watershed. Weather patterns influence the transport, deposition and dilution of contaminants (mercury, pesticides, and other toxins) in surface waters. Freshwater mussels, because they are long-lived, relatively stationary, filter their food from the water column, and require links with native fish hosts for reproduction, are considered good indicators of water quality and overall ecosystem integrity. However, sampling in systems like the BISO and OBRI can be difficult because of large boulders and strong currents.

Other Aquatic Macroinvertebrates – Other than mussels, 215 taxa of macroinvertebrates have been reported from BISO, and 45 genera have been found at OBRI. Systematic surveys of these groups have not been conducted at BLRI or APPA, but BLRI is known to have some rare or endemic taxa associated with springs and small wetlands. Five years of recent macroinvertebrate monitoring efforts by USGS scientists have resulted in the discovery of several new species to science at BISO (Chuck Parker, pers. com.). OBRI has a NAWQA site that has been in operation since 1996, with some collection of macroinvertebrates being part of that sampling; however, there is not a lot of specific, comprehensive data available on aquatic macroinvertebrates at OBRI. All aquatic macroinvertebrates are affected to some extent by the same factors that affect mussels (above), although many of the other macroinvertebrates have winged life stages that enable them to re-populate areas from which they have been extirpated, unlike mussels. Because of their sensitivity to toxins, siltation, and stresses caused by habitat modification, invertebrates are used more often than any other group of freshwater organisms to assess the health of freshwater environments. Protocols for sampling and monitoring aquatic macroinvertebrates are well established, although very specialized expertise is required to identify specimens to the lowest taxonomic level.

Fish – **W**ithin BISO, 68 species of fish have been found, including one Federally-listed Endangered species. The OBRI supports 28 fish species, including one Federally-listed as Threatened. Both parks support small populations of the extremely rare Cumberlandian muskellunge, which is Threatened due to environmental degradation and genetic swamping by stocked muskellunge from the Great Lakes. Naturally low pH and low alkalinity associated with the underlying geology of most of both parks limits productivity of aquatic organisms. BISO and OBRI are particularly vulnerable to CMD because of the prevalence of pyritic shales in their watersheds and sandstone-bedded streams that do not adequately buffer increased acid. Fish, as well as macroinvertebrates, have been completely eliminated from some stream reaches at BISO because of contaminated mine drainage from old coal mines, even though some of these mines have been reclaimed. 54 fish species have been reported from BLRI. Atmospheric deposition in high-elevation streams is a threat to native brook trout because of the low natural buffering capacity of these systems; the trout have been largely displaced from lower stream reaches by introduced brown and rainbow trout. Fish are generally inferior to aquatic invertebrates as indicators of water quality. Variability in fish distribution and the difficulty of consistent sampling makes them somewhat difficult to use as indices of environmental conditions. Even relatively stable fish populations can be completely altered by natural disturbances, such as drought and beaver activity. However, periodic tissue assays, particularly from predatory fish, for heavy metals and other bio-accumulated contaminants could be valuable.

Birds – Birds show close affinities to particular habitats and even to subtle variations in the same vegetation types. Because of this trait, and the ease with which they can be sampled (especially songbirds), they are good indicators of local ecological conditions, and are more often the focus of environmental monitoring efforts than any other taxonomic group. All four parks have an impressive diversity of breeding and wintering birds, including most of the high-priority species identified in regional Partners in Flight Conservation Plans and the USFWS Birds of Conservation Concern List. BLRI supports the largest known breeding population of Southern Appalachian yellow-bellied sapsuckers, as well as several significant breeding populations of cerulean warblers. The last documented breeding site for the Appalachian Bewick's wren was on BLRI; a pair of these extremely rare birds was reported in 1993 from APPA lands in Virginia. All three taxa are under consideration for Federal T/E listing. Both BLRI and APPA protect breeding sites for birds that are endemic to the high-elevations of the Southern Appalachians. The loss of mature Fraser fir from the high-elevation forests has impacted birds endemic to the spruce-fir forest type, and the loss of hemlock is affecting others. Native grasslands at BISO, BLRI, & APPA support birds dependent upon this rapidly declining habitat type (Hunter *et al*. 1999).

Amphibians – Amphibians as a group are increasingly the focus of monitoring efforts throughout the world, due to unexplained declines and malformations observed at many locations (Stuart *et al*. 2004). Causes for the declines are probably varied, and may not even be related (Dodd 2002). However, the seemingly sudden declines in widely separated areas suggest a need to monitor amphibian populations, as well as to identify the causes when declines or malformations are documented. Toward this end, in 2000, Congress directed the Department of the Interior to develop a plan to monitor trends in amphibian populations on DOI lands and to conduct research into possible causes of declines. The Amphibian Research and Monitoring Initiative (ARMI) was initiated by the US Geological Survey (USGS) to carry out this directive, and protocols for monitoring in GRSM have been developed (Dodd 2002). Amphibians represent a major factor in nutrient cycling; in undisturbed Eastern US forests, amphibian biomass can equal or exceed the biomass of all other vertebrate groups combined (Elzinga *et al*. 2001). They are also often particularly responsive to environmental changes in soil, water, and air because of the permeability of their skins. However, they are sometimes difficult to sample, with very high variability in results temporally and spatially, making trends difficult to detect (Hyde and Simons 2001; Bailey et al. 2004; Hyde and Simons In Press). In fact, a long-term salamander monitoring project that included plots at GRSM concluded that there were no discernible trends over a period of two decades in their Southern Appalachian study area (Hairston and Wiley 1993). Recently introduced pathogens such as the Chytrid fungus have seriously impacted pool-breeding species in many parts of the world; it is unknown if the APHN parks' populations have been affected.

The Southern Appalachians are a world-renowned center of salamander diversity. BLRI, BISO, and OBRI all contain vernal pools that are essential breeding habitat for many species of frogs, toads, and salamanders. BLRI and APPA support a large number of species (38), including some that are endemic to the southern Appalachians. The Peaks of Otter salamander is endemic to BLRI and immediately adjacent areas. A newly-discovered and undescribed form (the Waterrock Knob salamander) appears to be endemic to a single drainage on BLRI. The pygmy salamander is restricted to spruce-fir and northern hardwood forests at the higher elevations, where it may be affected by the demise of the mature Fraser fir, and the decline of beech and sugar maple (Petranka 1998; Dodd 2002; Hyde and Simons 2001; Heyer et al. 1994).

Mammals – Mammals are important components of many ecosystems, as predators and as herbivores. For example, in the absence of predators, white-tailed deer can overpopulate an area and change the composition and structure of forest stands, as well as the abundance and distribution of herbaceous species. The mammalian communities of the Southern Appalachians represent some of the most diverse mammalian assemblages in eastern North America. Included in these communities are eight species of shrews, twenty-five rodents, and twelve species of bats. River otter and black bear have both been reintroduced to BISO, and reintroductions of elk and introduction of fisher on adjacent lands may have impacts within the park. Reintroduced elk from GRSM have made their way to BLRI, and may eventually affect ecosystems in both parks. BLRI and APPA support three of the largest remaining populations of the Federally-listed northern flying squirrel. One of only two known North Carolina maternity colonies of the Federally-listed Endangered Virginia big-eared bat is immediately adjacent to BLRI lands. The Federally-listed Endangered Indiana bat has been reported from both BLRI and APPA. Additional rare species include Rafineque's big-eared bat, the eastern woodrat, water shrew, rock shrew, rock vole, New England cottontail, pygmy shrew, bog lemming and western fox squirrel. BISO and OBRI support Allegheny woodrat, Rafineque's big-eared bat, water shrew and fox squirrel.

Tremendous fluctuation in small mammal populations, as well as the difficulty of capturing some species (pygmy shrews, for instance), makes them generally unsuitable as indicators of ecological condition. However, monitoring some mammals that exert effects on entire ecosystems (white-tailed deer) or that are a major focus of public attention and interaction (black bear) may be desirable (Elzinga et al. 2001; Wilson et al. 1996). Additionally, for those parks where hunting takes place (BISO, OBRI, APPA) there is little information about the effects of park-permitted harvest on the hunted populations. Long-term monitoring may also be advisable where Network parks represent a significant amount of the remaining habitat for listed species (3 of the 8 remaining northern flying squirrel populations are on BLRI and APPA, for example).

Terrestrial Invertebrates – Very few systematic surveys of terrestrial invertebrate taxa have been carried out in Network parks, but some significant incidental finds have been made of rare lepidoptera, odonates, land snails, and beetles. This little-known fauna could represent another regionally important resource in these parks. BLRI, in cooperation with state heritage programs, has conducted surveys of Lepidoptera in areas to be treated for gypsy moth infestation. Several species under consideration for Federal T/E listing are known from Network parks or nearby areas, including the Diana fritillary, Baltimore checkerspot, and the Tawny crescent. Many butterflies and moths are dependent upon particular habitats and host plants, and can be sensitive indicators of habitat condition and extent. Terrestrial beetles are also a common focus of insect monitoring programs, in part because they are readily captured. However, beetle species diversity can be overwhelming; therefore distinctive, low-diversity groups are frequently chosen as indicators in terrestrial communities. Soil fauna can be extremely important to the functioning of an ecosystem and the cycling of nutrients, but are very difficult to measure. Land snails, of which there is a tremendous variety in the Southern Appalachians, can be used as an indicator of soil nutrients, particularly calcium (Elzinga et al. 2001).

***Interspecific Interactions* –** Relationships between and among different plants and animals can dictate how ecosystems function. An interdependence exists, for instance, between beavers and many species of plants, reptiles, amphibians, birds, and butterflies. Agricultural use of lands adjacent to the park, particularly rowcrops such as soybeans or corn, can artificially stimulate populations of deer and raccoons, which in turn increases herbivory on vegetation in the park (by deer) and predation on bird and reptile nests (by raccoons) in the park. Residential land use and its associated garbage, pet and bird food, can unnaturally stimulate raccoon and coyote populations, to the detriment of other native species (foxes, birds, reptiles). Abnormally high populations of raccoons also result in transmission of diseases such as rabies, and the brain parasite *Baylisascaris procyonis* (deadly to woodrats and some other mammals). Residential development near sites occupied by woodrats often results in high mortality rates for the woodrats from predation by pets (dogs and cats). Hunting/poaching can reduce exotic wild boar population numbers, which in turn reduces their competition with deer and turkey for available mast and herbaceous forage. Altered disturbance regimes, for example a gypsy moth infestestation, can affect distribution and abundance of mast-bearing trees, affecting deer, turkey, bear, woodrat and other animal populations. Fire suppression shifts forest composition away from oaks toward more mesophytic species that do not produce large quantities of hard mast. Woody understory tends to increase in density in the absence of fire, and there is less herbaceous forage available. The fisher, a major predator of tree-nesting birds and small mammals, has recently been (re)introduced by state game agencies adjacent to the Cumberland Plateau parks; there is some doubt whether it occurred there historically. Coyotes, which were not present in the East until recent decades, alter the wild canid hierarchy, displacing both red and gray foxes; on the other hand, they are one of the few effective predators of raccoons (which can be good where raccoon populations are artificially high) thereby having positive impacts on some breeding bird species.

Rare Animals – Rare animals are discussed in relation to their habitat types. They are ranked highly as indicators when a park contains a significant proportion of the remaining populations of a particular species, and when they can be monitored relatively efficiently.

VEGETATIVE COMPOSITION AND STRUCTURE

Cliffs/Rock Outcrop Communities – There are many rare or endemic species associated with this habitat type in all Network parks, including six that are Federally-listed as T/E. This habitat type occurs at high and mid-elevations at BLRI and APPA, and lower elevations at BISO and OBRI. Higher elevation sites are characterized by colder, harsher conditions, which slow natural succession and favor the species that are adapted to these open, rocky habitats. Because of the cool temperatures and very high moisture levels at high-elevation cliffs (which are often bathed in fog), fires play very little role. At middle-elevation sites, however, fire-suppression is a serious issue, threatening the continued existence of many species of plants and animals. Table mountain pine, pitch pine, Heller's blazing star (*Liatris helleri, a* Federally-listed Threatened species), death camas, turkeybeard, and many other components of this ecosystem are fire-adapted and are largely limited to mid-elevation rock outcrop and cliff sites. Hibernacula and birthing rookery sites for timber rattlesnakes are associated with mid-elevation cliffs; they are also negatively impacted by fire-suppression due to abnormally deep litter buildup which prevents the rattlesnakes from reaching hibernaculum entrances (resulting in high winter mortality for this declining reptile). Certain species with highly flammable volatile compounds in the leaves (eg., sand myrtle – *Leiophyllum buxifolium*) grow to abnormal densities in the absence of fire, crowding out other species and creating an abnormal fire hazard. Prescribed burns must be well-timed in these habitats (not in a season when seeds are dispersing from aggressive exotic trees and vines, if possible), and followed up where necessary with herbicide or mechanical treatment of exotics that invade newly-exposed mineral soil.

At BISO and OBRI, the ecology and species composition of these habitats is somewhat different from those at BLRI and APPA, incorporating more rock shelters and talus. Rock shelters are the primary habitat of the rare salamander, *Plethodon wehrlei*, and the sole habitat of the Federally-listed plant Cumberland rosemary, as well as Lucy Braun's snakeroot, and filmy fern. The cliff faces and top ledges are somewhat different from the damp rock shelters – the ledges are adapted to periodic fire, as are the mid-elevation outcrops at BLRI and APPA, with rare species at BISO and OBRI including climbing fumatory, fameflower, and Appalachian sandwort. Ancient red cedars (over 1,000 years old) have been found at OBRI on the clifflines. Some of the rare species inhabiting cliff sites exist in metapopulations, dependent for long-term survival upon the existence of many populations scattered across the landscape. Trampling or destruction of these fragile habitats by hikers/climbers/artifact hunters could disrupt this dynamic. Fire suppression is also a contributor to the decline of the gorge rim plants.

Native Grasslands/Savannas – All the Network parks, with the exception of OBRI, have some native grassland or savanna habitat, and OBRI has some areas that might be restored to historic grassland conditions with active management. This increasingly rare habitat type, which supports many declining species of plants and animals (especially birds), is fire-dependent. However, as invasive exotic plants proliferate on the landscape, exposing mineral soil with a burn can provide an ideal invasion site for aggressive, non-native trees and vines (season of burn is important; also follow up with herbicide where necessary). Drought favors the formation of grasslands, except for the oak savanna type where oaks growing on thin soils are sometimes killed in extended droughts. Oaks are also threatened by exotic pests and pathogens such as gypsy moth and Sudden Oak Death. High concentrations of carbon dioxide favor grass species over oaks. Pine beetle outbreaks can help to re-create this habitat type, if followed up with fire or other management aimed at sustaining the canopy clearings; however, surrounding development can make the use of prescribed fire inside the parks more difficult (smoke hazard, visibility, air quality concerns).

Grassy balds – Grassy balds (BLRI & APPA only) are mountain-top grasslands, many of which are characterized by boreal relict species and Southern Appalachian endemics that are adapted to open habitats at high elevations. Included are four Federally-listed E/T species, several others that are under consideration for Federal listing, and numerous state-listed species of plants and animals. Most of the grassy balds are now mountain-top "islands" of habitat; changes in successional patterns have limited dispersal of rare plants and animals and isolated them in very small populations that are vulnerable to inbreeding depression. Higher elevations in the Southern Appalachians are characterized by colder, harsher conditions, which slow natural succession. Successional patterns in these mountain grasslands have radically changed due to loss of natural disturbance factors, particularly elimination of large native ungulates (elk have recently been reintroduced to one of the Network parks). Because of the cool temperatures and very high moisture levels where these habitats occur, wild fires play very little role in controlling succession, and prescribed fires have actually accelerated succession of balds to woody shrubland and forest. High-elevation sites are more susceptible to acid deposition and high ozone levels; prevailing acidic geology gives the soils here a low natural buffering capacity, which exacerbates the effects of acid deposition on soil chemistry by leaching out calcium and magnesium and releasing toxins like aluminum. Concentrations of persistent pesticides have been found in soils at these elevations, which are probably having adverse effects on soil chemistry and biota. Excessive trampling of these thin, fragile soils results in the death of the shallow-rooted vegetation native to these sites and the subsequent elimination of the soil via erosion (water and wind).

Bogs and Fens – Unnatural succession to woody species is a major issue for bog conservation; excess nutrients and lowered water tables allow invasion by trees and shrubs that would not ordinarily thrive in these naturally saturated, nutrient-poor environments. Nutrients can come from atmospheric deposition, or from runoff from adjacent agricultural fields, golf courses, lawns, etc. Exotic species like privet and Japanese stilt grass invade bogs when the water table is lowered slightly. Natural disturbance regimes in bogs historically included beaver activity, browsing by large native ungulates (elk) which retarded woody succession and maintained the bogs in a relatively open state. (Note: mountain bogs with northern species in them appear NOT to be adapted to fire, as are coastal plain bogs; some of their rarest plant species are killed by fire.) The key to maintaining mountain bogs over long periods of time (some

Southern Appalachian bogs have been documented to be 10,000+ years old) is maintenance of the water table at the soil surface. Lowering of the water table in a bog is highly detrimental, even for relatively brief periods of time. Not only does this kill some species of bog plants outright, it also allows seedlings of woody species (like red maple) to become established in the bog, which further dries it out because of the increase in water consumption by woody species and the increased evapotranspiration rate of trees vs. herbaceous species. BLRI and APPA have most of the true bogs/fens in the Network.

Spruce–Fir Forest – The red spruce – Fraser fir community is endemic to the highest elevations of the Southern Appalachian Mountains (APPA & BLRI only), and has been described as one of the most Endangered forest types in North America. Almost all the mature Fraser fir has been killed by an introduced insect pest. Air quality in the spruce-fir zone is worse in some respects than air quality in major urban areas at lower elevations (such as Atlanta). Air quality problems here are particularly severe in their effects on headwater streams, where buffering capacity is extremely low; some species have been extirpated from the headwaters as a result (e.g., native brook trout). Under natural circumstances, this community type rarely burns because of the prevailing cool temperatures and extremely high moisture levels; however, adelgid-killed trees are providing an unnaturally high fuel load in some places. Six Federally-listed T/E species of plants and animals occur in this community type, along with a suite of birds that have been identified as high priority conservation targets in regional Partners in Flight Conservation Plans. Soils are generally shallow and rocky, high in organic matter, low in base saturation, and acidic (pH=3-5) with a high aluminum content, making this ecosystem very susceptible to the negative effects of acid deposition.

Northern Hardwood/Beech Gaps – These forests, dominated by beech, sugar maple, yellow birch, and buckeye, occur above 4,000 feet elevation at BLRI and APPA. This forest type grades into spruce-fir forest above, and cove hardwood below, and can include "islands" of somewhat unique habitats including "beech gaps" which are dominated by a thick growth of stunted beech that grows in gaps or on exposed ridges. Boulderfield forests, as well as high-elevation northern red oak forests, are also sometimes described as variations of this community. Beech bark scale disease threatens to eliminate mature beeches from this forest; and where oaks occur, gypsy moth infestations can cause defoliation and some mortality. Sudden oak death, when it arrives from the west, may eliminate many of the canopy trees of this and other eastern forest types. Many rare species inhabit the northern hardwood forests, including the Federally-listed northern flying squirrel, saw whet owl, Southern Appalachian yellow-bellied sapsucker, black-billed cuckoo, Waterrock Knob salamander, veery, trailing wolfsbane, Smoky Mountain mannagrass, Carolina saxifrage, bent avens, and mountain bittercress.

Rich Cove Hardwood – Found on sheltered slopes and broad coves of lower to middle elevations, where soils are typically deep, rich, and usually circumneutral; these forests are dominated mainly by tulip poplar, basswood, sugar maple, yellow buckeye, cucumber tree, black cherry, red maple, hickory, Fraser magnolia, white ash, beech, and silverbell. Severe disturbance on such a site can result in a second-growth forest of almost pure tulip poplar, or an unnaturally thick growth of shrubs that suppresses the herb layer. Species composition varies widely; underlying geology and disturbance history are responsible for the greatest differences. Undisturbed, old-growth examples of this type exist in an essentially stable state. Many rare and uncommon species grow in the understory, including ginseng, goldenseal, spotted mandarin, white-leaved sunflower, broad-leaved coreopsis, green violet.

Pine-Oak Heath – (This includes Table mountain, pitch, Virginia, and sometimes shortleaf pine sites, with some overlap with mid-elevation rock outcrop habitats described above.) This community type is found on low peaks, knobs, exposed sharp ridges and steep south-facing slopes, and is characteristically very dry and susceptible to fire. Table mountain pine has serotinous cones and requires bare mineral soil (such as that exposed after wildfire) to reproduce. Ericaceous shrubs usually dominate the understory. Table mountain pine tends to dominate the higher elevation sites, with pitch pine on the mid-elevations, and Virginia or sometimes shortleaf pine on the lower ones. The herb layer is very sparse.

Hemlock/Acid Cove – (Although there are some almost pure hemlock forests in the Southern Appalachians, few of these are known from Network parks, so this type has been lumped with acidic cove forest.) An introduced insect pest, the hemlock wooly adelgid, has been found in GRSM, BLRI, APPA and is expected to eventually invade OBRI and BISO, resulting in complete elimination of hemlocks (both eastern species). Acidic cove forests occur on sheltered slopes and in narrow gorges, ravines, and low ridges within broad coves, often on rocky, well-drained sites or on convex slopes where precipitation runoff leaches out soil nutrients and bases more effectively than in rich cove sites. Canopy and herb layer diversity in acid coves is much less than in rich cove forests, with dominant trees being mainly tulip poplar, black and yellow birch, hemlock, and red maple. There is usually a dense shrub layer, composed mainly of ericaceous shrubs. Hemlock needles, as well as leaves from the ericaceous species, further acidify the soil. Three rare plants are known to grow in association with hemlock and acid cove communities, with one (piratebush – *Buckleya distichophylla* – G-2) being an obligate parasite on hemlock. Other uncommon or characteristic species found in this community type include the green salamander, Swainson's warbler (with rhododendron), Blackburnian warbler (at APPA & BLRI), black-throated green warbler, golden-crowned kinglet, southern heartleaf (G-3), lesser rattlesnake plantain, smoky shrew, and wood thrush. The elimination of hemlocks by the adelgids will drastically alter sites that are dominated by this conifer. Some species need dense conifers for winter cover (juncos, ruffed grouse). With the death of the hemlocks, these sites will become drier and hotter during the growing season; understory structure and composition will change and be opened to exotic plant invasion. Although under normal circumstances dead hemlock rots quickly, adelgid-killed areas could result in unnatural fire hazards, at least temporarily. Water temperatures in small streams and wetlands will increase with the sudden removal of the dense shade provided by the hemlocks. Soil chemistry will change as well.

Riparian Forests – Cumberland Plateau sites are dominated by sycamore, river birch, sweetgum, tulip poplar, and green ash. In the Blue Ridge parks, this community is dominated by sycamore, red maple, white oak, tulip poplar, and river birch. This community lies immediately adjacent to larger river courses in the Network parks. Most floodplains are rather narrow, with the exception of the French Broad and James Rivers (BLRI, APPA). Periodic flooding, usually in winter and early spring, dictates the structure of the forest via this periodic disturbance and nutrient deposition. Soils are generally very fertile. The frequent disturbance and high nutrient availability make these forests subject to invasion by invasive exotic plants, especially Japanese stilt grass, Japanese honeysuckle and privet. Rare and characteristic species include Swainson's warbler (with rhododendron), streamside salamander, butternut (under consideration for Federal listing), Louisiana waterthrush, Kentucky warbler, red-shouldered hawk, and otter.

Tributaries, Streamheads, Seeps & Vernal Pools – There is considerable variation in the vegetation structure and composition of these small wetland habitats from one site to another. However, most are characterized by relatively open canopies and shallow water. Storms and floods can alter streamheads and tributaries by scouring the stream channels, removing vegetation and setting back succession. Other natural disturbance factors such as beavers can have dramatic effects on these habitats with their impoundments and removal of streamside woody species – this can be beneficial for some species and adverse for others. Water quantity alteration, as a result of withdrawals, impoundment, or severe extended drought, could cause significant lowering of the water table, potentially drying up some of the seeps and streamheads. Vernal pools are rare, and represent extremely important breeding habitat for many amphibians. Forest cover influences temperature and light regimes in the small streams; aquatic vegetation is habitat for many organisms, coarse woody debris in streams provides habitat for many fish and other aquatic species. The hemlock wooly adelgid could drastically alter the microclimate of these communities by removing hemlock, which is a major element of the canopy in these systems. Alterations in runoff could dramatically affect species at risk in these communities, since they are adapted to certain flood regimes. Water quality degradation is a potential problem, both from contaminants and from sedimentation (from agricultural use and development outside the park). As with all wetlands with an element of disturbance, invasive exotic species are a problem in certain sites. Rare species include the Federally-listed Rockcastle aster, the Federally-listed Cumberland elktoe, Big South Fork crayfish, Black Mountain salamander, Tippecanoe darter, ashy darter, four-toed salamander, mole salamander, Barbour's salamander, round-leaf bittercress, kidneyleaf grass-of-Parnassus, crested fringed orchid, and tawny cotton grass. Birds of concern that breed in this community type include the Louisiana waterthrush, Acadian flycatcher, and Swainson's warbler.

Cobblebar Communities – This G-2 community occurs only on the Cumberland Plateau of Kentucky and Tennessee on open, flood-scoured exposures of bedrock, as well as open substrates composed of siliceous cobbles and/or gravels on major rivers. Fewer than 500 acres of this habitat type remain, and the highest quality examples are in BISO. This community is prone to flood scouring in the higher parts, and sediment deposition in the lower areas and is typically characterized by a gradient from dry acidic conditions higher on the bank to moist, fairly enriched conditions lower down. It is also prone to severe drought periods that stress or kill some vegetation. Although there is considerable variation from site to site, the community is generally characterized by a luxuriant growth of robust grasses, including many with prairie affinities. Also occurring are indigo, goldenrods (including the rare *S. simplex var. randii*), asters, coreopsis, Itea, blazing stars, azaleas, and Carolina willow. Rare species include the Federally-listed Rockcastle aster, Federally-listed Cumberland rosemary, Federally-listed Virginia spiraea, Cumberland sand grass, large-flowered Barbara's buttons, hairy snoutbean, Michigan lily, northern white cedar, sweet fern, mountain witch alder, roundleaf shadbush, shortleaf sneezeweed, and fetter-bush.

Rare Plants – Rare plants are discussed in relation to their habitat types. They're ranked highly as indicators when a park contains a significant proportion of the remaining populations of a particular species, or when rare plant protection has been identified by the park as one of its highest priorities.

HABITAT PATTERNS

External Land Use Patterns – Land-use patterns influence management concerns in Network parks in many ways. For example, upstream industrial or residential developments may impact water quality and quantity in downstream environments. Increased combustion of fossil fuels near parks may exacerbate air pollution problems. Development along park boundaries may fragment sensitive habitats, disrupt animal migration across park boundaries, spoil scenic vistas, or expand wildland-urban interface zones. Informal trail accesses from outside park boundaries (including ATV and horse trails) may damage plant communities, or cause erosion.

Land Cover/Habitat Patterns – The arrangement of habitats in a landscape as well as differences in habitat quality, influence patch size and interconnectedness. Habitat fragmentation is a particular concern for small, isolated natural communities which function as habitat islands in the landscape. Communities where this may be a concern (as described in the Vital Signs workshops) include high elevation clifftop and rock outcrop communities, grassy balds, mountain bogs and remnant stands of spruce-fir forest. Occasionally assessing the number and arrangement of these community occurrences in the landscape would provide a quick reading of significant changes in habitat patterns, and would provide supporting information to corroborate population changes in the endemic biota that live in these communities.

Stream Channel Morphology – Alterations in the timing and amount of stream flow - due to water withdrawals and impoundments, for example - could cause significant changes in channel morphology, as well as in the arrangement of aquatic habitats within stream channels. These habitat patterns relate directly to the native biota streams can support, including sensitive species populations.

SOIL QUALITY AND BIOTA

Soil Structure and Chemistry, Soil Erosion and Deposition, Soil Flora and Fauna – Soil conditions are an important indicator in many community types in the southern Appalachian Mountains. The anthropogenic influences acting on soil conditions in Network parks are primarily acid deposition, climate change, resource extraction, and changes in fire regimes. These stressors may cause changes in soil chemistry, erosion/sedimentation, soil compaction, and changes in soil carbon and organic matter content. During Network Vital Signs meetings, concerns were raised over potential air pollution impacts on soil chemistry in high elevation communities (e.g. spruce-fir, grassy balds, high elevation bogs) including the leaching of nutrients, such as calcium, and the release of aluminum into the soil. The impact of atmospheric deposition on soil fungus diversity in these communities, particularly in northern hardwoods, is also of potential concern. Mycorrhizal fungi can be the limiting factor for many species of plants, including dominant forest trees as well as rare herbaceous species (Allen 1992). Soil erosion and compaction due to development, and/or recreational use is a problem at all Network parks. Initial findings from research at GRSM indicate that calcium cycling may be adversely altered by the elimination of dogwoods from Southern Appalachian forests by dogwood anthracnose, a pathogenic fungus that has been killing dogwoods here since the late 1980's (M. Jenkins pers. com. 2004).

VISIBILITY AND SOUND

Visibility/Viewsheds, Dark Night Sky – Visibility and viewsheds are key management concerns for BLRI and APPA. Both parks are situated at high elevations for much of their lengths, and are therefore subject to high levels of ozone and fine particulates. In addition, an important mission of both parks – particularly BLRI – is the preservation of viewsheds and the maintenance of historic landscapes. Visibility issues are less of a concern at BISO and OBRI, where haze-forming pollutants are present in lower amounts and where the preservation of long distance vistas is less of a management priority.

Natural Sound Levels - Preservation of natural sound levels is an important management issue at APPA, BISO, BLRI, and OBRI, primarily for maintaining the experience of natural quiet. The effects of anthropogenic sound on biota are largely unknown, though the potential impact of this stressor on animal life cycles cannot be discounted. APPA passes through narrow corridors with very little buffer at intervals along its length, and is subject to the elevated noise levels which often accompany development. BISO supports a significant number of backcountry motor vehicle roads and designated ATV trails, often adjacent to zones which are managed to maintain primitive natural conditions (including natural quiet). At BLRI, because much of the park is a relatively narrow corridor with the motor road at its center, the interruption of natural sound levels by motor vehicle noise is a frequent occurrence.

WATER QUALITY

Core Elements (DO, Temperature, pH, Conductivity) – These four core water quality monitoring elements have been mandated by the NPS as the minimum set of parameters required for monitoring funded by the Servicewide I&M program. They were chosen both because they are effective and inexpensive for characterizing water quality, and because they are relatively easily measured field parameters. Large changes in any of these parameters can have a significant impact on the aquatic biota supported by a particular water body.

Turbidity and Siltation – Turbidity is a highly important indicator at BISO and OBRI because of the diverse and rare aquatic biota these parks support, and because the mission of both parks centers on the preservation of their aquatic resources. Siltation can alter habitats, smother benthic fauna, and carry other contaminants with it. At APPA and BLRI, siltation is generally a moderate concern; however, both parks contain water bodies which are significant biologically and which support important recreational uses. While water clarity is easily measured, sedimentation is highly variable naturally, and distinguishing natural from anthropogenic effects can be difficult.

Contaminants – For all Network parks, aquatic contaminants are a highly important indicator. At BISO and OBRI, external land use is the main factor influencing water quality issues in the rivers and tributary streams. External sources produce contaminants associated with oil and gas extraction (e.g. brine contamination), coal mining (contaminated mine drainage, heavy metals), industrial pollutants, sewage treatment plant effluent, and agricultural runoff. At APPA and BLRI, water quality concerns are related to contaminants introduced in atmospheric deposition (e.g. mercury, pesticides, nitrogen and sulfur compounds), and their impacts in high elevation seeps, streams, vernal pools and bogs. Agricultural and suburban runoff is a concern in some water bodies. At all four parks, internal development and maintenance activities influence water quality, as do recreational activities (e.g. trail erosion at APPA, horse trail impacts at BISO, wastewater treatment at BLRI).

Bacteria (Fecal Coliform and Fecal Strep) – This is a moderately important indicator in all Network parks. External sources of bacteria include "straight-piping" of sewage from residential areas, insufficiently treated effluent from municipal sewage treatment plants, and runoff from agricultural operations. Internal sources of bacterial pollution include livestock in agricultural lease areas, recreational horse use in and near streams, insufficiently treated sewage in developed areas, and bacterial pollution near drinking water springs (APPA).

WATER QUANTITY

Flow/Discharge, Groundwater Dynamics – Surface water flow is a highly important indicator for Network parks because it directly influences aquatic biota, and because measures of water quality must also include some measure of flow in order to provide information on pollutant loading. Alteration of water quantity is an important management issue at BISO and OBRI, with water withdrawals by local utility districts, and upstream impoundments (for drinking water and recreation) being the greatest concerns. Water withdrawals and impoundments may result in altered flood regimes, concentration of contaminants, exacerbation of water quality problems, habitat destruction, and direct impacts on aquatic biota. At APPA and BLRI, water quantity issues are centered on the potential for development to impact groundwater levels, particularly in bogs, vernal pools, and seeps. In high elevation bogs, which support a unique flora and fauna, alteration of groundwater levels can irreversibly change vegetation community structure and composition.

3.3 CONCLUSIONS

The preliminary list of the highest priority Vital Signs was refined through continued review and discussion among the Network's Science and Technical Committee, and with continued input from the parks and outside experts. The final resulting hierarchical "short list" of Vital Signs for protocol development, presented in Table 3.1, was agreed upon by the STC and approved by the Board of Directors in the summer of 2004. (Note: the table includes some Vital Signs that are already being monitored by other programs or entities, and by GRSM, where a prototype monitoring program has been operating for over a decade).

This selection of Vital Signs includes (1) indicators of overall ecosystem integrity (intended to encompass the effects of future stressors that cannot now be foreseen), (2) effects of known stressors to park resources, and (3) resources of particular interest to park management. Knowledge of the complex and diverse ecosystems of the Appalachian Highlands Network parks is incomplete, and regardless of what process is used to set monitoring priorities, the results are inevitably somewhat subjective. Therefore, the direction of the monitoring program will be periodically reassessed and adjusted as new information is acquired, and as changes occur in the availability of resources.

Additional Notes on the Network's Vital Signs selection process:

1. The same indicators will not be monitored in all parks. Table 3.1 shows an obvious alignment between resources and stressors in the Blue Ridge parks and a similar relationship between the Cumberland Plateau river gorge parks, as would be expected. Air quality issues and visibility are a higher priority issue for the Blue Ridge Parkway and the Appalachian Trail than for the Plateau parks. On the other hand, freshwater mussels are a much more significant resource at the Big South Fork NRRA and Obed WSR than they are in the Blue Ridge parks, and monitoring efforts will be allocated accordingly.

2. Not all the Vital Signs identified will be monitored by the Park Service. Other agencies or organizations may be collecting data that will partially or completely satisfy our needs for information in those particular areas (e.g., climate & weather data, some air quality data, possibly mast surveys and game species).

3. Regarding rare species vs. community or landscape-level monitoring: Natural resource monitoring needs in the parks are great, and some compromise must be reached between those resources that the parks are mandated to monitor vs. the ones that provide more information about many ecological characteristics, across ecosystems and parks within the Network. The entire budget for the I&M program is not sufficient even to adequately monitor all the Federally-listed T/E species in Network parks. Nevertheless, there are some rare species of overwhelming significance to particular parks – for instance, the Federally-listed duskytail darter is critically Endangered; preliminary genetic studies now ongoing indicate that the populations at BISO may represent a separate taxon which is entirely endemic to this park, where this short-lived fish is imminently Threatened by toxic spills or other severe water quality degradation episodes. The Waterrock Knob salamander appears to be endemic to a single site on BLRI; the cerulean warbler, Southern Appalachian yellow-bellied sapsucker, Endangered northern flying squirrel and Endangered spreading avens all have some of their largest and most significant remaining populations on BLRI and APPA lands. All the Network parks have numerous populations of imperiled plants in many community types (Tables 1.6 and 1.7). A balance must be struck between the need to monitor these species whose status is important, in and of themselves, versus their use as broader indicators of ecological condition. The parks and Network staff have agreed to limit the monitoring of rare species by the I&M program to BISO and OBRI; BLRI staff is addressing these monitoring needs with park staff or outside cooperators.

4. Appalachian Trail monitoring: The 2,174-mile trail passes through five NPS I&M networks. This park unit has not yet received program funding for monitoring, and precise relationships with the various I&M networks have not been established, although inventory funding for the Trail is being administered by the Northeast Temperate I&M Network. Nevertheless, we included the southern portion of the Trail (approximately 836 miles in VA, TN, NC and GA) in our Vital Signs selection process to facilitate future monitoring efforts if and when monitoring funding is allocated. In the meantime, the Vital Signs prioritization process may be of some assistance to APPA in implementing a volunteer monitoring program (water quality, rare plants, invasive exotic species) that is currently ongoing for portions of the trail.

5. Relationship between the network and park-based monitoring activities: It is impossible for any monitoring program on a limited budget to develop a complete picture of ecosystem health with the network staff and funding alone. Therefore, the network’s subset of Vital Signs were chosen to “fill the gaps” in current monitoring in the parks and allow time and money to be spent on issues that had high management

relevance and would create a more complete picture of ecosystem health when synthesized with ongoing monitoring of other Vital Signs.

It is essential that the network integrate with ongoing park monitoring programs to maximize the amount of information available in order to make informed management decisions. To successfully synthesize and report on the state of the parks' ecosystems, the network will work with the parks to update and revise existing protocols as well as provide direct assistance with data management, to the extent possible. In addition to updating and revising monitoring protocols, the network will work with park staff to create models for database and information management, with the goal of increasing the usefulness and dissemination of collected data.

Table 3.1. APHN Final list of Vital Signs

(*APPA is excluded from this table because they have not yet received monitoring funding; GRSM has had an ongoing prototype monitoring program in place for over a decade, and is included here for reference)

Level 1	Level 2	Vital Sign	Measures	BISO	BLRI	GRSM	OBRI
Air and Climate	Weather & Climate	**Weather**	Rainfall and snowfall amounts, temperature, relative humidity, wind speed and direction, solar radiation, fog or cloud emersion time, UV-B radiation	✚	✚	●	✚
	Air quality	**Ozone**	Atmospheric ozone concentration, damage to sensitive vegetation	✚	✚	●	✚
		Wet and dry deposition	Wet and dry sulfate and nitrate deposition, concentrations of nitrates, sulfates in high-elevation streams	✚	✚	●	✚
		Visibility and particulate matter	IMPROVE station data, change in visibility deciviews	✚	✚	●	✚
		Air contaminants	Aluminum & mercury in high elevation streams	✚	✚	●	✚
Geology and Soils	Geomorphology	Stream/river channel characteristics	Distribution of riffles, runs, pools, gravel beds and cobblebars in the river channel; channel width, gradient	◊	–	–	◊
		Stream sediment transport	Depth and location of sediment deposits in the river channel	◊	–	–	◊
	Subsurface geologic processes	Seismic activity	Frequency and intensity of earthquake events	–	●	–	–
	Soil quality	Soil structure and stability	pH, cation exchange capacity (ANC) in high-elevation communities, soil nutrients, soil erosion rates, extent of exposed soil, erosion rates	◊	◊	–	◊
Water	Hydrology	Groundwater dynamics	Depth of groundwater in bogs/fens	–	●	–	–
		Surface water dynamics	Flow rate, annual water level fluctuation as ancillary data for water quality monitoring	✚	✚	●	✚

Level 1	Level 2	Vital Sign	Measures	BISO	BLRI	GRSM	OBRI
	Water quality	**Water chemistry**	Temperature, specific conductivity, pH, dissolved oxygen, ANC, turbidity, major ions	✚	✚	●	✚
		Nutrient dynamics	Nitrate, ammonia, total phosphate	✚	✚	●	✚
		Toxics	Heavy metals, coal, aluminum	✚	✚	●	✚
		Microorganisms	Fecal coliform, fecal strep	✚	✚	●	✚
		Aquatic macroinvertebrates	Species richness, diversity, IBI of stream macroinvertebrates, relative abundance	✚	✚	●	✚
Biological integrity	Invasive species	**Invasive exotic plants**	New invasions (early-warning emphasis); occurrence, distribution models	✚	✚	●	✚
	Infestations and disease	Insect pests	Extent and distribution of outbreaks, changes in vegetation species composition and distribution	●	●	●	●
		Plant diseases	Extent and distribution of outbreaks, changes in vegetation species composition and distribution	●	●	●	●
	Focal Species or Communities	**Riparian communities-Cumberlandian cobblebars**	Species composition, structure, distribution, patch size; distribution and trends in rare species occurrence within the community	✚	–	–	✚
		Grassy balds	Species composition, structure, distribution, patch size; distribution and trends in rare species occurrence within the community	–	●	●	–
		Forest Vegetation	Community structure and demography; species composition, relative abundance, exotic species occurrence	✚	✚	●	✚
		Freshwater invertebrates	Mussel species composition, abundance, age structure	✚	–		✚
		Amphibians	Salamanders-abundance and distribution of vernal pool-breeding species		●	●	
		Fishes	Native and exotic trout distribution and age structure	–	–	●	–

Level 1	Level 2	Vital Sign	Measures	BISO	BLRI	GRSM	OBRI
		Birds	Distribution, abundance, breeding success	●	●	–	●
	At-risk biota	**T&E species and communities**	Spotfin chub & duskytail darter-distribution, abundance, age structure; distribution and abundance of other selected T/E species	✚	●	●	✚
Human use	Consumptive use	**Plant poaching**	Population trends and changes in distribution patterns of medicinal and ornamental plants	◊	✚	●	–
		Game animals	Black bear, white-tailed deer - population size and age structure	●	●	●	–
	Visitor and recreation use	**Veg impacts from recreational rock climbing**	Veg community structure, species composition; extent of exposed substrate	◊	✚	–	✚
Landscapes (Ecosystem pattern and processes)	Fire	Fire and fuel dynamics	Fire effects monitoring, satellite imagery of fire intensity, fuel loads from vegetation maps and fuel models	●	●	●	–
	Landscape dynamics	**Land cover and use**	Area of dominant land cover types ,patch size distribution, connectedness (aerial & satellite photos; veg maps; FIA); road density, housing density, other development & resource extraction adjacent to parks	✚	✚	●	✚

✚ This symbol (**bold text** and colored shading) shows Vital Signs for which the APHN is working to develop monitoring plans and protocols according to the standards of Oakley *et al*. (2003); the protocol for some of these (weather, air quality) will involve methods for gathering, analyzing and reporting existing data being collected by other entities.

● This symbol shows Vital Signs that are already being monitored by a network park or another Federal or state agency, or organization

◊ This symbol shows Vital Signs with no known current or planned monitoring

– This symbol indicates that the vital sign does not apply to the park

4. SAMPLING DESIGN

4.1 INTRODUCTION

The primary purpose of our Vital Signs sampling design is to ensure that the data collected are representative of the resources of interest, and that the number of samples taken is sufficient to meet the Network's monitoring objectives (Chapter 5). This chapter describes, in a general way, how spatial locations will be chosen for sampling APHN Vital Signs, and how sampling effort will be allocated to these sites. The discussion in this chapter is conceptual in nature, and is not intended to cover the details of sampling logistics or of data analysis methods; these will be covered extensively in the monitoring protocol for each Vital Sign.

4.2 SAMPLING CONCEPTS AND DEFINITIONS

Subsequent sections of this chapter briefly describe various sampling approaches proposed for APHN Vital Signs monitoring. These sampling plans rely on a few underlying concepts and use specific statistical terms. The background concepts behind the recommended designs and some of the more important sampling terms are explained in this section.

During development of the Network monitoring designs, we have defined ***monitoring*** as the collection and analysis of repeated observations or measurements over a long period of time to document status and trends in measurable ecological characteristics. Through an appropriate sampling design, monitoring is usually intended to provide unbiased statistical estimates of status and trends in large areas or entire study units. Monitoring is different from research in that it does not aim to establish cause and effect relationships, although it may demonstrate correlations among trends in different ecological characteristics.

The monitoring plans proposed for APHN rely on concepts of finite population sampling. In finite population sampling, the ***target population*** is the resource for which information is desired, and is defined by the monitoring objectives. The target population is made up of ***sample units*** – the smallest entities upon which measurements are taken. ***Responses*** are the measurements taken on the sample units. If sample units are chosen from some kind of random draw, the sample is called a ***probability sample***. Probability sampling makes it possible to statistically estimate characteristics of interest about the target population. Whenever possible, APHN will employ probability sampling to monitor Vital Signs.

Most sampling designs proposed for the Network will rotate field sampling efforts through various sets of sample units over time. A ***panel*** of sample units is a group of units that are always sampled during the same time period (McDonald 2003). The way in which sample units become members of a panel is called the ***membership design***. The pattern of sampling visits through time is called a ***revisit design***. MacDonald (2003) proposed a shorthand notation that is useful for describing revisit designs. The total number of panels in the sampling design is the sum of the digits in the notation. For example, the digit pair [1-2] means that a total of three panels will be visited on a "one on, two off" rotation (Figure 4.1, A). The notation [1-0, 1-1] indicates two different revisit designs: sample units in one panel will be visited on every sampling occasion, while units in two other panels will be visited on alternating occasions (Figure 4.1, B). The latter sampling design, called a ***split panel design***, is a kind of compromise approach, which allows for monitoring trends efficiently (by sampling at least one panel on every sampling occasion), while also establishing the condition (status) of the resource at as many sites as feasible across the landscape.

A)

	SAMPLING OCCASION					
PANEL	**1**	**2**	**3**	**4**	**5**	**6**
1	X			X		
2		X			X	
3			X			X

B)

	SAMPLING OCCASION					
PANEL	**1**	**2**	**3**	**4**	**5**	**6**
1	X	X	X	X	X	X
2		X		X		X
3			X		X	

Figure 4.1. Examples of revisit designs. A) shows a "rotating panel" design with a "one on, two off" rotation (notation: [1-2]). B) is a "split panel" design, with one panel visited every year, and the other two on a "one on, one off" rotation (notation: [1-0, 1-1]).

4.3 OVERVIEW OF SAMPLING APPROACHES

Because of the diversity of resources selected for APHN Vital Signs monitoring, a single overarching sampling design for the Network is not practical. Nevertheless, Network Vital Signs are interrelated in many ways, and in some cases there are opportunities for developing multiple lines of evidence for detecting trends (Table 4.1.)

Table 4.1. Relationships among APHN Vital Signs.

VITAL SIGNS (rows) / VITAL SIGNS (columns)		Water Quality/Water Quantity	Aquatic Macroinvertebrates	Landscape Change	VEGETATION					Air Quality	Weather	Mussels (T&E)	Fish (T&E)
					Forest Vegetation	Poaching	Exotic Plants	Cobblebars	Recreational Impacts				
Water Quality/Water Quantity			X	X	X			X		X	X	X	X
Aquatic Macroinvertebrates		X		X						X	X	X	X
Landscape Change		X	X		X		X	X	X	X		X	X
VEGETATION	Forest Vegetation	X		X		X	X				X		
	Poaching				X		X						
	Exotic Plants			X	X	X		X	X				
	Cobblebars	X		X			X		X	X	X		
	Recreational Impacts			X			X	X					
Air Quality		X	X	X				X			X		X
Weather		X	X		X			X		X		X	X
Freshwater Mussels (T&E)		X	X	X							X		X
Fish (T&E)		X	X	X						X	X	X	

Vital Signs *target populations* exist at varying scales and our current knowledge of these resources, as well as practical sampling considerations, will influence each sampling design. With the exception of Landscape Change monitoring, the framework for sampling for Network Vital Signs will focus on target populations within individual parks; statistical inferences to multiple parks and regions are not intended. In considering sampling approaches for the Network, whenever possible, we will use a probabilistic sampling design which will allow us to make statistical inferences to larger populations. For some Vital Signs, *unequal probability sampling* will be employed. This version of probability sampling varies the probability of a sample being drawn, based on various physical or biological attributes. For example, the probability of a sample being drawn can be weighted by the accessibility of an area, or by the rarity of a target population. Subjective sampling, where sample sites are chosen based on expert opinion, will be avoided, because inferences from this kind of study depend on individual judgment, and are not replicable (the exception to this is water quality sampling, where index sites will be used – see discussion below).

For most of the APHN Vital Signs, at least one year of pilot sampling will be needed before the sampling design is finalized. The project objectives, spatial allocation of sites, and revisit designs may be altered when these initial results are analyzed. With the proviso that pilot sampling has not been fully completed for the APHN Vital Signs, Table 4.2 illustrates the general sampling approach the Network will be implementing over the five year period after the monitoring plan is approved. Sampling considerations for Vital Sign categories are discussed in more detail below.

Table 4.2. Overall sampling design approach for APHN Vital Signs to be implemented in the five years beginning in October, 2005.

Level 1 Category	Level 2 Category	Level 3 Category	Network Vital Sign	Overall Sampling Approach	Spatial Allocation	Revisit Plan
Air and Climate	Air Quality	Ozone	Ozone	NA	Index sites	Annual summary
		Wet and dry deposition	Wet and dry deposition	NA	Index sites	Annual summary
		Visibility and particulate matter	Visibility and particulate matter	NA	Index sites	Annual summary
		Air contaminants	Air contaminants	NA	Index sites	Annual summary
	Weather and Climate	Weather and Climate	Weather	NA	Index sites	Annual summary
Water	Hydrology	Surface water dynamics	Surface water dynamics	Aquatic – one dimensional	Index sites	Monthly/ bimonthly
	Water Quality	Water chemistry	Water chemistry	Aquatic – one dimensional	Index sites	Monthly/ bimonthly
		WQ Nutrients	Nutrient dynamics	Aquatic – one dimensional	Index sites	Monthly/ bimonthly
		Toxics	Toxics	Aquatic – one dimensional	Index sites	Monthly/ bimonthly
		Microorganisms	Microorganisms	Aquatic – one dimensional	Index sites	Monthly/ bimonthly
		Aquatic macroinvertebrates and algae	Aquatic macroinvertebrates	Aquatic-two dimensional	Index sites	Monthly/ bimonthly

Level 1 Category	Level 2 Category	Level 3 Category	Network Vital Sign	Overall Sampling Approach	Spatial Allocation	Revisit Plan
Biological Integrity	Invasive species	Invasive exotic plants	Invasive exotic plants	Terrestrial – two dimensional	Stratified random	TBD
	Focal Species or Communities	Forest vegetation	Forest vegetation	Terrestrial – two dimensional	Stratified random	TBD
		Riparian communities	Cumberlandian cobblebars	Terrestrial – two dimensional	Stratified random	Rotating panel
		Freshwater invertebrates	Freshwater mussels	Aquatic – two dimensional	Stratified random	Rotating panel
	At-risk Biota	T&E species and communities	T&E Fish - duskytail darter	Aquatic – two dimensional	Stratified random	Rotating panel
		T&E species and communities	T&E Fish - spotfin chub	Aquatic – two dimensional	Stratified random	Rotating panel
Human use	Consumptive Use	Plant poaching	Medicinal and ornamental plant poaching	Terrestrial – two dimensional	Probability sample	Rotating panel
	Visitor and Recreation Use	Visitor usage	Vegetation impacts from recreational rock climbing	Terrestrial – two dimensional	Probability sample	TBD
Landscapes	Landscape Dynamics	Landscape Dynamics	Land cover and use	Terrestrial – two dimensional	NA - Landscape analysis	Every five-to-ten years

AIR QUALITY

Because of the expense of establishing and maintaining air quality monitoring stations, the Network will be gathering and summarizing air quality data on an annual basis from existing stations near APHN parks. A recent review of air quality monitoring data for the Network (Appendix D) found that regional coverage of air quality monitors was generally adequate to characterize air quality in the parks. However, some data gaps do exist, particularly in sections of BLRI, due to local variations in elevation and topography. In relation to other Network Vital Signs, changes in air quality over time might be expected to correlate with various land use change indicators. Also, trends in atmospheric deposition at high elevations in the Blue Ridge should be reflected in water quality measures in these locations, particularly pH, acid neutralizing capacity, and levels of dissolved aluminum. Macro-invertebrate and fish populations would also be expected to mirror trends in atmospheric deposition.

WEATHER

As with air quality data, weather data will be collected and summarized annually from stations near the parks. Weather data is being collected by the Network as ancillary data to support some of our other protocols. Because weather events are often extremely localized in the region, this data is expected to be quite variable, and will need to be used cautiously when it is used in conjunction with other Vital Signs analyses. Gaps in the distribution of weather monitoring stations relative to monitoring sites will become more apparent once Vital Signs sampling designs are finalized. In relation to other Network Vital Signs, trends in weather measures are most prominently related to water quality parameters, population levels of aquatic macroinvertebrates, freshwater mussels, and fish, as well as to various aspects of vegetation composition and structure.

WATER QUALITY/WATER QUANTITY

The Network's draft water quality monitoring design can be found in Appendix J. The design is based on placing index sites in each park (BISO, BLRI, and OBRI) in locations which were determined using eight criteria (see below). The utility of probability sampling was much discussed among Network and park staff, as well as subject matter experts. In the end, the advantages of being able to make inferences to larger stream reaches were outweighed by practical considerations such as sampling efficiency and safety, and by the difficulty of defining sampling units which would make sense in the future as the nature and location of anthropogenic sources of pollution change.

Water Quality/Quantity Site Selection Criteria

- The site's utility as an "integrator site" – located downstream of river or tributary segments which are of interest either because they are significant sources of pollution, or because of their pristine water quality.
- The presence of significant aquatic resources in a stream segment, where water quality trend information is needed in order to corroborate trends in the resource of interest, or to provide managers with an early warning of possible problems.
- The management importance attached to a site, either because protection of the water body is mandated in park legislation, required in a park resource management plan, or designated by the state as a pristine or polluted (303d) body of water.
- The presence of existing water-quality information at the site. A long-term record of water quality monitoring data increases the functional utility of trend monitoring at a site, and makes it possible to detect changes in the resource without having to establish baseline water-quality conditions.
- The existence of a continuous discharge station near a site, which greatly increases the usefulness of the water-quality data, and enables mass transport calculations of loads and yields – information which is often of high significance to managers.
- The existence of other long-term resource monitoring near a site, where water quality information would be useful for corroborating other observed trends.
- The availability of good access to the site. Bridges or cableways are necessary for collecting water quality samples and measuring discharge during high flow conditions. Ease of access also increases time efficiency.
- Safety of sampling access. Reaching some of the more remote sites at BISO and OBRI would require expert whitewater skills. Identification of safe wading sections and stages is important.

In all cases, flow data will be collected in conjunction with water quality sampling, in order to provide pollutant loading information. Aquatic macroinvertebrate sampling sites will be colocated with water quality monitoring stations as well. Water quality sites will be sampled either monthly, or bi-monthly depending on the need for higher resolution status and trend information. A core list of sites will be sampled annually, in order to detect year-to-year effects; other stations will be alternated on a two-to-three year cycle, in order to gather status information over a larger number of water bodies.

Aquatic macroinvertebrate population trends would be expected to correlate with water quality trends. As Vital Signs, macroinvertebrates serve as "integrators" of water quality conditions, and may be affected by episodic events which would be missed by water quality sampling alone. Water quality trends will be expected to relate to trends in rare freshwater mussel and rare fish populations at BISO, and OBRI. At BLRI, we expect water quality trends in high elevation headwater streams to mirror trends in atmospheric deposition. Water quality and water quantity trends will also be important for explaining changes in cobblebar vegetation at BISO and OBRI; data for these Vital Signs will be collected on the same river reaches.

VEGETATION

The Network is developing monitoring designs for five different vegetation monitoring projects, each of which differ in objectives, target populations, and sampling approach. Sampling design considerations for each project are outlined below, however, pilot sampling has only been completed for two of the five, so many details are still to be worked out.

Forest Vegetation: This project primarily concerns focal vegetation communities at BISO. That park is interested in detecting change in community characteristics over time in riparian forests, as well as fire-adapted oak and pine communities. Sampling design for this project will not begin until the coming year (2006), however, it is likely that some kind of stratified random sampling will be employed based on elevation and position in the landscape. A draft vegetation map may be used to guide the placement of strata. Sampling efficiency will be a concern because these communities are relatively inaccessible. The revisit design is likely to be some form rotating panel. Because community composition and structure changes slowly, the revisit design will likely attempt to achieve greater spatial coverage with less frequent sampling of individual sites.

Plant Poaching: This project will attempt to track population trends in certain herbaceous plant species at BLRI. These species are either current poaching targets or potential targets of future illegal plant harvesting. The target populations were chosen because they all favor similar habitats and their phenology is similar. The sampling frame will be constructed with the aid of a habitat model developed by the U.S. Forest Service, which uses physical landscape characteristics to predict the locations of vegetation communities. Within the sampling frame, sample units will be randomly chosen and visited on a rotating panel design.

Exotic Plants: The exotic plant protocol will focus on early detection of exotic plant incursions along the boundary of BLRI. This sampling design will be developed in the coming months (Fall, 2005), and will center on disturbance corridors which cross the Blue Ridge Parkway, such as road and powerline crossings. There is a possibility that the Landscape Change protocol may be able to assist this project by investigating the feasibility of attaching invasion probabilities to different land use types along the park boundary. The plan is likely to be a stratified random design with sample units distributed by probability of invasion. The revisit design will need to consider the importance of early detection and frequent site visits versus the need for greater spatial coverage.

Cobblebars: Cumberlandian cobblebars - a rare riparian community occurring at BISO and OBRI - contain numerous rare plant species and are potentially threatened by water pollution and changes in river flow due to upstream water withdrawals. The Network will monitor changes in vegetation structure and composition at these sites, as well as population trends in selected rare plant species endemic to the cobblebars. An initial reconnaissance survey will be conducted to create a complete map of the cobblebars in both parks. Sampling units (the cobblebars) will likely be selected using a stratified random design, with major tributaries being assigned to different strata according to the quality of cobblebar habitat on each stream (mean cobblebar size, for example). Sampling transects will be laid out systematically on each cobblebar to measure vegetation structure and composition. A complete census of selected rare plants will also be conducted at each site. A rotating panel design will be used in order to determine status of this community over a large spatial extent.

Recreational Impacts: Climbing impacts and informal recreational trails are a concern at both BLRI and OBRI. Sampling design for this project will begin in 2006, and will focus on selected sites where impacts are occurring or are anticipated. The design will likely be a probability sample of trampled areas near sensitive sites, with the intent of measuring change in vegetation structure and composition. Sites will likely be visited on a rotating basis unless the intensity of trampling in some areas requires a split panel design.

FRESHWATER MUSSELS (T&E)

BISO and OBRI harbor eight Federally Endangered freshwater mussel species, and BISO is initiating a mussel reintroduction project in the near future. The Network is preparing a long-term monitoring protocol to track this highly significant fauna in both parks. Because mussel habitat in these rivers is fairly well defined – the vast majority of individuals are found in riffles – the monitoring design will begin with a reconnaissance survey in order to classify and map riverine habitats. A stratified random (or unequal probability) design will likely be used with samples units (riffles) assigned to different tributaries based on habitat suitability. A rotating panel design will be used to maximize the number of sample units that are monitored.

FISH (T&E)

BISO contains what could be the last remaining population of a unique strain of the Federally Endangered Duskytail Darter. OBRI harbors one of three remaining populations of the Federally Threatened Spotfin Chub. Both parks also contain a number of other state-listed fish species. Like freshwater mussels, these fish also prefer riffle areas and they occur in many of the same stream reaches as the mussels. The sampling approach for these animals will be much the same as for the mussels. A riverine habitat map will used to delineate existing or potential habitat, and a stratified random sample of these areas will be drawn. A rotating panel revisit design will be used.

LANDSCAPE CHANGE

All of the Network parks are experiencing various effects of development outside their boundaries, and all are interested in a periodic survey using remotely sensed data that will give them a better understanding of what kinds of external changes are occurring and where they may be likely to occur in the future. BISO and OBRI are particularly hoping to correlate these changes with water quality and water quantity trends, while BLRI is most interested in exotic plant incursions, sedimentation and other kinds of physical disturbance along its 1000-mile boundary.

A second category of questions that will be addressed by this protocol involves tracking changes in dominant vegetation types within the parks on a five-to-ten year rotation. This will be a particularly important analysis for the parks because vegetation changes are so central to other changes that occur on the landscape, and because the expense of repeating the current vegetation mapping effort on a periodic basis will be prohibitive.

5. SAMPLING PROTOCOLS

> ***Monitoring protocols** are detailed study plans that explain how data are to be collected, managed, analyzed, and reported, and are a key component of quality assurance for natural resource monitoring programs. Protocols are necessary to be certain that changes detected by monitoring actually are occurring in nature and are 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

Once a vital sign has been selected and an appropriate sampling design chosen, the next step is to develop a monitoring plan (protocol) for that vital sign. Monitoring protocols identify methods for gathering information on a resource or its stressor(s), outline a process to collect information, and establish how information will be analyzed and reported. Protocols are detailed study plans that are necessary to ensure that changes detected by monitoring actually are occurring in nature and do not stem from measurement variability introduced when different people or methods are used (Oakley et al. 2003). Protocols are essential for monitoring Vital Signs through time and personnel changes.

Monitoring protocols must include a narrative providing the rationale for vital sign selection, an overview of the monitoring protocol components, and a history of the development of the protocol. The narrative details protocol sampling objectives, sampling design (including location and time of sample collection), field methods, data analysis and reporting, staffing requirements, training procedures, and operational requirements (Oakley et al. 2003). Specific measurable objectives must be identified in the objective section of the narrative. Narratives also summarize the design phase of a protocol's development and any decision-making that is relevant to the final protocol. Documenting the history of a protocol during its development phase helps ensure that future refinement of the protocol continues to improve the protocol and is not merely repetition of previous trials or comparisons. Narratives also provide a listing and brief summary of all standard operating procedures, which are developed in detail as independent sections within the protocol.

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

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

Table 5.1 shows which monitoring protocols the APHN plans to implement in the next five years in the three network parks which are now initiating their Vital Signs monitoring programs (BISO, BLRI, and OBRI; as stated earlier in this plan, GRSM has already implemented a long-term ecological monitoring program, and APPA does not yet have funding for monitoring, so they are not included here). This table summarizes the importance and objectives of the monitoring, and shows which parks the monitoring will be done in (See the links to Protocol Development Summaries in Appendix I). A completed draft of the Water Quality Monitoring Protocol is presented in Appendix J. Network staff and cooperators are currently working to develop the remaining monitoring protocols (See Table 9.1, the Protocol Implementation Schedule in Chapter 9).

Table 5.1. Monitoring protocols the Network plans to implement in the next five years.

CATEGORY	PROTOCOL	PARKS			JUSTIFICATION & OBJECTIVES
		BISO	BLRI	OBRI	
Air and Climate	Weather	X	X	X	***Weather drives all ecological systems, both terrestrial and aquatic. Continuous weather data is a key factor in separating the effects of climate from the effects of human-induced disturbance on plant and animal community and population dynamics. This protocol will be designed to collect auxiliary climate information critical for interpreting the results of much of the other monitoring and research taking place within the Network parks.*** • Determine variability and long-term trends in climate for APHN parks through monthly and annual summaries of descriptive statistics for selected weather parameters, including air temperature, precipitation, cloud cover, and wind speed and direction. • Determine relationships between weather patterns and other resources of concern including timing/success of reproduction in selected species, outbreaks of forest insect pests and pathogens, and distribution of exotic invasive species.
Air and Climate	Air quality (Ozone, wet & dry deposition of sulfate, nitrate, visibility/particulate matter air contaminants)	X	X	X	***Air quality degradation is a major problem within the APHN region, involving some of the highest measured depositions of sulfur and nitrogen in North America. Nitrate levels in some high-elevation GRSM streams are the highest documented in the U.S. for undisturbed watersheds, and are close to exceeding the public health standard for drinking water; similar problems are suspected but undocumented at BLRI & APPA. Average visual range has declined in this region from 113 miles to 25 miles during recent decades, as a result of increased sulfur dioxide emissions and atmospheric particulates. GRSM has documented both high ozone levels and substantial injury to vegetation in recent years; similar problems are suspected but undocumented at BLRI and APPA. High ozone levels also threaten human respiratory health.*** • Determine levels of air pollutants in parks and correlate to observed effects. • Identify and assess trends in air quality. • Determine compliance with National Ambient Air Quality Standards. • Provide data for the development and revision of national and regional air pollution control policies. • Provide data for atmospheric model development and evaluation. • Use information to inform the public about conditions/trends in national parks. • Determine which air pollutants in parks contribute most to visibility impairment. • Establish existing, or baseline, concentrations of ozone in parks • Identify those air pollutants with the potential to injure or damage park biological resources, monitor these pollutants, and correlate measurable effects on resources to existing ambient levels of these pollutants.
Water	Water quality (Ancillary data on flow)	X	X	X	***Surface water flow is important because it directly influences aquatic and riparian biota, and because measures of water quality must also include some measure of flow to provide information on pollutant loading.*** • Determine trends in water quantity in support of water quality monitoring in the Big South Fork and Obed Rivers, and their major tributaries, and at selected sites at BLRI.

CATEGORY	PROTOCOL	PARKS			JUSTIFICATION & OBJECTIVES
		BISO	BLRI	OBRI	
Water	Water quality (including core parameters)	X	X	X	***BISO, OBRI and BLRI have many significant aquatic resources including Outstanding Resource Waters and imperiled species. BLRI protects half of the remaining high elevation wetlands in the Southern Appalachians. The waters of BISO and OBRI face perpetual upstream threats from coal mining activities, oil and gas extraction, logging, agricultural activities, urban development, and sewage effluent. BLRI is Threatened by acidification of high-elevation streams related to heavy atmospheric pollutant deposition.*** • Determine long-term trends in water temperature, pH, conductivity, dissolved oxygen, ANC, ammonium, major ions (sulfate, chloride, nitrate, magnesium, calcium, potassium, sodium), and trace metals (including aluminum, copper, iron, manganese, lead, zinc), and fecal coliform bacteria at selected sites.
Water	Aquatic macro-invertebrates (larval stoneflies, mayflies, caddisflies, dragonflies, damselflies, midges)	X	X	X	***Aquatic macroinvertebrates are effective long-term integrators of the short-term events influencing water quality in particular locations, as well as of chronic water quality problems. Often the presence of specific taxa is indicative of particular water quality and habitat conditions. The protocol will focus on sampling that reflects impacts associated with major threats in APHN parks, including oil and gas extraction (BISO, OBRI), coal mining (BISO, OBRI), acid deposition (BLRI), agricultural development, industrial pollution, and sewage effluent (all). Wherever possible, sampling stations will be co-located with flow gauges, long-term monitoring stations for rare fish and rare mussels, in order to provide park managers with information to determine whether changes in management are warranted.*** • Determine trends in water quality using aquatic macroinvertebrate species diversity and abundance as integrative indicators. • Determine long-term trends in species composition, distribution, and abundance of aquatic macroinvertebrate assemblages at selected sites in BISO, OBRI, and BLRI, comparing unimpacted sites with those that are subject to contaminated mine drainage, acidic atmospheric deposition, siltation and other anthropogenic impacts. • Correlate physical and chemical habitat measures with changes in distribution and abundance of macroinvertebrates.

CATEGORY	PROTOCOL	PARKS			JUSTIFICATION & OBJECTIVES
		BISO	BLRI	OBRI	
Biological Integrity (Focal species or communities & at-risk biota)	Vegetation composition and structure (forest community structure and demography)	X	X	X	***Forest ecosystems in Network parks are Threatened by a variety of biotic and abiotic stressors; the most significant are related to forest insects and diseases, air pollution, and disruption of natural disturbance regimes. Examples include the balsam wooly adelgid, which has nearly eliminated mature Fraser fir from high-elevation forests in the Southern Appalachians; the hemlock wooly adelgid, which is currently decimating both species of eastern hemlock; and beech bark disease, an insect/fungus complex that is killing beech trees in upper elevation northern hardwood forests. Air pollution impacts include deposition of sulfur dioxide and nitrogen oxides which acidify water and soil, releasing dissolved aluminum in amounts toxic to plant roots. High ozone levels at the upper elevations in the Blue Ridge parks add to the cumulative stress on plants. Overpopulation by white-tailed deer is believed to be changing species composition and structure in some areas. Exotic invasive plants are changing vegetative community structure and function in many areas of the parks.*** • Determine how vegetation composition and structure are changing across the landscape through measurements of percent change in cover of dominant or co-dominant canopy and understory species in predominant community types and communities that are imminently Threatened. • Determine long-term trends in vegetation composition and structure (percent cover and density by species) in selected areas on BLRI with high population levels of white-tailed deer (Peaks of Otter). • Determine changes in the distribution of the most damaging invasive exotic plants within and adjacent to the parks, including: - Identifying "land units" within 1 mile of park boundaries that have low (<25%), medium (25-75%) and high (>75%) probabilities of exotic plant occurrence for the 20 most invasive species (design of early warning system)
Biological Integrity (Focal species or communities & at-risk biota)	Vegetation composition and structure (early-successional community structure, demography)	X	X	X	***The cobblebar and cliffline communities of APHN parks represent globally imperiled communities that support many Federally- and state-listed T/E species. Network parks support the best remaining examples of these communities in many cases. Most of them are dependent on natural disturbances such as flooding and fire. Altered disturbance regimes change ecosystem processes, including nutrient cycling, productivity, and succession. This also influences species and natural community diversity and distribution, and amplifies effects of other stressors. Recreational rock climbing may potentially alter vegetation composition and structure along the clifflines at BISO, OBRI and BLRI.*** • Determine how vegetation species composition and structure (percent cover, density) are changing in focal communities (cobblebars, cliffline communities). • Determine long-term trends in species composition and community structure (e.g., cover, density by height class of woody species) of cobblebar communities at BISO and OBRI. • Detect at least a 20% change in successional patterns based on height of woody vegetation and species composition in the 1-2m size class. • Detect a 50% change in bare (unvegetated) substrate, associated with recreational use. • Determine long-term trends in plant species composition and structure at selected cliffline sites at BISO, BLRI, and OBRI, comparing trends at recreational rock-climbing sites with unclimbed control sites.

CATEGORY	PROTOCOL	PARKS			JUSTIFICATION & OBJECTIVES
		BISO	BLRI	OBRI	
Biological Integrity (Focal species or communities & at-risk biota)	Fish (T&E) (duskytail darter)	X			***The duskytail darter, a Federally-listed Endangered species, is limited to a range-wide total of three surviving populations and a fourth reintroduced population. The BISO population, critical to the survival and recovery of the originally-described species, is now believed to be a genetically distinct taxon, making its preservation all the more crucial. At BISO, the duskytail is limited to 12 shoals along a fourteen-mile reach of the most pristine and inaccessible portion of the main channel of the Big South Fork. This fish is dependent upon silt-free, rocky pools in large streams and rivers, and is sensitive to siltation-related water quality degradation. Water quality in the main stem of the Big South Fork is perpetually Threatened by a variety of upstream perturbations, including coal mining, oil and gas extraction, urban development, water withdrawal, impoundment, agricultural activities and logging. Because of the significance of the duskytail darter population protected by BISO, and the multitude of potential threats upstream, long-term trend data are needed to monitor changes in this population.*** • Determine long-term trends in distribution and relative abundance of duskytail darter populations at BISO. • Improve understanding of relationships between this species and its habitat by correlating physical and chemical habitat measures with changes in distribution and abundance of the fish.
Biological Integrity (Focal species or communities & at-risk biota)	Fish (T&E) (spotfin chub)			X	***The spotfin chub, a Federally-listed Threatened species and an obligate inhabitant of clear upland rivers, survives in only four isolated tributary populations in the Tennessee River basin, one of which is protected within OBRI. Water quality in the Obed River, like the Big South Fork, is perpetually Threatened by a variety of upstream perturbations, including coal mining, oil and gas extraction, urban development, water withdrawal, impoundment, agricultural activities and logging. Because of the significance of the spotfin chub population protected by OBRI, and the multitude of water quality threats upstream, long-term trend data are needed to monitor changes in the population.*** • Determine long-term trends in distribution and relative abundance of spotfin chub populations at OBRI. • Improve understanding of relationships between this species and its habitat by correlating physical and chemical habitat measures with changes in distribution and abundance of the fish.

CATEGORY	PROTOCOL	PARKS			JUSTIFICATION & OBJECTIVES
		BISO	BLRI	OBRI	
Biological Integrity (Focal species or communities & at-risk biota)	Freshwater mussels (T&E)	X		X	***Habitat protected by BISO represents the best remaining freshwater mussel refugium in the Cumberland River system, and is crucial for the survival of many imperiled species, including six that are Federally-listed as Endangered. Freshwater mussels are sedentary filter-feeders and are extremely sensitive to water quality degradation. Large declines in the mussel fauna since the turn of the twentieth century illustrate how rapidly changes can occur. Roughly 55 mussel species were known from the Big South Fork at the turn of the century; only 26 species remain, and seven of the original number are now believed extinct.*** • Determine long-term trends in species composition and age class structure of freshwater mussel populations in the main stem rivers and major tributaries of BISO and OBRI • Determine long-term trends in the distribution and relative abundance of freshwater mussels at BISO and OBRI. • Improve understanding of relationships between freshwater mussel communities and their habitat by correlating physical and chemical habitat measures with changes in mussel distribution, abundance, and age class structure.
Biological Integrity (Focal species or communities & at-risk biota)	Vegetation composition and structure (rare plants of cobblebars)	X		X	***The best remaining examples of the globally-imperiled Cumberalandian cobblebar community are in BISO and OBRI, along with some of the largest and most vigorous populations of the Federally-listed Cumberland rosemary, a Cumberland Plateau endemic, the Federally-listed Virginia spiraea, and many other rare and state-listed species. This community and its rare inhabitants are Threatened by alterations of natural river flow/flooding regimes and by exotic species invasion.*** • Determine long-term trends in the distribution and abundance of selected rare, Threatened, and Endangered plant species in cobblebar communities at BISO and OBRI. • Determine changes in size-class distribution for selected rare, Threatened, and Endangered plant species on cobblebars. • Monitor to detect a 25% change in populations of Federally-listed T&E species (Cumberland rosemary, Virginia spiraea), including numbers of individuals in plots, cover, patch size, number of occupied rock crevices. • Detect a 50% change in relative abundance and cover of other species of concern (incl. herbaceous, shrub, perennials, annuals)
Human Use	Vegetation composition and structure (poaching of native plants)		X		***Poaching of medicinal and ornamental native plants on a large scale is a problem, especially at BLRI, where individual poachers have been intercepted leaving the park with tens of thousands of plants. Some species do not recover quickly from this level of harvest, and are being eliminated from habitats that are accessible to poachers. Species composition, especially in rich hardwood coves, may be being altered as a result.*** • Determine long-term trends and document short-term shifts in species composition and community structure (indicative of large-scale poaching), and age/size class structure of selected poached plant species (black cohosh, bloodroot, galax, trillium species, orchid species) at BLRI. • Determine long-term trends in the distribution, abundance, and age/stage class structure of poached plant species in BLRI, comparing control sites to sites that are likely to be targeted by poachers.

CATEGORY	PROTOCOL	PARKS			JUSTIFICATION & OBJECTIVES
		BISO	BLRI	OBRI	
Ecosystem Patterns and Processes	Landscape change (Land cover, landscape pattern)	X	X	X	***Despite their protected status and considerable acreage, network parks have been altered by numerous biotic and abiotic factors which continue to threaten their ecological integrity. Exotic species and diseases have been particularly destructive. The arrangement of habitats in a landscape, as well as differences in habitat quality, influences the ecological functioning of plants and animals, particularly those that exist in metapopulations. Habitat fragmentation is a particular concern for small, isolated communities which function as habitat islands in the landscape. Communities where this may be a concern include high-elevation clifftop and rock outcrop communities, grassy balds, mountain bogs, cobblebars, and remnant stands of spruce-fir forest, all of which support a large number of rare or endemic species of plants and animals.*** • Determine long-term landscape-scale changes in dominant vegetation types/communities on park lands through remote sensing (area of dominant land cover/vegetation types, patch size distribution and connectedness/fragmentation). • Determine long-term changes in fire frequency and extent on park lands. • Determine long-term changes in frequency and extent of insect and disease outbreaks on park lands.
Ecosystem Patterns and Processes	Landscape change (Land use patterns)	X	X	X	***External land use influences park resource management in numerous ways, including the impact on water quality from upstream industrial or agricultural development; the proliferation of impoundments outside the river gorge parks may significantly decrease water quantity and disrupt natural flooding cycles in the large rivers flowing through the parks. Development along park boundaries may fragment sensitive habitats, introduce exotic species, disrupt animal migration across park boundaries, spoil scenic vistas, or expand wildland-urban interface zones. Informal trail accesses from outside park boundaries (including ATV and horse trails) may damage sensitive vegetation, cause erosion, and form conduits for invasive exotic species.*** • Determine through remote sensing how and at what rate land use/cover and development patterns (including areal extent and configuration of land cover/land-use types) are changing adjacent to and upstream of the parks.

6. DATA MANAGEMENT AND ARCHIVING

Natural resource data are the vital building blocks for our evolving ecological understanding about park resources. But a set of data – whether collected the previous year or 20 years ago – must also be accompanied by sufficient context of how and why it was collected to maintain its value beyond the lifetimes of those who collected it. Therefore, a data management strategy cannot simply attend to the tables, fields, and values that make up a data set. There must also be a process for developing, preserving, and integrating the context that makes it interpretable and valuable. The APHN Draft Data Management Plan (Appendix K) describes the Network data management program in some detail; the highlights of the Plan are outlined in this chapter.

6.1 APHN DATA MANAGEMENT GOALS

In accordance with national I&M goals, and APHN park priorities, Network activities revolve around five broad program themes, all which involve various aspects of data management:

- **DEVELOPING A COORDINATED LONG-TERM ECOLOGICAL MONITORING PROGRAM** to efficiently and effectively monitor ecosystem status and trends over time. The long-term monitoring plan was completed in 2005; monitoring of water quality, vegetation, and freshwater mussels began in 2005;

- **CONDUCTING BASELINE INVENTORIES** of natural resources in the parks. Vascular plant and vertebrate surveys will document 90% of the species in each taxonomic group; detailed vegetation cover maps are also being prepared for each park from aerial infrared photos;

- **DEVELOPING DECISION SUPPORT SYSTEMS** (including GIS and other tools) to aid park managers in identifying, implementing, and evaluating management options;

- **INTEGRATING INVENTORY AND MONITORING** programs with park planning, maintenance, interpretation and visitor protection activities to help the parks in their efforts to make natural resource protection even more of an integral part of overall park management, and;

- **COOPERATING WITH OTHER AGENCIES AND ORGANIZATIONS** to share resources, achieve common goals, and avoid unnecessary duplication of effort and expense. A concerted effort is being made to identify and carry out cost-sharing, data sharing, and technology exchange opportunities with other agencies conducting similar inventories or monitoring.

An integrated approach to Network data management is the cornerstone supporting these five broad program themes. The Network data management goals establish the foundation for building a sound, responsive data management program, namely, that data collected by the Network are of high quality, are readily available, can be easily interpreted, and are secure for the long-term.

APHN Data Management Goals

1) To ensure that data managed by the network are of high quality, *including, designing standardized data entry, importation, and handling procedures which effectively screen for bad data, and minimize transcription and translation errors;*

2) ***To make certain network data are readily available,*** *by implementing standard procedures for distributing data, while protecting sensitive data; and designing a standardized filing system for organizing I&M information;*

3) To ensure that network data can be easily interpreted, *by considering the users' needs as the primary factor driving the design of summary reports and analyses; establishing rigorous data documentation standards; integrating common data tables and fields in the NPS database template format; and making summary information available in formats tailored to the variety of audiences interested in I&M program results;*

4) To make certain that data are secure for the long term, *including, instituting standard procedures for versioning, data storage and archiving; and maintaining the necessary hardware and software configurations to support network data management needs.*

6.2 DATA MANAGEMENT ROLES AND RESPONSIBILITIES

Meeting the Network's data management goals requires the participation of everyone on the APHN staff, from field crews who collect data, to project managers who validate, analyze and summarize data, to the Network data manager, who ensures that "master" data sets are of high quality, and that proper data management standards and practices are adhered to. Because good data stewardship is so central to the mission of the Network inventory and monitoring program, significant staff time at all levels is devoted to that effort (Table 6.1).

Table 6.1. Appalachian Highlands I&M Network staff resources directed toward data management.

Title	# of Staff Positions	% of Time	Data Mgt. Activities	Total FTE	Total Cost (k)
Coordinator	1	30 %	data analysis, summary, and reporting, data validation and verification	.3	25.7
Data Mgr.	1	80%	data archiving and dissemination, database development, overall QA/QC	.8	54.4
Ecologists	2	35%	data analysis, summary and reporting, data validation and verification	.7	55.8
BioTechs	4	30%	data entry and verification	1.2	17.8

Project Management

The project manager and data manager play key roles in every Network I&M project. In the APHN, the project manager is normally a Network ecologist – ideally, the person who has the best training in the particular field which is the subject of the project. The project manager is responsible for data quality during all phases of the project, including, data collection, QA/QC, analysis and reporting. Developing project documentation and metadata are crucial elements of this function.

THE PROJECT MANAGER'S DATA MANAGEMENT RESPONSIBILITIES INCLUDE:

- Developing basic project metadata documentation
- Documenting and implementing standard procedures for data collection and data handling, including deviations from those procedures
- Developing quality control measures, including certification of field operations, equipment calibration, species identification, data entry, data verification and validation
- Maintaining hard copies of data forms and archiving original forms
- Scheduling regular project milestones, including data collection periods, data processing target dates, and reporting deadlines
- Acting as the main point of contact concerning data content

The project manager will work closely with the data manager to:

- Develop quality assurance and quality control procedures
- Identify training needs for staff related to data handling procedures, quality control measures, and database software use
- Coordinate the design of field data forms and the user interface for the project database
- Document and maintain master data
- Identify sensitive information that requires special consideration prior to distribution
- Ensure regular archiving of project documentation, original field data, databases reports and summaries, and other products related to the project
- Create data summary procedures to automate the process of transforming raw data into meaningful information
- Identify and prioritize legacy data for conversion to desired formats
- Increase the accessibility and interpretability of existing natural resources information

The Network data manager has a central role in ensuring that project data conforms with program standards, designing project databases, disseminating data, and ensuring long-term data integrity, security, and availability. In order to maintain high data quality standards, and promote ready use of project data, the data manager collaborates with the project manager to develop data entry forms, QA/QC procedures, and automated reports. The data manager maintains standards for this data and the associated metadata, and develops procedures for sharing and disseminating GIS data to Network parks and partners.

THE DATA MANAGER'S RESPONSIBILITIES INCLUDE:

- Developing and maintaining the infrastructure of metadata creation, project documentation, and project data management
- Creating and maintaining project databases in accordance with the best practices and current program standards
- Providing training in the theory and practice of data management tailored to the needs of project personnel
- Developing ways to improve the accessibility and transparency of digital data
- Establishing and implementing procedures to protect sensitive data according to project needs
- Establishing procedures for data dissemination
- Integrating tabular data with geospatial data in a GIS

The data manager will work closely with the project manager to:

- Define the scope of the project data, and create a data structure that meets project needs
- Become familiar with how project data are collected, handled and used
- Review quality control and quality assurance aspects of project protocols
- Identify elements that can be built into the database structure to facilitate quality control, such as required fields, range limits, pick-lists and validation rules
- Create a user interface that streamlines the process of data entry, review, validation, and reporting
- Ensure that project documentation is complete, complies with metadata requirements, and enhances the interpretability and longevity of project data
- Ensure proper archiving of project materials
- Identify and prioritize legacy data for conversion to desired formats

Data Management Coordination

The APHN staff works with national NPS I&M data management staff, and regional resource information management personnel, to maintain a high level of involvement in service-wide and regional databases and data management policy. The Network data manager works with Network personnel, park staff, and cooperators, to promote and develop workable standards and procedures for the purpose of integrating datasets and making them useful for a wider variety of applications.

The Network collaborates with other public agencies, universities and non-governmental organizations, either working together on inventory and monitoring projects, or sharing data and results from those projects. These relationships require coordination at all levels to ensure that data collected by NPS staff, cooperators, researchers, and others meet high quality standards, and that commonly accepted data management standards and procedures are adhered to.

6.3 PROJECT WORK FLOW AND THE DATA MANAGEMENT PROCESS

Both short-term and long-term projects share many work flow characteristics, and both generate data products needing management. Any I&M project managed by APHN is generally comprised of five primary stages: planning and approval; design and testing; implementation; product integration and dissemination; evaluation and closure. Each stage is characterized by a particular set of activities that are carried out by different people involved in the project:

> ***Planning and Approval.*** Establishing the project scope and objectives is the most important step in project development. It is crucial that Network and park staff work together at this stage to establish why the data are needed, how they will used, and what the data management requirements of the project will be.
>
> ***Design and Testing.*** At this stage, specifications are established for how data will be acquired, processed, analyzed, reported, and made available to others. The project manager and data manager work together to develop standard operating procedures (SOP's) related to data acquisition, processing, analysis, and quality control. Also at this stage, the project manager and data manager collaborate to develop the data design and data dictionary, where the specific data parameters that will be collected are defined in detail. In addition, decisions should be made regarding integration and permanent storage of deliverables as they are produced.
>
> ***Implementation***. During the implementation phase, data are acquired, processed, error-checked and documented. Data collection and data processing requirements vary by project, but include all aspects of data entry and verification and validation. All aspects of data acquisition should be specified in project protocols and SOP's. Similarly, quality assurance measures should be documented as part of the project metadata.
>
> ***Product Integration and Data Dissemination.*** In this phase, 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 the project's intended audience. This is also when

items that belong in collections, or archives, are accessioned and catalogued. Another aspect of integration is merging data from a working database to a corporate database maintained on the local network server. Certain projects may also have additional integration needs, such as when working jointly with other agencies for a common database.

Evaluation and Closure. For long-term monitoring and other cyclic projects, this phase occurs at the end of each field season, and leads to an annual review of the project. 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 project methodology, and the usefulness of the resulting information.

6.4 DATA MANAGEMENT RESOURCES

The APHN relies on Network, park, regional, and national NPS offices to maintain the database systems, applications and software tools we use, as well as the computers and computer networks which are the foundation of our information management system.

Computer Resources Infrastructure. "Infrastructure" refers to the system of computers and computer networks that our information management system is built upon. Our Network infrastructure works with three main components: park-based local area networks (LAN), a data server maintained by network staff, and servers maintained at the national level. These components each host different parts of our natural resource information system (Figure 6.1):

National servers
- master applications – integrated client-server versions of NatureBib, NPSpecies, NR/GIS Metadata
- centralized repositories – Natural Resource Data Store, Protocol Clearinghouse
- public access sites – portals to NatureBib, NPSpecies, NPSFocus, websites for monitoring networks

Network data server
- master project databases – compiled data sets for monitoring projects and other multi-year efforts that have been certified for data quality
- common lookup tables – park name, employees, species
- project management application – used to track project status, contact information, product due dates
- network digital library – network repository for read-only finished versions of project deliverables for network projects (e.g., reports, methods documentation, data files, metadata, etc.)

Park LAN
- local applications – desktop versions of national applications such as NPSpecies and Dataset Catalog
- working project materials – working databases, draft geospatial themes, draft copies of reports
- park digital library – base spatial data, imagery, and finished versions of park project deliverables
- GIS files – base spatial data, imagery, and project-specific themes that are managed from a central location

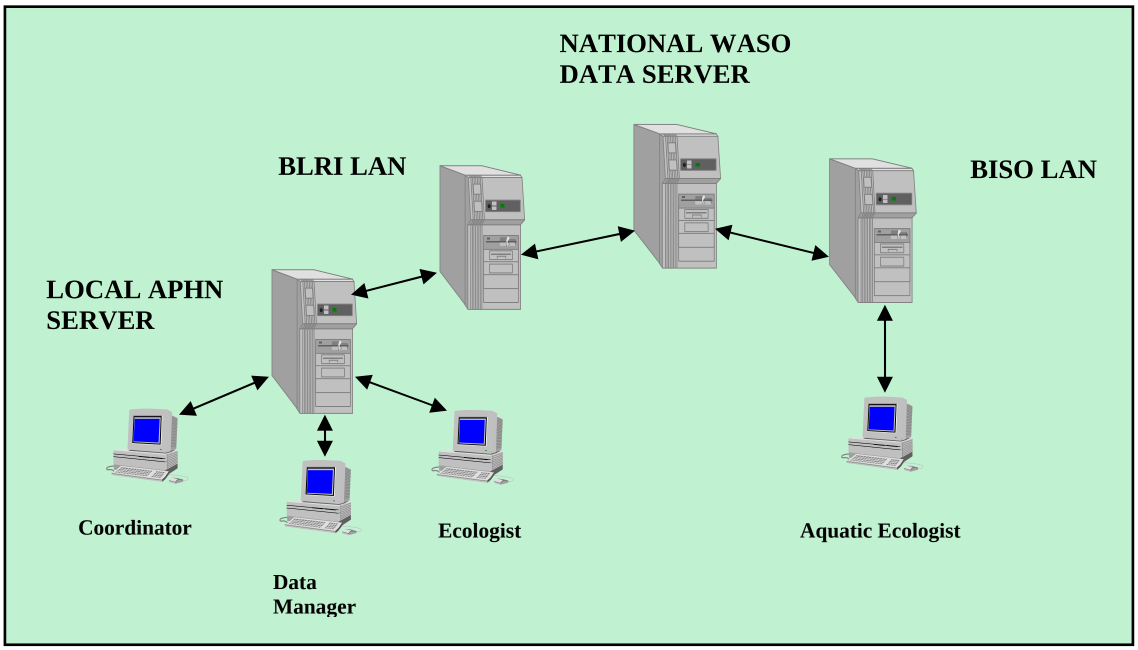


Figure 6.1. Schematic showing general connectivity of Network computer resources.

Network Systems Architecture. "Systems architecture" refers to the applications, database systems, repositories, and software tools that make up the framework of our data management effort. Rather than developing a single, integrated database system, the APHN data design relies upon standalone project databases that share design standards and links to centralized data tables. Individual project databases are developed, maintained, and archived separately.

The advantage of this design is that it allows for greater flexibility in accommodating the needs of each project. Individual project databases and protocols can be developed at different rates without a significant cost to data integration. In addition, one project database can be modified without affecting the functionality of other project databases.

Project database standards are necessary for ensuring compatibility among data sets, which is vital given the often unpredictable ways in which data sets need to be aggregated and summarized. When well thought out, standards also help to encourage sound database design and facilitate interpretability of data sets. Databases that are developed for park and network projects will contain the following main components (Figure 6.2):

- *Common lookup tables* – Links to entire tables that reside in a centralized database, rather than storing redundant information in each database. These tables typically contain information that is not project-specific (e.g., lists of parks, personnel, and species).
- *Core tables and fields based on network and national templates* - These tables and fields are used to manage the information describing the "who, where and when" of project data. Core tables are distinguished from common lookup tables in that they reside in each individual project database and are populated locally. These core tables contain critical data fields that are standardized with regard to data types, field names, and domain ranges.
- *Project-specific fields and tables* – The remainder of database objects can be considered project-specific, although there will typically be a large amount of overlap among projects.

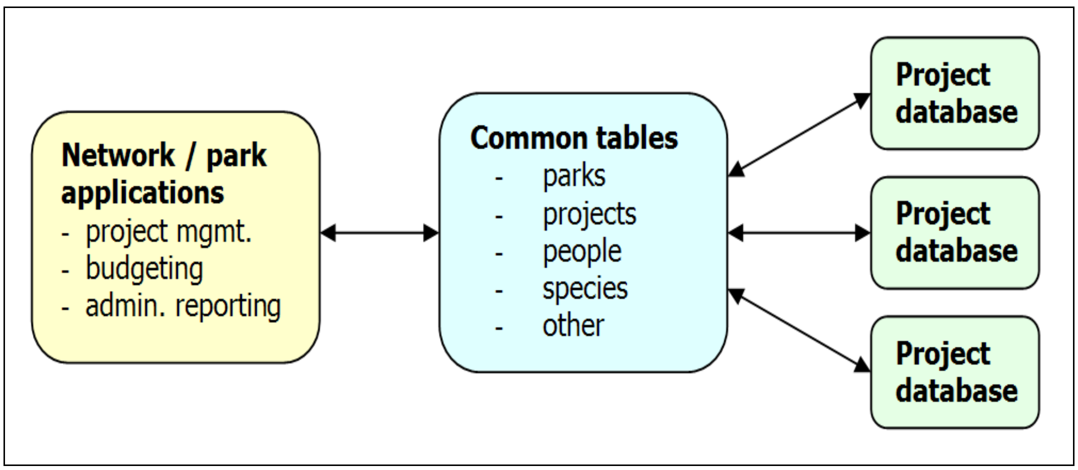


Figure 6.2. Linkage to common lookup tables.

National Information Management Systems. The need for effective natural resource information management cuts across NPS divisional boundaries, and management strategies must be defined at the highest level possible. The NPS Natural Resource

Program Center (NRPC) and the I&M Program actively develop and implement a national-level, program-wide information management framework (Figure 6.3). NRPC and I&M staff integrate desktop database applications with internet-based databases to serve both local and national-level data and information requirements.

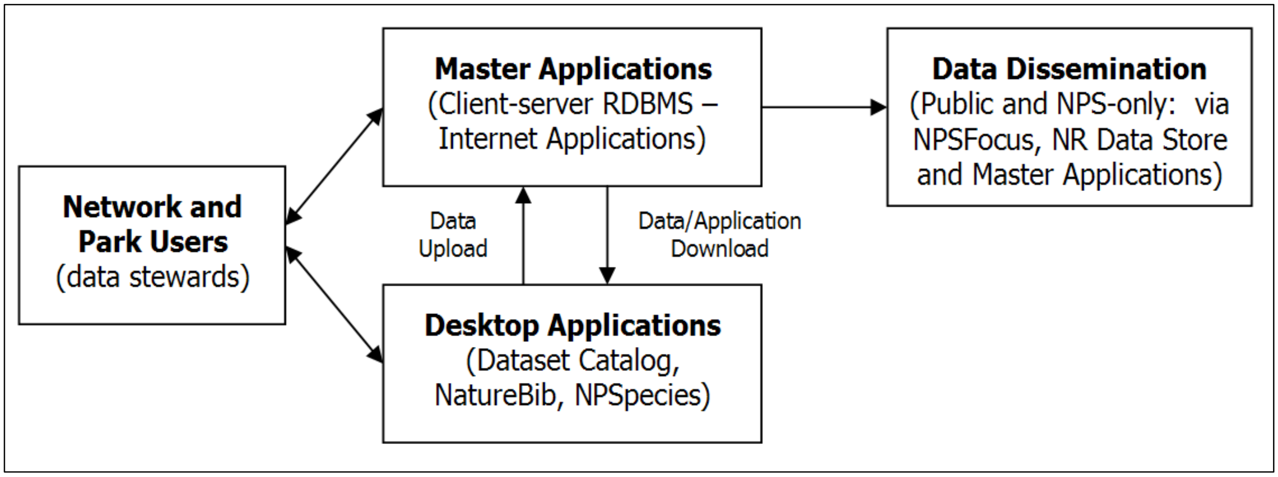


Figure 6.3. Model of the national-level application architecture.

NRPC staff members work with regional and support office staff to develop desktop GIS systems that integrate closely with the database systems. Centralized data archiving and distribution capabilities at the NRPC provide for long term data security and storage. NRPC sponsors training courses on data management, I&M techniques, and remote sensing to assist I&M data managers with developing and effectively utilizing natural resource information.

6.5 DATA ACQUISITION AND PROCESSING

The Network handles two general types of data:

Programmatic Data – data produced from projects that are initiated or funded by the I&M program.

Non-programmatic Data – data collected from other NPS sources or produced by external non-NPS sources.

The value of the data from these two sources is determined by the quality and usefulness of the data for addressing management, or scientific issues.

Programmatic Data. Projects initiated by the APHN typically involve I&M personnel, park staff, or cooperators/contractors. These efforts may consist of gathering existing information or conducting field data collection. All information collected by the Network is in either electronic or hard copy format, depending on how the data was collected. Electronic datasets are entered in Dataset Catalog. Any geographic datasets obtained during data mining should be accompanied by FGDC compliant metadata. Information relating to the biodiversity of Network parks is entered into NPSpecies and linked to the associated reference, voucher, or observation. Hard copies of reports, data sheets and field notes are copied and stored in file cabinets in the APHN offices. A filing system for these papers is being developed. The originals are archived in the appropriate park's collections.

All APHN field studies will have a Microsoft Access database associated with them. The Network has adopted the Natural Resources Database Template (NRDT) (http://science.nature.nps.gov/im/apps/template/index.htm) as the foundation for its database development program. The database template is highly flexible and can be modified and customized for each project to meet the needs and requirements of the researcher. Network databases will incorporate mechanisms such as pick lists and validation rules for quality assurance purposes.

Non-programmatic Data. These may be NPS projects outside the I&M program, or they may originate outside the Park Service. If projects are conducted by Park Service staff, the resulting data often do not require a great deal of processing because the I&M Program shares many of the file standards with Network parks and regional programs. Some basic processing steps include:

- Entering all new park biodiversity data into NPSpecies (this is especially important for park-based biological inventories) and entering all associated references into NatureBib.
- Ensuring that all GIS data is in the proper projection and accompanied by compliant metadata.
- Entering and tracking dataset information using Dataset Catalog.

It is important that park, regional and Network staff work closely together to ensure that information is maintained in a manner that promotes data sharing.

The APHN will rely on external sources for data to support three Vital Signs: air quality, weather, and landscape change (remote sensing data). In these cases, the agencies or organizations that collect these data have the expertise to conduct the proper quality control procedures and the capability to function as a repository and clearinghouse for the validated data.

Unlike the data from NPS sources, much of the data collected from external sources must undergo some degree of processing to meet program standards; however some of the basic processing steps are very similar.

- All GIS data obtained from other entities are stored in the proper format, have the correct spatial reference information and FGDC compliant metadata.
- All biodiversity data received from other entities should be entered into NPSpecies. This would include datasets like the Breeding Bird Survey. Also, if the data was taken from a report or published document, the reference must be entered into NatureBib.
- All data sets should be entered into and tracked using Dataset Catalog.

The level of data processing required for external data sets such as those used in the Vital Signs monitoring program depends on the desired output. Remote sensing datasets such as satellite imagery or aerial photography will require varying levels of processing depending on how they are received. These steps may include geospatial processing or spectral processing. Ideally, all spatial datasets will be received in a geo-referenced format and may only require geographic transformations to meet Network standards. Varying degrees of spatial and spectral processing may be necessary to adequately answer the proposed questions. The individual protocols will outline the necessary processing steps.

6.6 QUALITY ASSURANCE (QA) AND QUALITY CONTROL (QC)

Quality Assurance refers to a system of procedures which ensure that a process or product is of the quality needed or expected. *Quality Control* refers to the specific procedures employed to ensure that data products meet defined standards. QA procedures maintain quality throughout all stages of data development; QC procedures monitor or evaluate resulting data products. The Network will ensure that projects produce data of the right type, quality and quantity to meet project objectives and user needs. The most effective way of accomplishing this goal is to provide procedures and guidelines to assist the researcher with accurate data collection, entry, and validation. APHN will initiate a comprehensive set of SOPs and data-collecting protocols for quality control, field methodologies, field forms, and data entry applications with some built-in validation. Some important considerations in designing a comprehensive QA/QC program include:

Data Collection. Careful, accurate recording of field observations in the data collection phase of a project will help reduce the incidence of invalid data in the resulting data set. Before the data collection phase of a project begins, the data manager is responsible for providing the protocols/SOPs for data collection and storage to the project manager. The project manager, in turn, will ensure that field crews understand the procedures and closely follow them in the field. Field technicians are responsible for proofing raw data forms in the field, ensuring their readability and legibility, and verifying and explaining any unusual entries. They are expected to understand the data collection forms, know how to take measurements, and follow the protocols.

Data Entry. Transferring data from field projects into the computer seems like a fairly simple task. But the value of the data depends upon their accuracy, and we must feel confident about the overall data quality. The data manager, along with the project manager, will provide training in the use of the database to all data entry technicians and other users. Ideally, data entry occurs as soon as possible–immediately after data collection is completed, or as an on-going process during long projects–by a person who is familiar with the data. The primary goal of data entry is *to transcribe the data from paper records into the computer with 100% accuracy*. Yet, we know that a few transcription errors are unavoidable. Thus, all data should be checked and corrected during a data verification process.

Data Verification. *Data verification* is a check to make sure that the digitized data match the source data. To minimize transcription errors, our policy is to verify 100% of records to their original source by permanent staff. In addition, 10% of records will be reviewed a second time by the project manager, and we will report the results of that comparison with the data. If the project manager finds errors in the review, then we will verify the entire data set again.

Data Validation. *Data validation* is the process of reviewing data for range and logic errors. It can accompany data verification only if the operator has comprehensive knowledge about the data. More often, validation is a separate operation carried out after verification by a project specialist who can identify generic and specific errors in particular data types. Corrections or deletions of logical or range errors in a data set require notations in the original paper field records about how and why the data were changed. Modifications of the field data should be clear and concise while preserving the original data entries or notes (i.e., no erasing!). Validation efforts should also include a check for the completeness of a data set since field sheets or other sources of data could easily be overlooked.

General step-by-step instructions are not possible for data validation because each data set has unique measurement ranges, sampling precision, and accuracy. Nevertheless, validation is a critically important step in the certification of the data. Invalid data commonly consist of slightly misspelled species names or site codes, the wrong date, or out-of-range errors in parameters with well defined limits (e.g., elevation). But more interesting and often puzzling errors are detected as unreasonable metrics (e.g., stream temperature of 70°C) or impossible associations (e.g., a tree 2 feet in diameter and only 3 feet high). We call these types of erroneous data *logic errors* because using them produces illogical (and incorrect) results. The discovery of logic errors provides important feedback to the methods and data forms used in the field.

Version Control. *Version control* is the process of documenting the temporal integrity of files as they are being changed or updated. Change includes any alteration in the structure or content of the files, and such changes should not be made without the ability to undo mistakes caused by incorrect manipulation of the data. Whenever we complete a set of data changes, the file is saved with a unique name. Prior to any major changes to a file, we store a copy of the file with the appropriate version number. This allows the tracking of changes over time. With proper controls and communication, versioning ensures that only the most current dataset is used in any analysis.

Data Quality Review and Communication. Quality assurance procedures may need revision to improve quality levels if random checks reveal an unacceptable level of data quality. Quality checks should not be performed with the sole objective of eliminating errors, as the results may also prove useful in improving the overall process.
The APHN data manager will use periodic data audits and quality control inspections to maintain and improve their data quality program, and will track and facilitate the correction of any deficiencies. These quality checks promote a cyclic process of continuous feedback and improvement of both the data and the quality planning process. The Network will use data documentation and metadata to notify end users, project managers, and network management of data quality. A descriptive document for each data set/database will provide information on the specific QA/QC procedures applied and the results of the review.

6.7 DATA DOCUMENTATION

Metadata is information about the content, quality, condition and other characteristics of data. While the importance of metadata is universally accepted within the data management community, there are many approaches to data documentation, involving varying levels of detail.

NPS Metadata System Plan. There are three desktop application systems recommended for collecting metadata. These include Dataset Catalog (developed by the I&M Program), and two commercial, off the shelf metadata tools, ArcCatalog and SMMS. 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). However, efforts are currently underway to unify and streamline metadata development. This new approach utilizes existing desktop metadata creation applications, as well as an online integrated metadata database (NR-GIS Metadata) and a web based data server (NR-GIS Data Server) (Figure 6.4). The NR-GIS Metadata and Data Store will comprise a web based system to integrate both data dissemination and metadata maintenance.

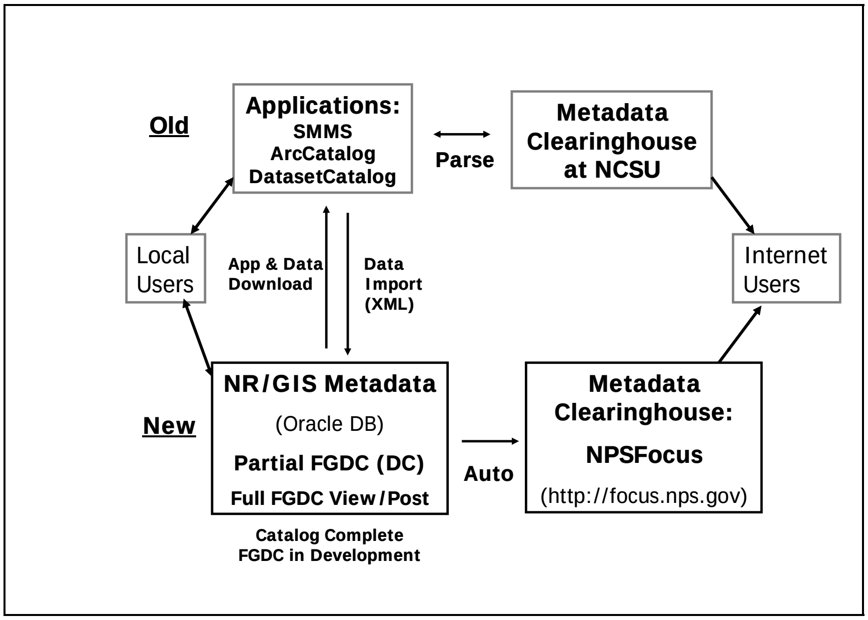


Figure 6.4. NPS integrated metadata system.

Metadata Process and Workflow. As mentioned in an earlier section, I&M datasets may originate from data mining efforts, or from field data collections; and the sources may be internal or external. With data mining efforts, it is important to capture as much of the original metadata as possible. For new projects, metadata development will begin as early in the project design phase as possible. When project data are submitted, updates and revisions to the metadata will be kept in a revision log.

The Network will develop a simple Dataset Catalog record for relevant spatial and non-spatial data. This approach provides brief metadata for all Network data holdings in a searchable, centralized location. Managers can identify and prioritize datasets for which formal metadata will be developed. Prioritization of datasets for further documentation will be based upon current or anticipated future use. Datasets, which will be used repeatedly in analysis or with high probability for data sharing, will be addressed first. All GIS layers will be documented with applicable FGDC metadata standards.

At a minimum, metadata and associated data will be submitted to NR-GIS Metadata and Data Store. This will be accomplished using the recommended desktop applications. Additionally, information on data holdings will be conveyed in a meaningful manner for park resource managers, researchers, and others with a potential interest in park management and/or research endeavors.

6.8 DATA ANALYSIS AND REPORTING

Data Analysis. Appropriate analysis of monitoring data is directly linked to the monitoring objectives, the sampling design, and management uses of the data. Analysis methods need to be considered when the objectives are first identified and the sampling design is selected, rather than after the data are collected. Failure to adequately consider analysis methods during monitoring program development could result in use of sampling designs that are either inadequate or too complex to meet the monitoring objectives.

It is important that the data analysis Standard Operating Procedures (SOPs) for each Vital Sign ensure that the sampling designs and analysis methods we use meet Network monitoring objectives. In addition, making the connection between the analyses that are produced and the decisions that are faced by park managers is critical. Interpretation of these analyses will emphasize the use of simple, graphical displays and visual summaries, so that the implications of monitoring results to management decision making are readily apparent.

For water quality monitoring, summary statistics (minimum, maximum, median, mean) and annual time series graphs (concentration vs. time) will be generated by site and compared with state use classifications. Boxplots of each water-quality parameter by site will be produced, to compare and contrast data visually. Annual comparisons will also be compared to historic data.

Trends will be calculated using non-parametric analyses after about 5 years on sites where monthly data is collected, and after about 8 years for sites where bimonthly data is collected. Loads and yields can be calculated for sites with continuous discharge stations when there is an adequate period of flow and water quality data (about 3 to 5 years of data).

Reporting of Monitoring Information. The primary audience for many of the products from the I&M Program is at the park level, where the key role of the I&M Program is to provide park managers and interpreters with the information they need to make better-informed decisions and to work more effectively with other agencies and individuals for the benefit of park resources. However, certain data are also needed at the regional or national level for a variety of purposes, and as stated by the National Park Advisory Board, project findings “must be communicated to the public, for it is the broader public that will decide the fate of these resources”. Toward this end, the APHN is developing strategies for effectively sharing information with Network parks, scientists, cooperators, adjacent land managers and other potential collaborators. A detailed summary of network reporting formats, and their information content, target audience, and reporting schedule is presented in Table 7.3.

6.9 DATA DISSEMINATION

Data Ownership. The National Park Service defines conditions for the ownership and sharing of collections, data, and results based on research funded by the United States government. All cooperative and interagency agreements, as well as contracts, should include clear provisions for data ownership and sharing as defined by the National Park Service:

- All data and materials collected or generated using National Park Service personnel and funds become the property of the National Park.

- Any important findings from research and educational activities should be promptly submitted for publication. Authorship must accurately reflect the contributions of those involved.

- Investigators must share collections, data, results, and supporting materials with other researchers whenever possible. In exceptional cases, where collections or data are sensitive or fragile, access may be limited.

Data Distribution. One of the most important goals of the Inventory and Monitoring Program is to *integrate natural resource inventory and monitoring information into National Park Service planning, management, and decision making.*

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

- Data are easily discoverable and obtainable;
- Data that have not yet been subjected to full quality control will not be released by the Network, unless necessary in response to a FOIA request;
- Distributed data are accompanied by complete metadata that clearly establishes the data as a product of the NPS I&M Program;
- Sensitive data are identified and protected from unauthorized access and inappropriate use;
- A complete record of data distribution/dissemination is maintained.

APHN's main mechanism for distribution of the Network's inventory and monitoring data to the broader public will be the internet. As part of the NPS I&M Program, web-based applications and repositories have been developed to store a variety of park natural resource information. APHN will use the following applications and repositories to distribute data, formal and informal reports and publications:

- **NatureBib**–a master web-based database housing natural resource bibliographic data for I&M Program parks (NatureBib Home Page)

- **NPSpecies**–a master web-based database to store, manage and disseminate scientific information on the biodiversity of all organisms in all National Park units (NPSpecies Home Page)

- **Biodiversity Data Store**–a digital archive of document, GIS dataset and non-GIS dataset files that document the presence/absence, distribution and/or abundance of any taxa in National Park Service units (Biodiversity Service Center Home Page)

- **Natural Resource and GIS Metadata and Data Store-**online repository for metadata and associated data products (NPS NR-GIS Metadata and Data Store Home Page) (**Note:** Currently under development.)

- **Appalachian Highlands I&M Network Website**–provides detailed information about the network and it's I&M Program. Metadata on all inventory and monitoring products developed as part of the Network's I&M plan will be posted to this site. Data and products will either be available through the site, or users will be directed to where the data are stored. (APHN Home Page)

Handling Sensitive Data. In some cases, public access to data can be restricted. Under one Executive Order, Director's Order #66 (draft), and four resource confidentiality laws, the National Parks Omnibus Management Act (16 U.S.C. 5937), the National Historic Preservation Act (16 U.S.C. 470w-3), the Federal Cave Resources Protection Act (16 U.S.C. 4304) and the Archaeological Resources Protection Act (16 U.S.C. 470hh), the National Park Service is directed to protect information about the nature and location of sensitive park resources. Through these regulations, information that could result in harm to natural resources can be classified as 'protected' or 'sensitive' and withheld from public release (National Parks Omnibus Management Act (NPOMA)).

Classification of sensitive I&M data is the responsibility of Network park superintendents. Network staff will work closely with park staff to identify sensitive data on a case by case basis. APHN will work with investigators for each project to ensure that potentially sensitive park resources are identified, and that information about these resources is tracked throughout the project. The Network staff is responsible for making principal investigators aware of sensitive resources. The investigators, whether Network staff or partners, will develop procedures to flag all potentially sensitive resources in any products that come from the project, including documents, maps, databases, and metadata. Network staff will remove any sensitive information from public versions of documents or other media.

6.10 DATA MAINTENANCE, STORAGE AND ARCHIVING

It is important to standardize procedures for the long-term management and maintenance of digital data, documents, and objects that result from APHN projects and activities, in order to avoid the loss of information over time, and to ensure that information can be easily obtained, shared, and interpreted by a broad range of users.

Digital Data Maintenance. Monitoring projects will have variable long-term data archiving requirements. Raw data sets that are later manipulated or synthesized will need archiving in the original form. Modifications to protocols will typically require complete data sets to be archived before modifications are implemented. With frequent changes to the monitoring project, it is necessary to preserve interim data sets (data "milestones") over the long term. Data archiving requirements for ongoing projects will be detailed in the data management SOPs for each monitoring project. At this time there is no practical way to save GIS data in a software or platform-independent format. Spatial data sets that are essential to APHN (i.e., base layers) will be maintained in a format that remains fully-accessible by the current ArcGIS version. Both uncorrected and corrected GPS data (e.g., .ssf and .cor files) will be archived in their native format in addition to the corresponding GIS files that are created.

Storage and Archiving Procedures – digital data. Digital data need to be stored in a repository that ensures both security and ready access to the data in perpetuity. The organization and naming of folders and files should be intuitive to users unfamiliar with a specific project. A standardized structure may not be practical; however, all project archives will include several to most of the following elements:

- administrative documents such as agreements, correspondence, research permits
- programmatic documents including protocols, procedures, supporting documents
- interim data sets or "milestones"
- data sets reformatted or manipulated by APHN
- data sets original form – ascii
- conceptual or statistical models used for data interpretation
- final report
- readme files -- includes an explanation of directory contents, project metadata (including a dataset catalog report), and version documentation

Storage and archiving procedures – documents and objects.

Documents
All paper documents managed or produced by the APHN will be housed in three locations:

1. APHN central files, Asheville, NC
These files contain project files, administrative documents and non-record copies of documents that are archived at an off-site facility (see item 2, below). Examples include: meeting minutes, correspondence, memoranda of understanding, contracts and agreements, research permits, interim and selected final reports produced by the program.

2. Network park museums.
Network park archives will be the first option for original documents and associated materials produced by the network (e.g. photographs, field notes, permits) that are a high priority to maintain under archival conditions. Examples include: original inventory reports and accompanying slides and maps; original vegetation mapping reports; APHN monitoring reports. Copies of these reports will be maintained in the APHN central files, and all will have an electronic equivalent (e.g. pdf) for distribution or reproduction.

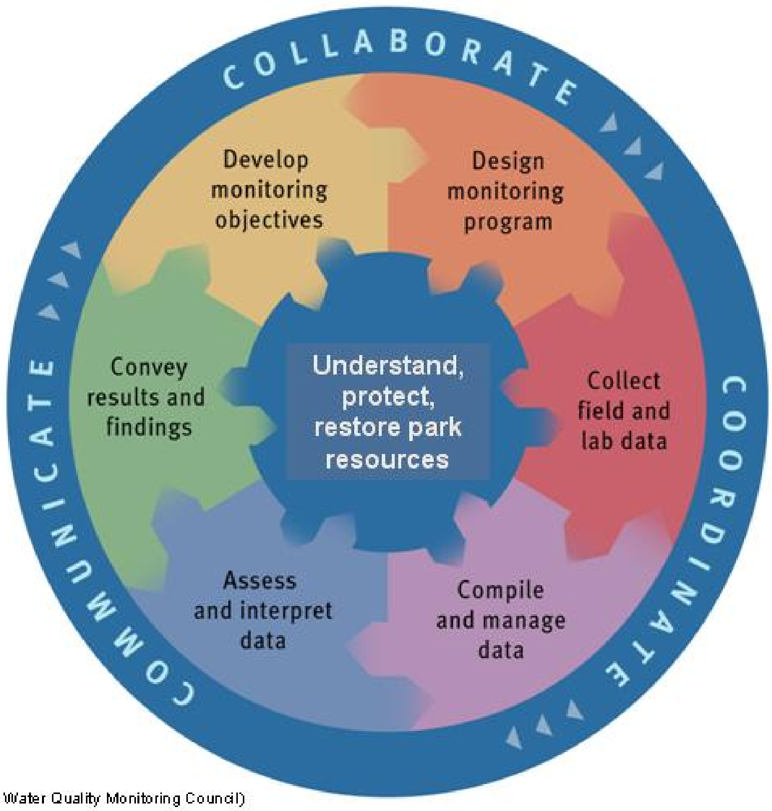
For all materials submitted for archiving, APHN will assist with cataloging, and will provide essential cataloging information such as the scope of content, project purpose, and range of years, to facilitate ANCS+ record creation and accession. APHN will also ensure that materials are presented using archival-quality materials (e.g. acid-free paper and folders, polypropylene or polyethylene slide pages).

3. Network park central files and museums.
High-quality copies of park-related documents resulting from APHN projects, along with electronic versions, will be provided to park resource management staff. Parks may choose to accession these materials into their museums, incorporate them into their central files, or house them in their resource management library. APHN will not manage documents at the park level.

Specimens
Specimens collected under the direction of the APHN will be provided to the network repository/museum in which they were collected for curation, or to a repository approved by a park (where the specimens are considered on loan). APHN will assist with cataloging, and will provide park curators with associated data required for cataloging each specimen. This data will be in comma-delimited format (.csv) format for automated uploading into ANCS+. Data provided to non-NPS curators will be in Excel format.

Role of curators in storage and archiving procedures
Curators for parks within APHN are an ongoing source of expertise, advice, and guidance on archiving and curatorial issues. Project managers should involve park curators when projects are in the planning stage, to ensure specimen curation and document archiving is considered, and that any associated expenses are included in project budgets.

7. DATA ANALYSIS AND REPORTING



(Adapted from National Water Quality Monitoring Council)

A primary purpose of the Inventory and Monitoring Program is to develop, organize, and make available natural resource data and to contribute to the Service's institutional knowledge by transforming data into information through analysis, synthesis and modeling. The broad-based, scientifically sound information obtained through natural resource monitoring has multiple applications for management decision-making, research, education, and promoting public understanding of park resources.

> ***INFORMATION*** **is the common currency among the many different people and programs involved in the stewardship of a park's natural resources.**

The primary audience for many of the products from the I&M Program is at the park level, where the key role of the I&M Program is to provide park managers and interpreters with the information they need to make and defend management decisions and to work with others for the benefit of park resources. However, other key audiences for monitoring results include park planners, interpreters, researchers and other scientific collaborators, the general public, Congress, and the President's Office of Management and Budget (OMB). To be most effective, monitoring data must be analyzed, interpreted, and provided at regular intervals to each of these key audiences in a format they can use. There must be several different scales of analysis, and the same information needs to be distributed in different formats to the key audiences.

The scientific data needed to better understand how park systems work and to better manage the parks will come from many sources. In addition to new field data collected through the I&M Program, data on status and trends in the condition of park resources will come from other park projects and programs, other agencies, and from the general scientific community (Figure 7-1). To the extent that staffing and funding is available, the Network monitoring program will collaborate and coordinate with these other data collection and analysis efforts, and will promote the integration and synthesis of data across projects, programs, and disciplines.

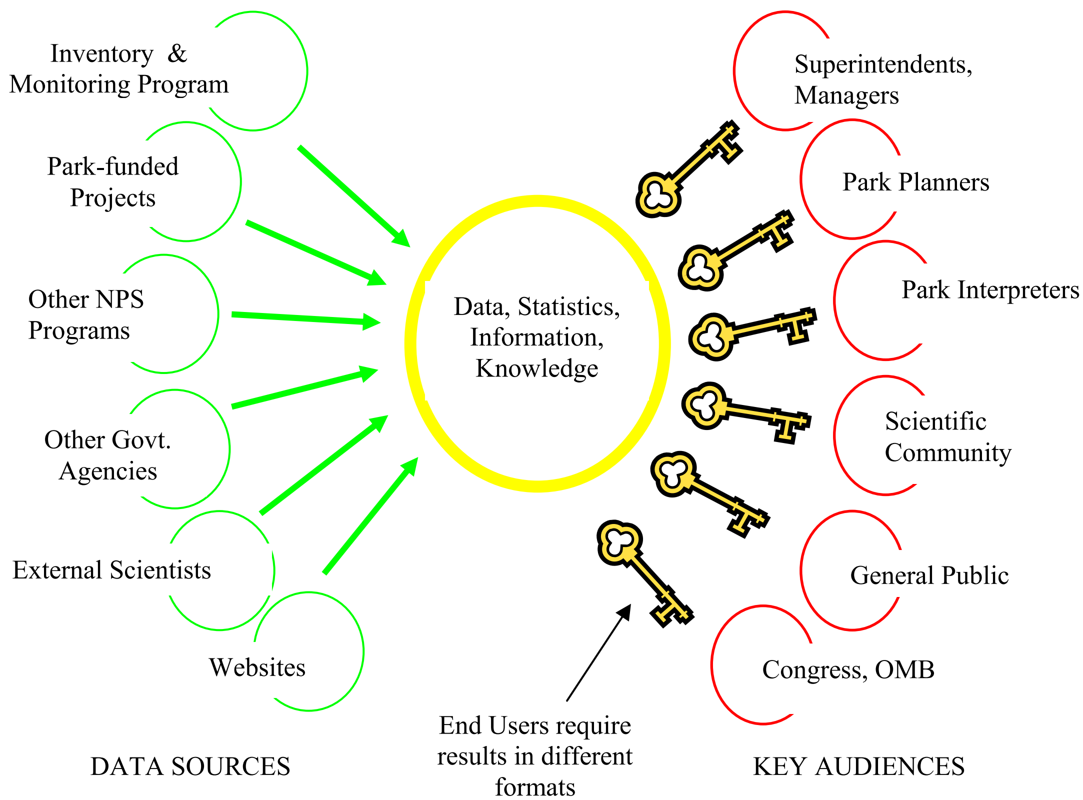


Figure 7.1. Scientific data for determining the status and trends in the condition of selected park natural resources will come from multiple sources, and will be managed, analyzed, and disseminated to multiple audiences in several different formats in order to make the results more available and useful.

This chapter presents an overview of how the Network proposes to analyze, synthesize, and disseminate monitoring results to the key audiences above.

7.1 ANALYSIS OF MONITORING DATA

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

Table 7.1 summarizes four general categories of analysis for APHN Vital Signs, and the lead analyst responsible for each. The lead analyst will ensure that data are analyzed and interpreted within the guidelines of the protocol and program, but they may not actually perform the analyses or interpret the results in some cases.

Table 7.1. Analysis of Monitoring Data

Level of Analysis	Description	Lead Analyst
Data Summarization/ Characterization	Calculation of basic statistics of interest from monitoring data including measures of location and dispersion. Summarization encompasses measured and derived variables specified in the monitoring protocol. Data summarization and characterization forms the basis of more comprehensive analyses, and for communicating results in both graphical and tabular formats.	The Principal Investigator for each monitoring protocol, working with the data management staff, will produce routine data summaries. Parameters and procedures are specified in the monitoring protocols.
Status Determination	Analysis and interpretation of the ecological status (point in time) of a vital sign to address the following types of questions: •How do observed values for a vital sign compare with historical levels? •Do observed values exceed a regulatory standard, known or hypothesized ecological threshold? What is the level of confidence that the exceedance has actually occurred? •What is the spatial distribution (within park, network, ecoregion) of observed values for a given point in time? Do these patterns suggest directional relationships with other ecological factors? Status determination will involve both expert interpretation of the basic statistics and statistical analysis to address these monitoring questions. Assumptions about the target population and the level of confidence in the estimates will be ascertained during the analysis.	The Principal Investigator for each monitoring protocol is the lead analyst for status determination, although the Network coordinator, cooperators, partners, interns or other Network staff may conduct analyses and assist with interpreting results. Consultation with regulatory and subject matter experts will support status determination.

Level of Analysis	Description	Lead Analyst
Trends Evaluation	Evaluations of trends in Vital Signs will address: •Is there directional change in a vital sign over the period of measurement? •What is the rate of change (sudden vs. gradual), and how does this pattern compare with trends over broader spatial scales and known ecological relationships? •What is the level of confidence that an actual change (or lack thereof) has occurred? Analysis of trends will employ parametric, nonparametric, or mixed models based on assumptions that can or cannot be reasonably made about the target population. Where appropriate, exogenous variables (natural, random phenomena that may influence the response variable) will be accounted for in the analysis.	The Principal Investigator for each monitoring protocol is the lead analyst for status determination, although the Network coordinator, cooperators, partners, interns or other Network staff may conduct analyses and assist with interpreting results. Comparison with relevant long-term experimental results will aid interpretation.
Synthesis and Modeling	Examination of patterns across Vital Signs and ecological factors to gain broad insights on ecosystem processes and integrity. Analyses may include: •Qualitative and quantitative comparisons of Vital Signs with known or hypothesized relationships. •Data exploration and confirmation (e.g., correlation, ordination, classification, multiple regression, structural equation modeling). •Development of predictive models. Synthetic analysis has great potential to explain ecological relationships in the nonexperimental context of Vital Signs monitoring and will require close interaction with academic and agency researchers.	The Network coordinator is the lead analyst for data synthesis and modeling, although the P.I.s for various protocols and cooperators, partners, interns or other Network staff may conduct analyses and assist with interpreting results. Integration with researchers and experimental results is critical.

7.2 COMMUNICATIONS AND REPORTING

The APHN is developing strategies for effectively sharing information with Network parks, scientists, cooperators, adjacent land managers and other potential collaborators. The various approaches and products we plan to use to disseminate the results of the monitoring program and to make the data and information more available and useful to our key audiences are organized into the following seven categories and described in the following sections:

1. Annual Reports for Specific Protocols and Projects
2. Annual Briefings to Park Managers
3. Analysis and Synthesis Reports
4. Protocol and Program Reviews
5. Scientific Journal Articles and Book Chapters, and Presentations at Scientific Meetings
6. Internet and Intranet Websites
7. Interpretation and Outreach

7.2.1 Annual Reports for Specific Protocols and Projects

The primary purposes of annual reports for specific protocols and projects are to:

- summarize and archive annual data and document monitoring activities for the year;
- describe current condition of the resource;
- document changes in monitoring protocols; and,
- increase communication within the park and network.

The primary audiences for these reports are park superintendents and resource managers, Network staff, park-based scientists, and collaborating scientists. Most annual reports will receive peer review at the Network level, although a few may require review by subject matter experts with universities or other agencies. Many of our monitoring protocols involve data collection each year, and those protocols will generate an annual report each year. However, some sampling regimes do not involve sampling every year - those projects will produce "annual" reports only when there are significant monitoring activities to document. Wherever possible, annual reports will be based on automated data summarization routines built into the MS Access database for each protocol. The automation of data summaries and annual reports will facilitate the Network's ability to manage multiple projects and to produce reports with consistent content from year to year at timely intervals. For analyses beyond simple data summaries, data will first be exported to external statistical software.

7.2.2 Annual Briefings to Park Managers

Each year, in an effort to increase the availability and usefulness of monitoring results for park managers, the Network coordinator will take the lead in organizing a 1-day "I&M Science briefing for park managers" (possibly in conjunction with a Board of Director's meeting) in which Network staff, park scientists, USGS scientists, collaborators from academia, and others involved in monitoring the parks' natural resources will provide managers with a briefing on the highlights, key findings, and potential management action items for each particular protocol or discipline. These briefings may include specialists from the air quality program, fire ecology program, Research Learning Center, and collaborators from other programs and agencies to provide managers with an overview of the status and trends in natural resources for their parks. The scientists will be encouraged to prepare a 1- or 2-page "briefing statement" that summarizes the key findings and recommendations for their protocol or project; these written briefing statements will then be compiled into an annual 'Status and Trends Report' for the Network. In the process of briefing the managers, the various scientists involved with the monitoring program will learn about other protocols and projects, and the process will facilitate better coordination and communication and will promote integration and synthesis across disciplines.

7.2.3 Analysis and Synthesis Reports

The role of analysis and synthesis reports is to:

- determine patterns/trends in condition of resources being monitored;
- discover new characteristics of resources and correlations among resources being monitored;
- analyze data to determine amount of change that can be detected by this type and level of sampling;
- provide context: interpret data for the park within a multi-park, regional or national context;
- recommend changes to management of resources (feedback for adaptive management).

The primary audiences for these reports are park superintendents and other resource managers, Network staff, park-based scientists, and collaborating scientists. These reports will receive external peer review by at least 3 subject-matter experts, including a statistician. Analysis and synthesis reports can provide critical insights into resource status and trends, which can then be used to inform resource management efforts and regional resource analyses. This type of analysis, more in depth than that of the annual report, requires several seasons of sampling data. Therefore, these reports are usually written at intervals of every three to five years for resources sampled annually, unless there is a pressing need for the information to address a particular issue. For resources sampled less frequently, or which have a particularly low rate of change, intervals between reports may be longer.

It is important that results from all monitoring projects within and across all parks be integrated across disciplines in order to interpret changes to park resources. This will be accomplished with a Network synthesis report produced at no more than 10-year intervals.

7.2.4 Protocol and Program Reviews

Periodic formal reviews of individual protocols and the overall monitoring program are an important component of the overall quality assurance and peer review process. A review of each protocol will be conducted before the first 5-year Analysis and Synthesis Report and in conjunction with future Analysis and Synthesis Reports as needed, but at least at 10-year intervals. (Because protocols must be reviewed in light of the data they produce, it is most efficient to review protocols coincident with these synthesis reports.) Features of these protocol reviews include:

- A USGS scientist, outside contractor or academic is enlisted to analyze data and evaluate results of the monitoring protocol (e.g., power analyses of the data) and report findings.

- Subject-matter experts/peers are invited to review the Analysis and Synthesis Report, power analysis, and protocol.
- Subject-matter experts/peers are invited to a workshop to discuss the protocol, results of the data analysis and evaluation, whether or not the protocol is meeting its specific objectives and is able to detect a level of change that is meaningful, and to recommend improvements to the protocol.
- The protocol P.I., Network coordinator, or contractor writes a report summarizing the workshop. The report is reviewed and edited by the participants, and then the final report is posted on the Network's website. Copies of the report are sent to NPS regional and WASO program offices.

The Network Coordinator will initiate the Network Monitoring Program review. The purpose of these reviews is to have the program evaluated by highly qualified professionals. Features include:

- Network staff and collaborators provide a summary of the program and activity to date including a summary of results and outcomes of any protocol reviews.
- Scientific review panel obtains input from Board of Directors, Network staff, park scientists, and others. Panel holds a workshop to discuss the program and whether it is meeting its goals and expectations. Review Panel makes recommendations for improving the effectiveness and value of the monitoring program.
- Network coordinator develops a strategy with the APHN Technical Committee and Board of Directors as to which of the review panel's recommendations to implement, how, and when.

Topics to be addressed during the program review include program efficacy, accountability, scientific rigor, contribution to adaptive park management and larger scientific endeavors, outreach, partnerships, data management procedures, and products. These reviews cover monitoring results over a long period of time, as well as program structure and function to determine whether the program is achieving its objectives, and also whether the list of objectives is still relevant, realistic, and sufficient.

Table 7.2 I&M Programmatic Reports and Publications

Report	Schedule	Who does it?
Annual Administrative Report and Work Plan	Annually – October 30	Network coordinator, staff
Annual monitoring reports or specific project reports	Annually – Variable, usually Dec. – Jan.	Network coordinator, staff
Analysis and synthesis of data, trends	Annual analysis – Variable, usually Dec. – Jan.; trends vary by monitoring topic (many will not be discernable over short time periods)	Network coordinator, staff
National Report-Condition of Natural Resources in National Parks	Annually – Date variable	NPS WASO, with input from parks, I&M networks, other divisions
Periodic program reviews	Every five years	WASO I&M staff

7.2.5 Scientific Journal Articles and Book Chapters, and Presentations at Scientific Meetings

The publication of scientific journal articles and book chapters is done primarily to communicate advances in knowledge, and is an important and widely-acknowledged means of quality assurance and quality control. Putting a program's methods, analyses, and conclusions under the scrutiny of a scientific journal's peer-review process is basic to science and one of the best ways to ensure scientific rigor. Network staff, park scientists, and collaborators will also periodically present their findings at professional symposia, conferences, and workshops as a means of communicating the latest findings with peers, identifying emerging issues, and generating new ideas.

All journal articles, book chapters, and other written reports will be listed in the Network's Annual Administrative Report and Work Plan that is provided to Network staff, Technical Committee, Board of Directors, and regional and national offices each year. Additionally, all scientific journal articles, book chapters, and written reports will be entered into the NatureBib bibliographic database maintained by the Network.

7.2.6 Internet and Intranet Websites

Internet and intranet (restricted) websites are a key tool for promoting communication, coordination, and collaboration among the many people, programs, and agencies involved in the Network monitoring program. All written products of the monitoring effort, unless they contain sensitive or commercially valuable information that needs to be restricted, will be posted to the main Network website:

http://www1.nature.nps.gov/im/units/aphn/index.html

Documents to be posted to the Network website include this monitoring plan, all protocols, annual reports, analysis and synthesis reports, and other materials of interest to staff at the park, Network, regional, and national levels, as well as our collaborators.

In addition, to promote communication and coordination within the Network, we will maintain a password-protected "team website" where draft products, works in progress, and anything that needs to have restricted access can be shared within the program.

7.2.7 Interpretation and Outreach

The National Park Advisory Board, in their July 2001 report "Rethinking the National Parks for the 21st Century", wrote that "A sophisticated knowledge of resources and their condition is essential. The Service must gain this knowledge through extensive collaboration with other agencies and academia, and its findings must be communicated to the public, for it is the broader public that will decide the fate of these resources." In keeping with this statement, the Network will make a concerted effort, working with park interpreters and others, to ensure that the results of natural resource monitoring are made available to the interested public. In addition to providing scientific reports and briefings to managers for their protocols, each scientist involved with the Network will be asked to contribute story ideas, photographs, and other materials to interpreters for use in newsletters, interpretive talks and exhibits, and other media for informing and entertaining the public. Park interpreters will be invited to participate in monitoring field efforts to increase communication and promote integration between the programs. Network staff may also speak at training sessions for seasonal employees and to special interest groups.

We are currently working with the Southern Appalachian CESU, the Appalachian Highlands Science Learning Center and park interpreters to more effectively interpret inventory and monitoring results to the parks and the public. We are also exploring the possibility of sharing information from Network projects with the Southern Appalachian Information Node of the National Biological Infrastructure (NBII). NBII is a collaborative effort that links information, high-quality biological databases, and analytical tools with information consumers such as government agencies, academic institutions, non-government organizations, and private industry.

Table 7.3 Dissemination of Monitoring Data: summarizes the content of reports and other information products of the Network monitoring effort, intended audience, reporting schedule, and responsible entities for each. (NOTE: ALL PUBLIC NEWS RELEASES WILL BE COORDINATED THROUGH THE PARKS' RESOURCE MANAGERS AND SUPERINTENDENTS PRIOR TO RELEASE.)

Monitoring Protocol	Information Content	Target Audience & format	Responsible Person	Schedule
Water Quality	Summary of baseline, trends in pH, temperature, DO, specific conductivity, major ions, aquatic macro-invertebrate species diversity & numbers	-Park Managers, cooperators (executive summaries, briefings)	APHN hydrologist, data manager	At least annually; eventfully
		- Public (news releases, brochures, network newsletters, website)	APHN hydrologist, data manager	Eventfully
		- Presentations at professional meetings, journal articles, informal presentations	APHN hydrologist, data manager	Eventfully
Air Quality	Summary of baseline, trends in ozone levels, deciviews (visibility), nitrate and sulfate deposition, particulates	-Park Managers, cooperators (executive summaries, briefings)	APHN ecologist, data manager	Annually
		- Public (news releases, brochures, network newsletters, website)	APHN ecologist, data manager	Eventfully, or at least annually
Rare fish	Distribution and numbers for the year, trends	-Park Managers, cooperators (executive summaries; briefings)	APHN ecologist, hydrologist, data manager	Annually, or more often if noteworthy events are observed
		- Public, without specific locations (website, newsletters, news releases) SENSITIVE INFORMATION – no site-specific details		
Rare mussels	Distribution and numbers for the year, observed age structure, evidence of reproduction, trends	-Park Managers, cooperators (executive summaries, briefings)	APHN ecologist, hydrologist, data manager	Annually, or more often if noteworthy events are observed (e.g., first reproduction of reintroduced Endangered mussels)
		- Public, without specific locations (website, newsletters, news releases) SENSITIVE INFORMATION – no site-specific details		
Rare plants & cobblebars	Species cover, relative abundance, trends	-Park Managers, cooperators (executive summaries; briefings)	APHN ecologist, data manager	Annually
		-Public (network newsletters, website) SENSITIVE INFORMATION - no site-specific details		Periodically, or eventfully

Monitoring Protocol	Information Content	Target Audience & format	Responsible Person	Schedule
Weather	Annual rainfall, snowfall, temperatures (average, extreme highs, lows), storm frequency, frost dates	-Park Managers, cooperators (executive summaries), other scientists working in the parks, interpreters	APHN data manager	Annually
Forest vegetation structure, composition, landscape pattern	Percent cover by dominant forest or other vegetation types, changes and trends	-Park Managers, cooperators (executive summaries; briefings)	APHN ecologist, data manager	Annually
		- Public (news releases, brochures, network newsletters, website)	APHN ecologist, data manager	Periodically, when noteworthy trends are documented
Plant poaching	Changes in species composition in vulnerable communities, disappearance of target species (trilliums, orchids, galax, bloodroot, etc.)	-Park Managers, Law Enforcement, cooperators (executive summaries; briefings with key details on location, seasonality of poaching events)	APHN ecologist, data manager	Eventfully (fresh evidence of poaching will be reported immediately); Annual summaries of data
		- Public (news releases, network newsletters) with prior review and clearance from parks Law Enforcement, Resource Managers; no details on specific site locations	APHN ecologist, data manager	Periodically, when situations warrant
Land use patterns	Changes and rates of change in development and land use patterns adjacent to and upstream of the parks; effects on park resources	-Park Managers, cooperators (executive summaries; briefings)	APHN ecologist, data manager	Initial baseline report, repeated every 5 years
		-Public – prior coordination is required with parks' superintendents through Resource Management before any public release of this type of information SENSITIVE INFORMATION	APHN Coordinator	To be determined
Landscape pattern	Changes in composition and structure of dominant vegetation types (loss of dominant forest trees to disease, insect pests, etc.)	-Park Managers, cooperators (executive summaries, briefings)	APHN ecologist, data manager	Initial baseline report, repeated every 5-10 years
		-Public (newsletters, website) -Professional presentations, journal articles		Periodically, or eventfully

8. ADMINISTRATION/IMPLEMENTATION OF THE MONITORING PROGRAM

8.1 ADMINISTRATION

The Appalachian Highlands I&M Network includes five National Park Service units in North Carolina, Virginia, Tennessee, Kentucky and Georgia: Appalachian National Scenic Trail (APPA) (from Shenandoah National Park to its southern terminus), Big South Fork National River and Recreation Area (BISO), Blue Ridge Parkway (BLRI), Great Smoky Mountains National Park (GRSM), Obed Wild and Scenic River (OBRI) (Figure 1.1). As a "prototype" I&M park, GRSM provides input to the Network concerning protocol development and sampling design, however, the Smokies' I&M program is operationally distinct from the rest of the Network. While the southern portion of the Appalachian Trail was incorporated into the early stages of the Network's long-term monitoring planning process, I&M planning for APPA is currently being coordinated through the Northeast Temperate I&M Network. Regarding implementation of Vital Signs monitoring, discussion of APPA and GRSM is limited mostly to issues concerning integration of data among Network parks, and with partners outside APHN.

Board of Directors

Name	Title
Phil Francis (*Chair)*	Acting Superintendent, BLRI
Phil Campbell	Superintendent, OBRI
Reed Detring	Superintendent, BISO
Dale Ditmanson	Superintendent, GRSM
Robert Emmott	I&M Coordinator, APHN
Larry West	I&M Coordinator, SERO

Science and Technical Committee

Name	Title
Ray Albright	NPS Research Coord., S. Appal. CESU
Tom Blount	Chief of Resource Management
Robert Emmott (*Chair*)	I&M Coordinator, APHN
Patrick Flaherty	Data Manager, APHN
Mike Jenkins	Ecologist, GRSM
Nancy Keohane	Resource Mgt. Specialist, OBRI
Nora Murdock	Ecologist, APHN
Bambi Teague	Chief of Resource Management, BLRI

Figure 8.1. Current makeup of the Appalachian Highlands I&M Network Board of Directors, and Science and Technical Committee

The APHN charter, created in 2001, describes the process used to plan, manage, and evaluate the inventory and monitoring program within the Network. Significant management and budgeting decisions are made by the Network Board of Directors, comprised of the Superintendents of the Network parks, together with the regional and Network I&M Coordinators. A Science and Technical Committee, which includes Network and park resource management staff, provides technical assistance and advice to the Board of Directors (Figure 8.1). The NPS Southeast Region provides program quality assurance, oversight and other technical assistance, as requested from the Board of Directors. This management structure is designed to foster the development of an I&M program which is responsive to the unique set of long-term resource issues and threats within the Network parks.

8.2 STAFFING PLAN

In accordance with national I&M goals, and APHN park priorities, Network activities revolve around five broad program functions (Figure 8.2). The Network staffing plan is designed to support these functions, and to provide park managers with the professional expertise they need to implement a scientifically credible I&M program addressing the parks' most critical long-term resource issues. These issues, reflected in the Network Vital Signs, are centered upon aquatic resources (BISO, OBRI) and vegetation, but also include air pollution (BLRI), rare mussels and rare fish (BISO, OBRI).

- **CONDUCTING BASELINE INVENTORIES** of natural resources in the parks, including those currently underway (vascular plant and vertebrate surveys, vegetation mapping, soils mapping), as well as other critical inventory needs of Network parks;
- **DEVELOPING AN INTEGRATED, SCIENTIFICALLY CREDIBLE, LONG-TERM ECOLOGICAL MONITORING PROGRAM** to efficiently and effectively monitor status and trends of selected Vital Signs;
- **DEVELOPING DATA MANAGEMENT AND DECISION SUPPORT SYSTEMS** (including GIS and other tools) to aid park managers in identifying, implementing, and evaluating management options;
- **INTEGRATING INVENTORY AND MONITORING** programs with park planning, maintenance, interpretation and visitor protection activities to help the parks in their efforts to make natural resource protection even more of an integral part of overall park management;
- **COOPERATING WITH OTHER AGENCIES AND ORGANIZATIONS** to share resources, achieve common goals, and avoid unnecessary duplication of effort and expense.

Figure 8.2. Five broad program functions encompassing APHN activities

In order to meet the Network's need for broad subject matter expertise in these areas, to institutionalize professional data management practices, to meet the need for qualified field personnel, and to properly administer the I&M program, the Network has created a staffing plan made up of a Coordinator, two professional Ecologists, a Data Manager, and four Biological Technicians (Table 8.1). Short descriptions of these positions and their primary functions follow:

Coordinator – The Coordinator provides overall direction for the APHN I&M program. The Coordinator works with network parks, the Network Science and Technical Committee, Board of Directors, and the SERO I&M Coordinator, to develop inventory and monitoring strategies, and recommend implementation schedules for funding and staffing consideration. This position coordinates project-specific data analysis and reporting, and ensures that information is provided to park managers in useful formats. The Coordinator supervises the APHN professional level positions, and provides general oversight and accountability for the Network program.

Data Manager – The Data Manager has a central role in ensuring that project data conforms with program standards, designing project databases, disseminating data, and ensuring long-term data integrity, security, and availability. In order to maintain high data quality standards, and promote ready use of project data, the Data Manager collaborates with the project manager to develop data entry forms, QA/QC procedures, and automated reports. The APHN Data Manager maintains spatial data themes associated with Network inventory and monitoring projects, and incorporates spatial data into the Network GIS. The Data Manager maintains standards for this data and the associated metadata, and develops procedures for sharing and disseminating GIS data to Network parks and partners.

Ecologist – The Ecologist serves as the primary Network subject matter expert for terrestrial resource issues. The Ecologist coordinates all aspects of terrestrial inventory and monitoring projects, including: protocol design and pilot testing; data collection, whether it is oriented toward field data collection, or gathering existing data from other sources; data quality during all phases of a project, including the QA/QC process and the creation of project documentation and metadata; and the preparation and dissemination of project analyses and reports. The Network Ecologist also provides oversight and supervision for biological technicians working on APHN projects. In addition, this position serves as the primary Network technical contact for potential Network partners working on terrestrial resource issues.

Aquatic Ecologist – The Aquatic Ecologist serves as the primary Network subject matter expert for aquatic resource issues. The Aquatic Ecologist coordinates all aspects of aquatic inventory and monitoring projects, including: protocol design and pilot testing; data collection, whether it is oriented toward field data collection or gathering existing data from other sources; data quality during all phases of a project, including the QA/QC process and the creation of project documentation and metadata; and the preparation and dissemination of project analyses and reports. The Network Aquatic Ecologist also provides oversight and supervision for biological technicians working on APHN projects. In addition, this position serves as the primary Network technical contact for potential Network partners working on aquatic resource issues.

***Biological Technicians* –** These are seasonal positions, working under the Network Ecologists. Their primary duties include data collection, whether it involves field data collection, or gathering data from existing sources. The biotechnicians follow existing protocols to gather data, record, verify and correct data values, and to perform regular data transfer and backup. These positions also assist with dataset and procedural documentation, and are responsible for documenting any deviations from protocols or study plans.

The Network Ecologist is stationed at BLRI, where most field work associated with vegetation monitoring occurs. Duty station location is less critical for the Coordinator and Data Manager; these positions are located at BLRI.

Table 8.1. APHN staff positions and their primary duties (cost in approx. FY2006 dollars)

POSITION	PRIMARY DUTIES	% OF TIME	TOTAL FTE	TOTAL COST (K)
Coordinator	Provides direction, and manages overall planning and implementation of the Network I&M program	35%	.3	26.9
	Coordinates project-specific data analysis, summary, and reporting	30 %	.3	26.9
	Ensures information is provided to parks and partners in useful formats	15%	.15	13.5
	Coordinates I&M partnerships	10%	.1	8.9
	Provides program oversight and supervision	10%	.1	8.9
Data Manager	Conducts data archiving and dissemination, database development, overall QA/QC for the I&M program	50%	.6	42.8
	Works with ecologists to ensure information is provided to parks and partners in useful formats	20%	.2	14.3
	Implements data management partnerships	20%	.2	14.3
	Provides oversight and supervision for data management activities	10%	.1	7.1

POSITION	PRIMARY DUTIES	% OF TIME	TOTAL FTE	TOTAL COST (K)
Ecologist	Provides guidance, oversight and management of terrestrial I&M projects	25%	.25	23.0
	Conducts project-specific data analysis, summary and reporting, data validation and verification	35%	.35	33.6
	Works with program professionals to provide information to parks and partners in useful formats	20%	.2	19.2
	Coordinates I&M partnerships	10%	.1	9.6
	Provides supervision for terrestrial I&M projects	10%	.1	9.6
Aquatic Ecologist	Provides guidance, oversight and management of aquatic I&M projects	25%	.25	16.7
	Conducts project-specific data analysis, summary and reporting, data validation and verification	35%	.35	22.3
	Works with program professionals to provide information to parks and partners in useful formats	20%	.2	13.4
	Coordinates I&M partnerships	10%	.1	6.7
	Provides supervision for aquatic I&M projects	10%	.1	6.7
BioTechs (4 seasonals)	Work with program ecologists to collect field data, and document methods, procedures and anomalies	70%	1.4	41.6
	Conduct data entry and verification	30%	.6	17.8
TOTAL			**6.0**	**383.8**

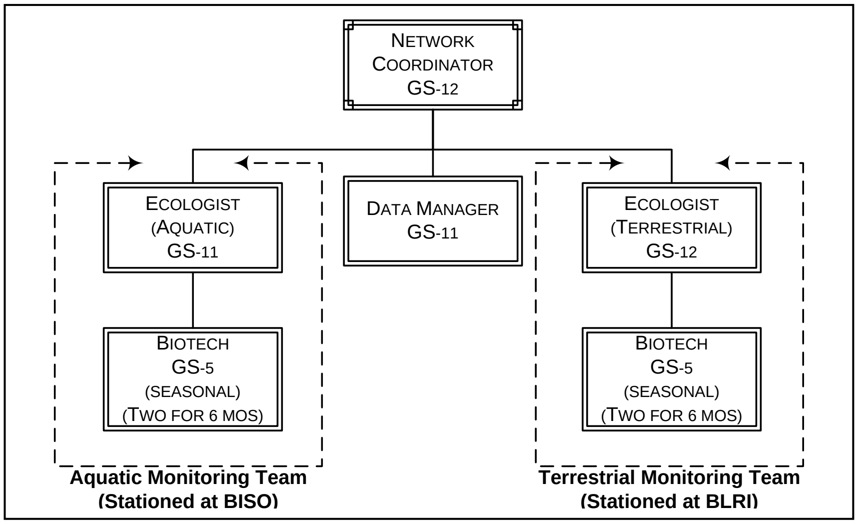


Figure 8.3. Organizational structure of the APHN

8.3 PROGRAM INTEGRATION

I&M data will be made available to all other park operations, including interpretation, law enforcement and maintenance. Interpretation is particularly important, since it is the major conduit of natural resource information from the parks to the public. The APHN staff has been working with the network Science Learning Center at GRSM and with park interpreters to convey information in an interesting and understandable fashion to various audiences. Articles have been prepared for park newspapers on I&M activities, presentations have been given to all-employees meetings in the parks, and newsletters have been distributed among park staff. I&M information should also be helpful to maintenance and planning divisions, with compliance reviews of proposed projects inside the parks. Integration with law enforcement began for the APHN with the start of the inventories. Cooperators and Network staff met with district rangers and other law enforcement staff to discuss what sorts of activities law enforcement personnel wanted to be told about. The "extra eyes and ears in the woods" have already proved useful, when inventory crews spotted and reported vehicles in closed areas and signs of wildlife or plant poaching. Inventory crews also reported some significant cultural resources found during the course of plant inventories in park backcountry.

The APHN I&M Program office is located in one of the network parks, which facilitates integration of the network staff with the park staff. Hopefully, as field work begins on the monitoring, more integration with park staff will be possible. Opportunities to help all divisions in the parks will be actively sought. The Network's Board of Directors is made up of the Superintendents of the network parks, and the Science and Technical Committee is made up of the parks' Chiefs of Resource Management and other resource management specialists, which further helps to integrate the Network's planning with the parks' concerns and activities.

8.4 PARTNERSHIPS

Key partners and cooperative agreements:

- U.S. Geological Survey, TN and NC offices – interagency agreements for assistance with water monitoring protocol. An agreement is being negotiated with an expert malacologist in the TN office to design a mussel monitoring protocol for the network.

- Southern Appalachian CESU (host: University of Tennessee) – cooperative agreements for facilitation of conceptual modeling and Vital Signs workshops as part of the design of the network's long-term monitoring program.

- Western Kentucky University – cooperative agreement to analyze water samples.

- Southern Appalachian Man and the Biosphere – helped facilitate our Vital Signs and conceptual modeling workshops; frequent and active participants in our meetings. Cooperative agreement for data mining for the parks from major university, herbaria, museum collections.

- U.S. Forest Service Coweeta Hydrologic Laboratory and Long-term Ecological Research Center, Otto, NC - participants in our Vital Signs planning process and advisors on monitoring design.

- Conservation Fisheries, Inc. – cooperative agreement for fish inventories for the network; they also track the status of Federally-listed fish that have recently been reintroduced to GRSM. They specialize in non-destructive surveys.

- Tennessee Valley Authority – cooperative agreement for fish inventories.

- University of Tennessee – agreement being negotiated with water quality lab for analysis of samples and trend data.

- U.S. Forest Service – Southern Research Station, and biologists from the Daniel Boone, Pisgah, Nantahala, and Cherokee National Forests share natural resource monitoring data, particularly on birds; participants in our Vital Signs workshops.

- Tennessee Technological University – cooperative agreement with long-term bird monitoring project coordinator at BISO, OBRI.

- U.S. Fish and Wildlife Service – sharing of monitoring data on migratory birds and Endangered species; USFWS funds monitoring for some listed species of plants and animals within APHN parks.

- University of Maryland, Appalachian Lab (Phil Townsend and Robert Gardner) – cooperative agreement to develop a landscape change protocol for the network.

- University of Georgia, Center for Remote Sensing and Mapping Science – cooperative agreement for preparation of detailed vegetation maps for all of the network parks from aerial infrared photography.

- NatureServe – Cooperative agreement for protocol development for monitoring poached plants, forest community change (species composition or structure), vegetation inventories and plot installation. Assistance with vegetation mapping.

- The Nature Conservancy – Cooperative agreement is being negotiated for assistance with vegetation monitoring protocols; active participants in our Vital Signs workshops.

8.5 REVISIONS

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

9. SCHEDULE

9.1 PROTOCOL IMPLEMENTATION SCHEDULE

The Network's protocol implementation schedule for FY05 through FY10, is shown in Table 9.1. The schedule is tentative and will depend in large part on our eventual ability to implement monitoring designs which are only now beginning to be developed. As each monitoring design takes shape, we expect that monitoring objectives will continue to be refined, based on a better understanding of the sampling effort required to address our monitoring questions, and how the design fits into our overall monitoring program. In some cases, it is even likely that better information about sampling logistics and costs will cause us to shift our Vital Signs monitoring priorities.

Table 9.1 breaks down the prospective implementation schedule for each protocol into four basic tasks, some of which are recurring and some which will take place only once: pilot sampling, protocol development, data collection, and data analysis/reporting. As shown in the table, tasks differ for some protocols, depending on whether they involve periodic collection and analysis of existing data (e.g., weather, air pollution) as opposed to field studies. When the interval for data collection, analysis, and reporting is longer than five years, as it is with landscape change, the second monitoring cycle doesn't appear in the table. A brief description of the implementation schedule for each protocol follows:

Water Quality/Quantity

A draft water quality monitoring protocol was submitted for peer review in December, 2004. Peer review comments were incorporated, and approval was obtained to begin field work by October, 2005. An aquatic ecologist will be hired by spring 2006. This position will oversee all aspects of the long-term water resources monitoring program for the Network, and will supervise the summary and analysis of monitoring results from 2005.

A synoptic sampling project to characterize water quality in high elevation streams and seeps along the Blue Ridge Parkway was conducted in 2005, focusing on water bodies where atmospheric deposition may be an issue, and where sensitive aquatic resources exist. The project was designed with input from GRSM, SHEN, USFS personnel, and the University of Virginia to make sure our sampling efforts are concentrated on the most critical sites. Field work was conducted during the summer and fall, and data analysis and reporting will take place in the winter and spring of 2005-06. Project results will be used to determine whether additional long-term water quality monitoring sites are needed at BLRI.

The Network's water quality monitoring protocol calls for sampling throughout the year. Each October, a monthly sampling schedule will be created for the coming year, to indicate sampling sites, the frequency of sampling, and the schedule for quality control samples. The sampling schedule will require fixed dates, and water samples will be collected regardless of flow regime. This approach allows for a range of hydrologic conditions to be sampled over time.

Water quality sampling will be conducted monthly at BISO, BLRI, and OBRI. In a typical month, sampling will take place over a two week period. Prior to a typical sampling week, the preceding Friday will be dedicated to preparation for sampling, entering metadata into field databases, and other planning activities. Preparation for sampling, together with field work, and data entry, should take anywhere from three (OBRI) to nine (BLRI) days each month for each park. Sampling will begin on Monday, and continue for three to four days, depending on the park. On the Thursday or Friday following field data collection, equipment cleaning and maintenance will be done, and preparations will be made for the next sampling trip. Table 9.2 shows a suggested sampling schedule for BISO, and OBRI. The sampling schedule at BLRI is similar in concept, and will take about nine days per month.

Lab analysis will be conducted at the University of Virginia, and results emailed to the Network aquatic specialist, typically within two days of analysis. Data will be archived monthly, once verification and validation have been completed. Analysis and reporting of annual sampling results will take place as close to the end of the calendar year as possible. Annual data will be sent to the NPS Water Resources Division at this time, for entry into NPStoret.

Aquatic Macroinvertebrates

This protocol will be completed by spring, 2006, with peer review comments incorporated by October. Sampling will likely be done once a year at BISO, BLRI, and OBRI, at from 5 to 10 sites per park. Sampling will take from four days (OBRI) to two weeks (BLRI) per park. Lab identification will be contracted out, with results due within a month. Data validation, annual analysis and reporting will normally take place in the fourth quarter of the calendar year. The database file containing annual sampling results will be archived at this time, as well.

Landscape Change

A draft landscape change monitoring protocol will be completed by the end of calendar year 2005. Part of the project will consist of a retrospective analysis of landscape change in the areas surrounding BISO, BLRI, and OBRI. The protocol will likely call for periodical (once every 5 to 10 years) assessment of changes in vegetation community composition and distribution in the parks, as well as changes in external land use that may be affecting the parks. Therefore, data collection, and reporting/analysis tasks will not be repeated within the timeframe depicted in Table 9.1.

Vegetation

This category consists of five separate monitoring issues for which protocols are to be completed over the course of calendar years 2005 and 2006. These projects address various vegetation monitoring objectives at BISO, BLRI, and OBRI, and will involve pilot sampling in these parks during 2005-06. Three draft protocols will be completed by February, 2006, and the remaining three will be done by February, 2007. Data collection for these completed protocols will begin during the field seasons of 2006, and 2007, respectively. Data validation, analysis and annual reporting will be done during the fourth quarter of each calendar year. The database file containing annual sampling results will be archived at this time as well.

Air Quality

Air quality data will be collected for Network parks following guidelines completed by the NPS Air Resources Division in the spring of 2005. A protocol describing the nature of the data to be summarized, the kind of analysis that may conducted, the way the data will be archived, and the schedule for reporting, will be completed by the first quarter of calendar year 2006. Thereafter, it is likely that air annual air quality data will be collected as close to the end of each calendar year as possible. Analyses and reports will be prepared during the first quarter of the following year.

Weather

Weather data will be collected in support of the Network's other long-term monitoring projects. Cooperative Agreements are being worked out at the national level between the I&M program and NOAA/NWS; therefore network efforts on this protocol are pending further developments on the national-level. As with air quality data, it is anticipated that annual weather data will be collected as close to the end of each calendar year as possible. Analyses and reports will be prepared during the first quarter of the next year.

Freshwater Mussels (T&E)

A protocol will be developed to monitor trends in rare mussel populations at BISO and OBRI, beginning in fall, 2005, with a draft protocol being completed one year later. A draft monitoring design will be done during the spring, and pilot sampling will take place in the summer of 2006. The sampling design will be finalized based on the pilot sampling results, and a report summarizing these results will be submitted, along with a draft protocol, in fall, 2006. It is expected the protocol will call for periodic systematic surveys, to be conducted approximately once every three years. During each of these survey years, sampling will occur during the summer and an analysis and report will be completed by the end of the calendar year. Annual sampling data will be archived at this time.

Fish (T&E)

Monitoring trends in rare fish populations at BISO and OBRI, will be addressed in a protocol to be developed beginning in January, 2006, with a draft protocol scheduled for completion one year later. A draft monitoring design will be done during the spring of 2006, and pilot sampling will take place in the summer. The sampling design will be finalized based on the pilot sampling results, and a report summarizing these results will be submitted, along with a draft protocol, in January, 2007. It is expected the protocol will call for periodic systematic surveys, to be conducted approximately once every three years. During each of these survey years, sampling will occur during the summer and an analysis and report will be completed by the end of the calendar year. Annual sampling data will be archived at this time.

Table 9.1. Project implementation schedule for APHN Vital Signs monitoring (years are calendar years; Q1, Q2, etc., are quarters).

Protocol/Task	2005	2006				2007				2008				2009				2010			
	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Water Quality																					
Pilot Sampling	■	■																			
Protocol Development	■																				
Data Collection			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Analysis/Reporting					■	■			■	■			■	■			■	■			■
Aquatic Macroinvertebrates																					
Protocol Development	■	■	■																		
Data Collection								■				■				■				■	
Analysis/Reporting					■	■			■	■			■	■			■	■			■
Landscape Change																					
Retrospective Analysis		■	■	■																	
Pilot Sampling			■	■																	

Protocol/Task	2005	2006				2007				2008				2009				2010			
	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Protocol Completion	■	■	■	■	■																
Vegetation																					
Pilot Sampling			■	■			■	■													
Protocol Development	■	■	■	■	■	■	■	■	■	■											
Data Collection							■	■			■	■			■	■			■	■	
Analysis/Reporting									■	■			■	■			■	■			■
Air Quality																					
Protocol Development		■	■	■	■	■															
Data Collection					■				■				■				■				■
Analysis/Reporting						■				■				■				■			
Weather																					
Protocol Development		■	■	■	■	■															
Data Collection					■				■				■				■				■

Protocol/Task	2005	2006				2007				2008				2009				2010			
	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Analysis/Reporting						■				■				■				■			
Freshwater Mussels (T&E)																					
Pilot Sampling			■	■																	
Protocol Development	■	■	■	■	■	■															
Data Collection			■	■											■	■					
Analysis/Reporting						■											■				
Fish (T&E)																					
Pilot Sampling				■	■																
Protocol Development			■	■	■	■	■														
Data Collection																			■	■	
Analysis/Reporting										■											

Table 9.2. Water quality sampling sequence at BISO, OBRI.

MONTH ONE	*Monday*	*Tuesday*	*Wednesday*	*Thursday*	*Friday*
First week					equipment preparation, loading vehicle and other activities
Second week	1) New River 2) Clear Fork 3) White Oak Creek	1) Obed River at Alley Ford 2) Deliver samples to lab 3) Rock Creek TN	1) Big South Fork at Leatherwood Ford 2) Bandy Creek 3) North White Oak Creek	Deliver samples to lab	Data entry, Equipment cleaning, Other maintenance
Third week	1) Bear Creek 2) Big South Fork at Stearns, KY 3) Roaring Paunch	1) Pine Creek, 2) Deliver samples to lab 3) Rock Creek KY	1) Laurel Fork of Station Camp Creek, 2) Williams Creek	Deliver samples to lab	Data entry, Equipment cleaning, Other maintenance
MONTH TWO					
First week					equipment preparation, loading vehicle and other activities
Second week	1) New River 2) Big South Fork at Leatherwood Ford	1) Obed River at Alley Ford, 2) Deliver samples to lab 3)Daddy's Creek	1) Otter Creek, 2) Obed at Adams Bridge	Deliver samples to lab	Data entry, Equipment cleaning, Other maintenance
Third week	1) Clear Creek 2) White Creek 3) Emory River at Montgomery Bridge	Deliver samples to lab			Data entry, Equipment cleaning, Other maintenance

10. BUDGET

The Appalachian Highlands I&M Network receives monitoring funds from two primary sources: the National Park Service Vital Signs Monitoring Program provides $417,400 in annual operating funds; an additional $70,000 per year is supplied by the NPS Water Resources Division. The Network's anticipated annual operating budget at full staffing level is shown in Table 10.1. Operating funds are held in NPS Washington office base accounts and transferred annually to the Network through the Southeast Regional Office. All funds are managed by the APHN Coordinator with the oversight of the Network Board of Directors (BOD).

Table 10.1. Anticipated annual budget for the APHN at full staffing level - after review and approval of the monitoring plan.

Income	**Amount**	***% by category***
Vital Signs Monitoring	**$417,400**	**86%**
Water Resources Division	**$70,000**	**14%**
TOTAL	***$487,400***	***100%***
Expenditures		
Personnel - Permanent	**$337,000**	***69%***
Personnel – Seasonal	**$61,500**	***13%***
Cooperative Agreements	**$41,000**	***8%***
Operations and Equipment	**$25,900**	***5%***
Travel	**$22,000**	***5%***
TOTAL	***$487,400***	***100%***

The Network's Annual Work Plan, which is developed in conjunction with the APHN Science and Technical Committee, and is approved by the BOD, directs the annual allocation of funds to various projects. All I&M funds are strictly accounted for, and expenditures are enumerated in a detailed Annual Administrative Report.

As shown in Table 10.1, personnel costs comprise the majority of the Network's annual budget (82% of the total, with permanent and seasonal personnel combined). This reflects the Network's intention to accomplish most of our Vital Signs monitoring with Network staff. Nevertheless, because we can currently afford to monitor only a few of our original candidate Vital Signs, APHN is focusing on integrating Network, park and non-NPS monitoring efforts to the maximum extent possible, in order to make the best use of scarce resources.

To accomplish key portions of the monitoring program, APHN will enter into Cooperative Agreements thru Cooperative Ecosystem Studies Units, or other entities. Because the Network is making a substantial effort to monitor various aspects of freshwater quality and quantity, it will be particularly important to establish a productive working relationship with a reputable water lab. APHN will also require periodic collaboration with subject matter experts to carry out specialized field data collection, and to assist with analyzing monitoring data.

As indicated in Table 10.1, the cost of travel is planned to be about five percent of the total Network budget. However, with rising gasoline prices, this figure is likely to increase. For the Network model to work, adequate travel funds will be required in order to accomplish field data collection according to established monitoring protocols. Travel is also critical to maintain close communication among the Board, Science and Technical Committee, Network and park staff.

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GLOSSARY

Glossary of Terms Used by the NPS Inventory and Monitoring Program

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

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. See Indicator.

Ecological integrity is 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 is 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 are major external driving forces such as climate, fire cycles, biological invasions, hydrologic cycles, and natural disturbance events (e.g., earthquakes, droughts, floods) that have large scale influences on natural systems.

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

Endangered – any species that is in danger of becoming extinct throughout all or a significant portion of its range.

Focal resources are 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.

G-1 –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). May apply to species or ecological community.

G-2 –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). May apply to species or ecological community.

G-3 –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. May apply to a species or community.

Indicators are 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. 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.

Measures are the specific feature(s) used to quantify an indicator, as specified in a sampling protocol.

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.

Threatened – a species that is likely to become Endangered in the foreseeable future.

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

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U.S. Department of the Interior

Appalachian Highlands Inventory and Monitoring Network

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