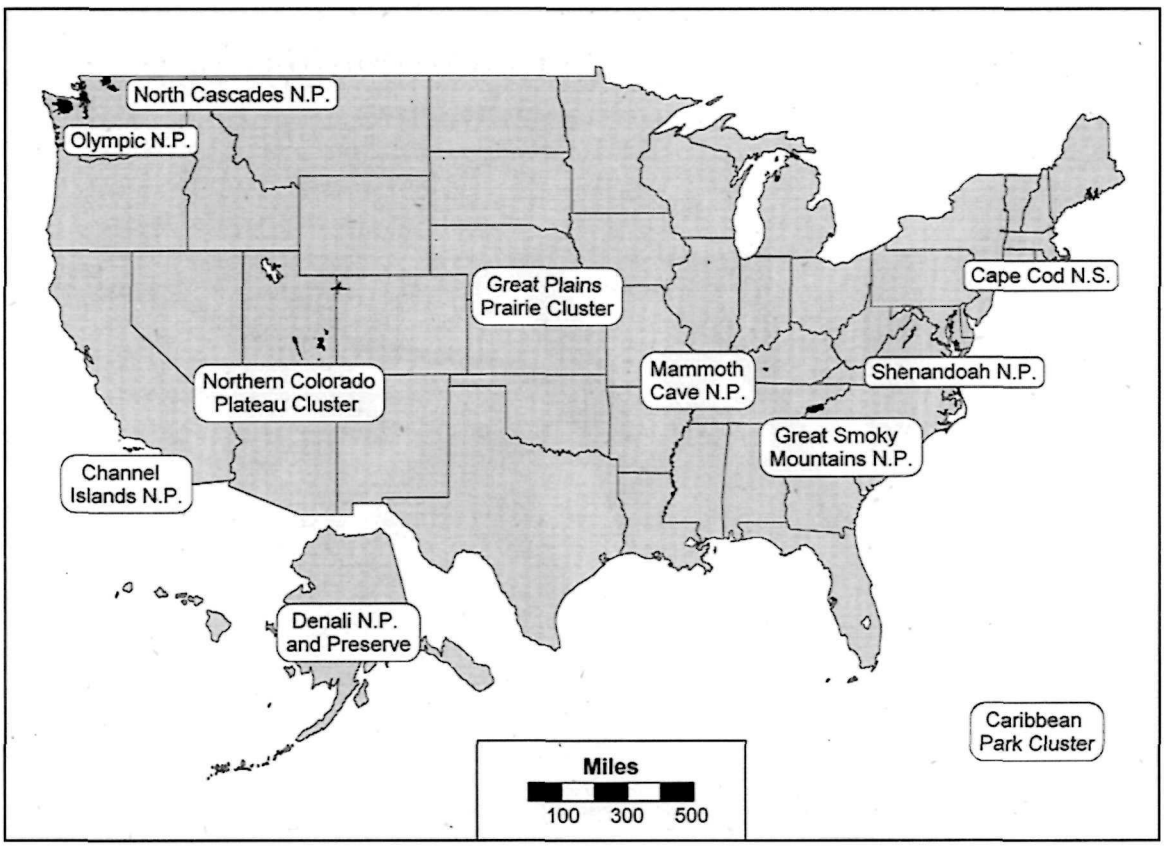
Inventory and Monitoring Program Annual Report

Fiscal Year 1996

U.S. Department of the Interior
National Park Service
Natural Resource Information Division

National Park System units selected for prototype experimental monitoring of natural resources.



Map by Joe Gregson

This report is dedicated to the late Patricia Patterson in appreciation of her significant contributions to the Natural Resource Inventory and Monitoring Program.

Photograph by David Roessner

Patricia E. "Trish" Patterson was the I&M Program Coordinator for the Southeast Region before being appointed Superintendent of Congaree Swamp National Monument, three months prior to her untimely death in May 1995. Trish was deeply committed to natural resources and worked diligently to assist parks with resource inventory and monitoring in the southeastern region and nationwide. Her enthusiasm, dedication, and professionalism are greatly missed.

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Photographs without credit lines are from the files of respective National Park System units.

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FOREWORD

Although some parks made inventories and conducted monitoring during the past decade and earlier, the National Park Service first requested additional funds for these purposes in 1988. The funds were received and given to several pilot parks that were already collecting information. In 1991, formal proposals were solicited from parks and four were selected to receive servicewide funds for prototype monitoring. The parks were Channel Islands, Great Smoky Mountains, and Shenandoah national parks and Denali National Park and Preserve. Because these parks had been conducting some inventory and monitoring, benefits from the additional funds could be shown quickly and used to request increases in future funding and bring other parks on line. Although only a portion of the requested annual funding has ever been received, the Inventory and Monitoring (I&M) Program has been successful in developing baseline information on park natural resources. When monitoring reveals changes, park managers are provided with sound biological data for policy and management decisions.

Since its inception, the I&M Program has amassed a great deal of information--too much to describe in a single volume. We therefore focused on some of the major accomplishments to date and indicate how this information has been used by park managers for making decisions. Part I of the report features descriptions of the principal functions and the structure of the I&M Program and the status of inventory and monitoring in 12 National Park System units. Part II consists of six reproduced fact sheets about inventories of natural resources in the National Park Service. Part III is the largest of the three parts. It is organized by type of resource and describes the reasons for monitoring and the last known status of the resources.

I am pleased to share the progress of the I&M Program with all of you and plan to provide a similar report each year. I welcome all comments on this effort.

Richard W. Gregory, Chief, Natural Resource Information Division, Natural Resource Program Center, Fort Collins, Colorado

ACKNOWLEDGMENTS

The materials for the report were contributed by Leslie Armstrong, Tom Blount, Tim Coonan, Rikki Dunsmore, Kate Faulkner, Ginger Garrison, Joe Gregson, Penny Knuckles, Robert Krumenaker, Matt Kulp, Keith Langdon, Larry Pointer, Caroline Rogers, Mike Reynolds, Elizabeth Rockwell, Mike Story, Lisa Thomas, Gary Williams, and Gary Willson. Jen Coffey and John Oldemeyer provided critical reviews of the material and keen suggestions for revisions that significantly improved the presentation of the material. Jeff Selleck assisted with the registration of the report and with the scope of work for the contractor.

The Inventory and Monitoring Program

The National Park Service is mandated to conserve the natural resources in the National Park System[1] (National Park Service Organic Act, 16 U.S.C. 1 et seq., ch. 408, 39 Stat. 535). Significant natural resources occur in more than 250 of the 368 units of the system (Table 1), and many are subjected to unfavorable influences from a variety of sources, for example, air and water pollution, urban encroachment, and excessive visitation. Left unchecked, such effects can threaten the very existence of many natural communities in the units. To help prevent the loss or impairment of natural resources, the National Park Service established the *Natural Resource Inventory and Monitoring (I&M) Program.*

The principal functions of the program are the gathering of information about the resources and the development of techniques for monitoring the ecological communities in the National Park System. The detection of changes and the quantification of trends in the conditions of natural resources are imperative for the identification of links between changes in resource condition and the causes of changes and for the elimination or mitigation of such causes. Inventory and monitoring will provide important feedback between natural resource conditions and management and trigger specific management and evaluation of managerial effectiveness. Ultimately, the inventory and monitoring of natural resources will be integrated with park planning, operation and maintenance, visitor protection, and interpretation to establish the preservation and protection of natural resources as an integral part of park management and improve the stewardship of natural resources by the National Park Service.

[1]National parks and other entities of the National Park Service such as national monuments, national rivers, wild and scenic riverways, national scenic trails, and others are called *units* and collectively constitute the *National Park System.*

STAFFING

A servicewide I&M Program Manager and two support staff members of the Natural Resource Information Division in Colorado coordinate the I&M Program goals and objectives. A National Advisory Committee—which consists of park superintendents, natural resource management specialists, program managers, and research scientists of the Biological Resources Division (U.S. Geological Survey; Appendix)—develops strategic policies and makes programmatic, technical, and budgetary recommendations to the program manager who refers them for approval to the Deputy Associate Director for Natural Resource Stewardship and

Table 1. National Park System Units. From The *National Parks: Index 1995* by the Office of Public Affairs and the Division of Publications, National Park Service, U. S. Government Printing Office, Washington, D.C. 20402

Classification	**Number**	**Acreage** (as of 31 Dec 1994)
International Historic Site	1	35.39
National Battlefield	11	13,098.41
National Battlefield Park	3	8,727.27
National Battlefield Site	1	1.00
National Historic Site	72	23,111.03
National Historic Park	37	161,976.48
National Lakeshore	4	228,847.52
National Memorial	26	8,049.24
National Military Park	9	38,016.36
National Monument	73	2,064,444.67
National Park	54	51,711,507.00
National Parkway	4	170,706.51
National Preserve	14	23,689,219.85
National Recreation Area	18	3,700,629.20
National Reserve	2	33,407.19
National River	6	416,018.22
National Scenic Trail	3	184,234.65
National Seashore	3	592,627.65
National Wild and Scenic River and Riverway	9	219,377.93
Without Designation	11	38,945.07
Total number of units	368	83,302,980.64

Science. Ad Hoc working groups of technical experts from the field convene as necessary to address specific policies and technical issues. Natural resource personnel in support offices provide coordination between parks and the national program office.

Partnerships

Prototype monitoring and basic inventories are being implemented in a close partnership between the National Park Service and the Biological Resources Division of the U. S. Geological Survey. During the initial phases of research and design of long-term prototype monitoring—usually a period of 3-5 years—funding and full-time employees are provided by the Biological Resources Division. After completion of research and protocol designs, monitoring is considered to be operational. From then on, funding and full-time employees become the responsibilities of the National Park Service (also see *Vegetation Mapping* in Part II of this report).

Budget

The I&M Program is funded by annual line-item appropriations from the Congress. The Fiscal 1996 I&M Program budget was $2.92 million of which 12% was used for salaries and program administration, 67% for inventories, and 21% for long-term monitoring. An additional $1.05 million and 13 FTE (full-time equivalent) were available in park base accounts to operate prototype long-term ecological monitoring. In Fiscal 1996, the Biological Resources Division of the U. S. Geological Survey provided $1.18 million to map vegetation communities in parks throughout the United States except in Alaska, $878,000 to support research and development of prototype long-term monitoring, and $180,000 for inventory protocol development.

Prototype Ecological Monitoring

The tremendous variability in the ecological conditions, sizes, and management capabilities of national parks poses significant problems for ecological monitoring throughout the National Park Service. To deal with this ecological and managerial diversity, the I&M Program used a competitive process to select parks in which *prototype experimental monitoring* of each of 10 major biomes could be conducted (Table 2).

To ensure that the broad range of managerial situations is adequately represented, three of the prototypes were selected as *clusters*, i.e., a grouping of 4-6 small units, each of which lacked the full range of staff and resident expertise for long-term monitoring on its own. Monitoring in the selected parks varies widely by structure and function of a park. However, the monitoring of trends in species abundance, population dynamics, watershed ecology, and other indicators of environmental change tends to be uniform throughout the prototypes. Notwithstanding, all monitoring is designed to provide useful ecological information for addressing questions beyond today's issues.

Table 2. The seven National Park System units in which prototype monitoring was implemented and the biomes that the units represent.

Prototype	Biome
Cape Cod National Seashore, Massachusetts	Atlantic/Gulf Coast
Channel Islands National Park, California	Pacific Coast
Denali National Park and Preserve, Alaska	Arctic/Subarctic
Great Plains Prairie Cluster; Iowa, Minnesota, Missouri, and Nebraska	Prairie and Grassland
Great Smoky Mountains National Park, Tennessee and North Carolina	Deciduous Forest
Shenandoah National Park, Virginia	Deciduous Forest
Virgin Islands/Southern Florida Cluster	Tropical/Subtropical

Protocols and expertise developed by the selected parks will be shared with other parks in similar ecological and managerial settings. The selected parks will also serve as training centers for natural-resource managers throughout the National Park Service.

Table 3. The four National Park System units in which prototype monitoring will be implemented and the biomes that these units will represent.

Prototype	Biome
Mammoth Cave National Park, Kentucky	Caves
Olympic National Park, Washington	Coniferous Forest
North Cascades National Park, Washington	Rivers and Lakes
Northern Colorado Plateau Cluster, Colorado and Utah	Arid Lands

The Seven Selected Parks

Prototype monitoring of natural resources was implemented in 7 of 11 selected parks (Tables 2-3). The 7 parks represent 6 biomes; deciduous forest is represented by 2 parks. Monitoring in the remaining 4 parks (Table 3) will be implemented as soon as funding is appropriated.

Figure 1. Cape Cod National Seashore, Massachusetts

Cape Cod National Seashore (Atlantic-Gulf Coast Biome)

Cape Cod National Seashore, Massachusetts (Fig. 1), was created in 1961 to protect some of the unique natural and cultural resources of Cape Cod. Although the beaches are its most popular and well-known feature, the 40-mile length of the national seashore preserves other outstanding examples of this coastal environment, including pine and hardwood forests, salt water and freshwater marshes, kettle ponds, and majestic sand dunes. The record of human occupation of Cape Cod begins with evidence of prehistoric use by Native Americans and includes key sites associated with European exploration and settlement. The Marconi Wireless Station Site, the Captain Edward Penniman House, and the Old Harbor Lifesaving Station are several outstanding reminders of the rich human history of the cape. The national seashore provides numerous opportunities for swimming, bicycling, walking, horseback riding, fishing, hunting, and oversand vehicle use.

Like other parks in the Atlantic Coast and Gulf Coast regions, Cape Cod National Seashore is a landscape mosaic of natural areas, recreation areas, and residential development. During the past 100 or more years, its ecosystems have been profoundly altered by an industrial society. For example, dikes and roadways changed the natural tidal water flow to several estuaries that in turn reduced the water quality, disturbed the environment, and altered the hydrology of these ecosystems. Fire suppression has probably prevented the perpetuation of pitch pines (*Pinus rigida* P. Mill.) and heathland communities that predominated in the area before and during early European settlement. Anthropogenic protection of shorelines, construction of dunes, and stabilization of shores have interfered with the normal, constant changes of the contours of barrier islands, spits, dunes, and shorelines in response to sea levels and storms. Discharges from nonpoint sources such as runoff from roads and fertilized lands and from diffuse point sources such as landfills and septic systems have polluted the groundwater, ponds, and estuaries of the seashore. Withdrawal of groundwater and interbasin transfer have been causing an inflow of

underlying seawater that can contaminate the fresh aquifers. The reduced fresh water discharge to coastal waters may increase the salinity of adjacent estuaries and drastically change fauna and flora. Some of the highest ozone levels in the Northeast have been recorded on Cape Cod National Seashore. Expanding adjacent residential and commercial development place unsustainable demands on the natural resources of the seashore. Federal, state, and municipal holdings inside Cape Cod National Seashore and 5 million visitors per year complicate the management and the protection of natural resources.

Monitoring on Cape Cod National Seashore was initiated in 1996 and addresses five major coastal ecosystem components: (1) shoreline margins, (2) barrier islands/spits/dunes, (3) estuaries, (4) kettle ponds and freshwater habitats, and (5) maritime forests. Monitoring in each ecosystem will address management that is specifically related to Cape Cod National Seashore and other coastal parks. Currently, the Biological Resources Division and the park are in the early phases of staffing and establishing protocols. The University of Rhode Island is the primary partner of the park.

Cape Cod National Seashore has already benefited from several long-term, cooperative relations with universities that enabled researchers to sustain long-term studies, to acquire a keen appreciation for the functioning of the ecosystems on the seashore, and to provide constancy and technical integrity to the inventory and monitoring of the resources in the park. Investigators from the University of Rhode Island, University of Massachusetts, Woods Hole Oceanographic Institution, University of Wisconsin, and other universities have sustained research on the seashore for more than 30 years.

Figure 2a. Channel Islands National Park, California.

Channel Islands National Park
(Pacific Coast Biome)

Channel Islands National Park (Figs 2a–b) off the coast of California consists of five islands: Anacapa, San Miguel, Santa Barbara, Santa Cruz, and Santa Rosa. Nesting seabirds, sea lion (Family Otariidae) rookeries, and unique plants occur on the islands. Organisms exhibit the effects of a vast array of ecological factors that are expressed in changes in population dynamics such as abundance, distribution, growth rate, and mortality. Monitoring to determine the status of the resources and changes in the popu-

Figure 2b. Channel Islands National Park, California.

lation dynamics is therefore imperative and has been conducted in the park since 1992. A conceptual model of the park's ecosystems was used to identify mutually exclusive system components for monitoring. Protocols for monitoring weather, air quality (ozone), water quality, kelp forests, rocky intertidal communities, sandy beaches or lagoons, terrestrial vegetation, seabirds, pinnipeds, land birds, and visitor numbers have been established.

Monitoring in the park is conducted by its natural-resource management staff. Although only partially implemented, monitoring already revealed needs for specific research and provided useful information for planning recreation, evaluating conservation, and identifying critical issues. Information from monitoring revealed the efficacy of the removal of exotic rabbits and feral pigs on the restoration of native terrestrial vegetation and birds on Santa Barbara and Santa Rosa islands; enabled management to substantially reduce unfavorable effects by visitors on tidepools; and was instrumental in a decision to impose a statewide ban on the harvest of black abalone (*Haliotis cracherodii*) in 1993 to reverse an alarming decline of the species.

Biosphere Reserve

In 1971, the United Nations created the *Man and the Biosphere* program to provide a framework for global cooperation in finding solutions to environmental problems. The *U. S. Man and the Biosphere* program was established in 1970 at the general conference of the United National Educational, Scientific, and Cultural Organizations (UNESCO). The program provides funds for interdisciplinary research on ecosystem sustainability, global change, and biological diversity. Its mission is the exploration, demonstration, promotion, and encouragement of harmonious relations between people and their environments. Its long-term goal is a substantial contribution toward a sustainable society in the early 2000s.

Under the auspices of the U. S. Man and the Biosphere program, a site that is representative of a biogeographic province may be permanently protected from unrestricted development by being designated a *Biosphere Reserve*. Such sites are dedicated to research on the function and management of ecosystems and on ways to support sustainable, integrated development. Biosphere reserves also serve as training centers for sharing gained knowledge and as demonstration sites for the use and management of land and water resources. In the United States, designations of sites are strictly voluntary and do not affect the prerogatives, rights, and use of land and water resources by owners or administrators.

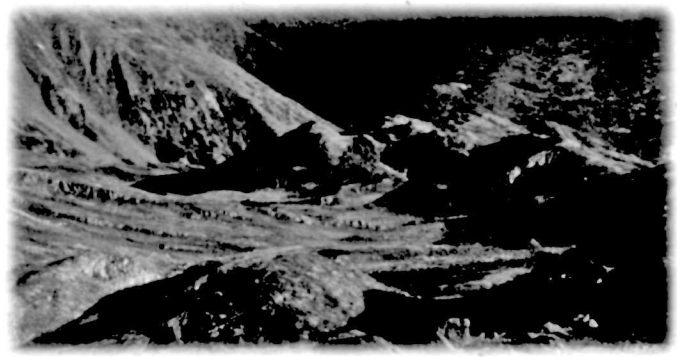


Figure 3. Denali National Park and Preserve, Alaska.

Denali National Park and Preserve
(Arctic-Subarctic Biome)

Denali National Park and Preserve (Fig.3) provides an excellent opportunity for the study of ecosystem dynamics and the effects of human activities on them. In this large, intact ecosystem are complex and diverse geological features such as Mt. McKinley, the highest mountain on the North American continent. The Alaska Range bisects the park, and a range of glacier types reflects two climate regimes that are well suited for the study of global climate change. A continental climate regime prevails north of the Alaska Range, and a transitional climate regime between humid maritime and continental climates prevails south of the range. The wilderness area encompasses about 1 million hectares (more than 2 million acres) and is the largest continuously protected area in the world. The global significance of the park was recognized with its designation as a biosphere reserve in 1976. The park is a significant Class I air quality area (a classification established by the U.S. Congress to implement the prevention of significant deterioration of air quality in specific areas, including national parks larger than 24.3 km2 [6000 acres]). Denali National Park and Preserve provides access for hikes through premier Alaskan wilderness landscapes, views of remarkably scenic vistas, and sightings of the full range of subarctic wildlife.

Denali National Park and Preserve is one of three national parks in the subarctic with a core area that is closed to consumptive use. Additional park and preserve lands created by the Alaska National Interest Lands Conservation Act of 1980 (16 U.S.C. 3101 et seq [1988], Dec. 2, 1980, 94 Stat. 2371, Pub. L. 96–487) resulted in a gradient of designations that permits various human activities around the protected core area. The combination of pristine areas and used lands presents opportunities for comparative research. As a result, monitoring techniques that are developed in Denali National Park and Preserve will be applicable to the major land-use designations throughout Alaska. At the same time, the park can provide fertile ground for testing monitoring techniques that were developed elsewhere in the subarctic and for sharing results with a range of other management agencies.

Since the establishment of the park in 1980, research has been substantial. The U.S. Geological Survey and its Biological Resources Division, the University of Alaska, and the U. S. Fish and Wildlife Service have studied bedrock and surficial deposits, glaciological topics, and long-term dynamics of large mammal communities and developed techniques for the restoration of placer-mined watersheds. Dozens of independent studies are conducted each year. The wide array of research provides a firm foundation for monitoring.

In 1992, Denali National Park and Preserve was selected for prototype monitoring of watersheds in large Alaskan parks. Thus far, the monitoring has been based on the premise that techniques to monitor basic resource attributes in one watershed can be replicated in other watersheds that exemplify the major terrestrial habitats, aquatic systems, and climatic regimes throughout the park. Field work has largely been focused on Rock Creek, a small, second order stream in the eastern end of the park. Communities that are being studied were selected based on prevalent vegetation from the lowest to the highest elevation. The structures and dynamics of vegetative and aquatic communities and the chemical and geophysical parameters, including water and soil characteristics, are being monitored at a series of permanent plots in the watershed. Co-location of plots with weather stations, small-mammal productivity grids, and bird productivity stations allow the integration of data from multiple disciplines. The applicability of protocols for the monitoring of air quality, meteorology, stream hydrology, surface water chemistry, vegetation, aquatic macroinvertebrates, passerine birds, and small mammals is under review. A protocol for the monitoring of soils will be completed in 1997.

Some attributes do not lend themselves well to a sampling design based on a small (<1000 ha, <2471 acres) watershed. Certain program elements (i.e., meteorology, glaciers, and passerine birds) have been expanded to areas beyond Rock Creek. Stream hydrology, surface water chemistry, and aquatic macroinvertebrates have been sampled extensively throughout the park to obtain information for the stratification of aquatic systems into representative categories.

Park staff and cooperating investigators are developing a variety of monitoring programs that are applicable beyond the boundaries of the watershed. These programs are for the measuring of the statuses and trends of significant resources such as birds of prey, large mammals, and various vegetation variables and wildland fires and should eventually be linked to the long-term ecological monitoring.

Great Plains Prairie Cluster
(Prairies and Grasslands Biome)

In the Great Plains Prairie Cluster, long-term monitoring was implemented in 1994. It is structured around a group of six small prairie parks in the Midwest and was the first prototype for monitoring in a group of parks. Wilson's Creek National Battlefield in southwestern Missouri serves as the headquarters for the cluster. The focus of monitoring is on the development of information to ensure sustainability of small remnant and restored prairie ecosystems, to determine the effects of external land use and watersheds on small-prairie preserves, and to evaluate the effects of fragmentation on the biological diversity of small-prairie parks.

Although each park in the Great Plains Prairie Cluster has a unique mission and represents a distinctive component of regional biotic diversity, all parks must address many similar resource management issues. In each park are high-quality prairie remnants (Fig.4) and sites that require complete restoration. The parks are restoring prairie vegetation in disturbed sites and are using prescribed fire to manage prairie communities. Because of their small sizes, the parks of the Great Plains Prairie Cluster are particularly susceptible to external threats. Agricultural, residential, and industrial developments are prominent land uses adjacent to these parks. Because small parks are often inadequately buffered against edge effects, invasion by exotic species is a pervasive problem. Pollution of waters may be the most urgent external threat. The springs, creeks and ground water of the parks are particularly vulnerable to external sources of contaminants and cannot be insulated by buffer zones or management inside the parks. Most of the parks are also faced with protecting unique habitats and managing state listed or federally listed rare and endangered species. This collection of issues represents a typical cross-section of resource concerns in prairie parks throughout the Great Plains.

Figure 4. Mixed-grass prairie and wooded draws in Scotts Bluff National Monument, Nebraska, 1996.

The Six Units of the Great Plains Prairie Cluster

Agate Fossil Beds National Monument, Nebraska, was authorized in 1965 to preserve paleontological sites with some of the world's best deposits of mammalian remains from the Tertiary Age. Two-thirds of the 1215 ha (3000 acres) consist of mixed grass prairie. The Niobrara River, originating 96.5 km (60 miles) to the west, flows through the monument. The associated wetlands provide important habitat for resident and migratory wildlife.

Effigy Mounds National Monument, Iowa, was established in 1949 to preserve earth mounds created by the mound-building culture of prehistoric Native Americans between 500 BC and 1300 AD. The steep slopes of the monument are covered primarily with eastern hardwood forests. Prairie openings on the ridge tops and bluff edges overlook the Mississippi River. Several rare plant species are associated with talus fields on north-facing slopes. The monument also includes floodplain forests along Sny Magill Creek and the Yellow River.

Homestead National Monument of America, Nebraska, was established on the original homestead of Daniel Freeman to commemorate the hardships and pioneer life of the early settlers. When the monument was established in 1936, the upper slopes of the site were severely eroded, the lower slopes were covered with heavy silt deposits, and the wood-

lands were cut over and heavily grazed. In 1939, The National Park Service began restoring native prairie through seeding and sod transplants to halt soil erosion. Today, the monument represents the second oldest prairie restoration in the Midwest, preceded only by the University of Wisconsin's Curtis' Prairie. Plant diversity in the oldest sections of the restored prairie is greater than that of some native prairie remnants in the area. Cub Creek winds through the western half of the monument.

Pipestone National Monument, Minnesota, was established in 1937 to preserve the pipestone quarries in their natural tallgrass environment, to manage the quarries, and to provide Native Americans with free access to quarry the pipestone. The most significant natural resources of the park include the Sioux Quartzite rock formation, 8.1 ha (20 acres) of associated Sioux Quartzite prairie, 64.8 ha (160 acres) of virgin tallgrass prairie (Fig. 5), and Pipestone Creek. The tallgrass prairie supports more than 250 native vascular plant species, including the federally listed threatened western prairie fringed orchid (*Platanthera praeclara* Sheviak & Bowles). The Nature Conservancy designated the Sioux Quartzite prairie type as endangered throughout its range and cites the Pipestone outcrops as one of the few intact examples of this rare community type. The combination of water retaining swales and the arid environment of the thin soils on the outcrops supports many species at the eastern edge of their range.

Figure 5. Culver's root, *Vernonicastrum virginicum* (L.) Farw., in a tallgrass prairie in Pipestone National Monument, Minnesota, 1996.

Scotts Bluff National Monument, Nebraska, was created in 1919 to protect the historic and scientific integrity of Scotts Bluff, a massive promontory that rises nearly 244 m (800 ft) above the North Platte River. The goals of the park are the restoration and maintenance of the native prairie landscape to the conditions that were seen by overland emigrants during 1840–70. The vegetation of the monument is primarily mixed grass prairie, dominated by needle-and-thread grass (*Hesperostipa comata* ssp. *comata* (Trin. & Rupr.) Barkworth), blue grama (*Bouteloua gracilis* (Willd. ex Kunth) Lag. ex Griffiths), and black-root sedge (*Carex filifolia* Nutt.). The monument also includes Rocky Mountain juniper (*Juniperus scopulorum* Sarg.) woodland in the steep upland draws, badlands, and riparian communities along the North Platte River. A black-tailed prairie dog (*Cynomys ludovicianus*) colony occurs in the park.

Wilson's Creek National Battlefield, Missouri, was established in 1960 to commemorate the battle between the Confederates and the Union on 10 August 1861. Wilson's Creek is unique as a Civil War battlefield because the historic landscape consisted primarily of presettlement savanna, prairie, and glade communities and a few farms scattered along the creek. In addition to restored prairie grasslands, the battlefield includes oak (*Quercus* spp.) woodland on the steeper slopes and some of the best examples of limestone glade vegetation in Missouri. Four populations of the federally listed endangered Missouri Bladderpod (*Lesquerella filiformis* Rollins) occur on the limestone glades. Several caves and sinkholes are on the battlefield that are associated with rare fauna, including the federally listed endangered gray bat *(Myotis grisescens)*. Wilson's Creek flows through the park.

Great Smoky Mountains National Park
(Deciduous Forest Biome)

Great Smoky Mountains National Park, which encompasses approximately 211,026 ha (521,053 acres) in the states of Tennessee and North Carolina, was selected for prototype ecological monitoring in 1992. The species richness of the flora and fauna in this park is one of the greatest in the National Park System. However, this richness is threatened by the invasions of exotic forest insects, diseases, plants, and vertebrates; by high ozone and nitrate depositions at upper elevations; by fire suppression; and by the destruction of habitats on the peripheries of the park.

Long-term monitoring in very large parks presents a special problem because of spatial and temporal scales. Therefore, monitoring in Great Smoky Mountains National Park is structured in a hierarchy of five spatial scales: landscapes, ecosystems, watersheds, communities, and species. Within these spatial levels, 13 key ecosystem processes and components identified in the park's resource management plan are being monitored. The monitoring at the landscape level primarily serves to determine the effects of air pollution and climatic change on the structure and dynamics of the spruce-fir (*Picea-Abies*) forests. At the species level, the population dynamics of the black bear (*Ursus americanus*) and the white-tailed deer (*Odocoileus virginianus*) are being monitored. The monitored components in the park also include water quality, rare plants, exotic plants and animals, and brook trout (*Salvelinus fontinalis*) populations.

As in Channel Islands and Shenandoah national parks, monitoring in Great Smoky Mountains National Park is fully operational. All research and monitoring designs were completed, and the monitoring was integrated into the park's natural-resource management.

Figure 6. View north from Little Stony Man in Shenandoah National Park, Virginia, 1990

Shenandoah National Park
(Deciduous Forest Biome)

Shenandoah National Park (Fig. 6) represents the northernmost park of the two selected parks for prototype monitoring in the eastern deciduous forest biome. The park was established by the Congress in 1924 under the same legislation that established Great Smoky Mountains National Park. The park was dedicated by Franklin D. Roosevelt in 1936. Shenandoah is approximately 79,380 ha (196,000 acres) in size and straddles the crest of Virginia's Blue Ridge Mountains for approximately 121 km (75 miles). The park is long and narrow and ranges from about 1 km to approximately 21 km (13 miles) in width. Located less than 113 km (70 miles) from the nation's capital, the park is a heavily used recreational area. Hiking, camping, horseback riding, fishing, and driving the 169-km-long (105-mile-long) historic Skyline Drive are common recreational activities.

The park is often described as a *recycled park* because the forested landscape today is the result of forest protection after the establishment of the park. In the early 1900s, chestnut blight (*Endothia parasitica*) caused widespread mortality of the American chestnut (*Castanea dentata* (Marsh.) Borkh.) that composed as much as 50 percent of some forest stands. Being one of the earliest settled areas in the country by European immigrants, much of the land

area was previously disturbed on a regular basis by farming, timber harvesting, tan bark removal, and grazing. After creation of the park, most of the land was allowed to revert to forests, although early park records indicate that many areas were reclaimed or planted by the Civilian Conservation Corps, especially along the Skyline Drive. Today the park is primarily forested and contains approximately 32,400 ha (80,000 acres) of designated wilderness.

Infestations of gypsy moths (*Lymantria dispar*) throughout the entire park in the late 1980s and early 1990s caused significant defoliation and subsequent tree mortality in many areas. Introductions of non-native pests and pathogens such as the hemlock woolly adelgid (*Adelges tsugae*), dogwood anthracnose (*Discula sp.*), and others are doing severe harm to native plant species.

Sixty peaks in the park are higher than 610 m (2000 ft). Hawksbill is the highest at 1235 m (4049 ft). These peaks are the locations of several unique northern plant communities—for example, balsam fir (*Abies balsamea* (L.) P. Mill.) that survived the last ice age intact because of the cool moist conditions at the high elevations. The mountains of Shenandoah National Park are home to more than 1400 plant species and are in a zone where southern and northern plant species mix. The park contains numerous plant species that are listed as endangered by the state and one federally listed endangered plant, the variable sedge (*Carex polymorpha* Muhl.).

Two hundred ninety-five terrestrial vertebrate species occur in the park. Of particular interest to many park visitors are the numerous white-tailed deer (*Odocoileus virginianus*) and black bears (*Ursus americana*) throughout the park. The estimated density of the bears is in excess of 1 bear/2.5 km^2 (>1 bear/square mile) and continued high bear reproduction provides adjoining counties with excellent hunting opportunities. The Shenandoah salamander (*Plethodon shenandoah*) is the only federally listed animal species that is completely endemic to the park. As a result of the extinction of the eastern peregrine falcon (*Falco peregrinus*) from DDT contamination in the 1950s, western peregrine falcons were successfully reintroduced in the park between 1990 and 1994. The first known successful, naturally reproducing pair of birds in the mountains of western Virginia was discovered in the park in 1994.

Because of the geologic structure of Shenandoah National Park, the mountain soils contain minimal acid buffering capacity. In close proximity to the high population centers of the Northeast and industrial centers of the Ohio River valley, the park is subjected to some of the highest levels of acid deposition in any of the parks in the United States. The effects of acidification on stream water, fishes, soils, and plants in the park have been documented.

Approximately 50 streams in the park contain naturally reproducing populations of the native brook trout (*Salvenlinus fontinalis*). The trout are the primary focus of visiting anglers, although 29 other fish species also occur in the park.

The I&M Program in Shenandoah National Park is focused on the monitoring of populations of selected species, forest communities, aquatic communities, and hydro-geochemical processes. Although not a part of the I&M Program, the monitoring of air quality in the park by the Air Resources Division of the National Park Service is a critical link to the monitoring of natural resources.

The I&M Program in Shenandoah National Park is considered operational, and all funding is included in the park's base funding. Although operational, several monitoring protocols are still being developed by park staff through cooperative agreements or contracts. The I&M staff moved into a new state-of-the-art facility in October 1995. Continued refinement of existing protocols is underway and parkwide inventories are continually being updated by I&M staff.

Virgin Islands - Southern Florida Cluster
(Tropical-Subtropical Biome)

The Virgin Islands-Southern Florida Cluster—created in 1996—consists of three park units with remarkable terrestrial and marine biological diversities in the Caribbean Sea and southern Florida: Buck Island Reef National Monument, Dry Tortugas National Park, and Virgin Islands National Park. Virgin Islands National Park serves as the lead park for the cluster.

The magnificent marine resources include Buck Island's barrier reef and numerous fringing reefs off St. John. The coral reefs and nearby seagrass beds support a high diversity of fishes, sea turtles, and other marine organisms. Buck Island is one of the most significant nesting area of hawksbill sea turtles (*Eretmochelys imbricata*) under United States jurisdiction and one of only three known areas of concentrated nesting by this species in the Caribbean Sea. The federally listed threatened green sea turtle (*Chelonia mydas*) and the federally listed endangered hawksbill sea turtle also nest on the beaches of St. John.

Forests on St. John and Buck Island represent remnants of the formerly widespread tropical dry forest ecosystem in the Caribbean Sea and are the only forests of this kind that are under the protection of the United States. Most of the remaining dry forests on other islands in the area are vulnerable to development. The diversity of native plants in the forests on St. John is unusually high. Extensive clearing of the vegetation during the plantation era , intensive grazing by livestock before the establishment of the park, and the introductions of several exotic plants did not eliminate the native plant species but changed their relative abundances. The dry forests on Buck Island and St. John are secondary forests that have been recovering under the protection of the National Park Service. However, wooded areas in some parts on St. John may be remnants of the original forest.

More than 800 species of vascular plants have been identified on St. John. One species is on the federal list of endangered species, two other species have been proposed for placement on the list, and several species are rare. One endemic plant on Buck Island is also listed as endangered by the Federal Government.

Recent studies revealed a high density of warblers (Family Emberizidae) on St. John. The density is attributed to the relatively intact forest that provides habitat that no longer exists on most other Caribbean islands. Virgin Islands National Park may well be the only remaining significant wintering area under the jurisdiction of the National Park Service for migratory warblers.

Dry Tortugas National Park in Florida comprises an area known as the Dry Tortugas Banks and was formerly the Fort Jefferson National Monument built in 1846-66 to help control the Florida Straits. The outstanding natural resources of the park are significant coral formations; fishes and other marine organisms; a sooty tern (*Sterna fuscata*) colony that in 1908 was nearly decimated by egg collectors; the only colonies in the continental United States of a frigate bird (*Fregata* spp.), the masked booby (*Sula dactylatra*), the sooty tern, and the noddy (*Anous* spp.) tern; and a great variety of passerines and birds of prey that pass through the area during spring and fall migrations.

The marine environment of Dry Tortugas National Park is less disturbed by anthropogenic activities than any other coral reef ecosystem in North America. The reefs consist of a full complement of Caribbean coral species, some of which are rare elsewhere. The diversity—represented by 442 fish species—may be unsurpassed on the Atlantic Coast of the United States.

The monitoring in the Virgin Islands-Southern Florida Cluster is designed to expand existing and prior monitoring in the parks and to integrate them into a systematic, comprehensive program. The major emphasis is on monitoring coral reefs, marine fish communities, water quality, and forests.

Inventories of Natural Resources

Inventory Overview

Since 1992, the I&M Program has funded 380 inventories and verified species lists from 95 park units. Progress in taking inventories of bibliographies, base cartography, vegetation, and soils has been significant. Baseline assessments of water quality and geology in all natural resource parks also were funded. The assessment of baseline water quality was funded jointly with the Water Resources Division of the National Park Service.

Twelve natural resource data elements are the core set of the minimum information for park management, planning, and natural resource protection. The I&M Program must complete the basic resource data sets for each natural resource park unit. For cost effectiveness and quality control, most of the inventories are done by other agencies under national-level contracts and cost-sharing arrangements. Specialized inventories of invertebrates or fossils, for example, are the responsibility of parks.

Park priorities for each separate resource inventory were initially developed during 1993. Plans are now underway to reconsider and update those priorities because of the completion of some inventories by some parks; the need for more explicit information about sensitive species and geology data; a better understanding of the linkages among inventories; new activities, threats, and issues that increased the urgency of some inventories; and new opportunities for leveraging to complete more inventories with existing funds.

A collection of six fact sheets about inventories in the I&M Program are provided here. The fact sheets were written by various staff of the Natural Resource Information Division. Hard copies were distributed to various entities of the National Park Service, including all parks with significant natural resources. The fact sheets were also posted on the Natural Resource Bulletin Board and on the Natural Resources website of the National Park Service. Each fact sheet provides the name and address of at least one person who may be contacted for further information about a specific topic.

Baseline Water Quality

Status and Trends

Baseline Water Quality Data Inventory and Analysis Reports are being prepared for all units of the National Park System with significant water resources. The reports provide parks with complete inventories of all water quality data collected in and near the parks and stored in the STORET national water quality database of the U. S. Environmental Protection Agency (EPA). Each report features descriptive statistics and graphics of central tendencies and trends in annual, seasonal, and period-of-record water quality. Also provided are results from comparisons of water quality in parks with relevant national water quality criteria by EPA and Level I water quality parameters of the NPS-75 Guideline: *Natural Resources Inventory and Monitoring Guideline*. The entire report (text, tables, graphics) and all databases (water quality parameter data; hydrography; water quality station; water gage; National Pollutant Discharge Elimination System permit; drinking water intake; and water impoundment locations) are provided in analog and digital format to encourage additional analysis and incorporation into park geographic information systems (GIS). Copies of Baseline Water Quality Data Inventory and Analysis Reports are available from the National Technical Information Service of the Department of Commerce and from the NPS Technical Information Center.

Background

Good water quality in the parks is imperative to the persistence of natural aquatic communities and to the consumptive and recreational use of water by visitors. Ensuring the integrity of water quality in parks, therefore, is fundamental to the mission of the National Park Service. However, a recent report by the General Accounting Office identified water quality impairment as one of the greatest threats to park resources. As a consequence, parks frequently collect water quality data. Sound science and public

policy, however, require an assessment of previously collected data before the collection of new data. The assessment can improve the design of further collections, avoid duplication, and facilitate comparisons with baseline data. To assist parks with evaluating water quality, the Inventory and Monitoring Program in concert with the NPS Water Resources Division initiated the *Baseline Water Quality Status and Trends Project* in 1993.

Partnerships

Implementation of the Baseline Water Quality Status and Trends Project is a joint public-private sector initiative involving Horizon Systems Inc.; the Colorado State University; the NPS Inventory and Monitoring Program and Water Resources Division; the EPA; and numerous other federal, state, and local government agencies that store water quality data in the EPA STORET database.

Program Status

As of September 1996, 60 Baseline Water Quality Data Inventory and Analysis Reports were completed and sent to parks. Reports for all parks should be completed by late 1998.

Bibliographic Database

The comprehensive inventory of parks with significant natural resources began with surveys, cataloging, and archiving of information from all the natural resource studies in parks. All historical scientific material including rare event records, maps, photographs, manuscripts, and specimen collections is incorporated into an automated database.

Standards and Products

The gathered information will be used to produce a data theme layer for each of the park units in the program. Each park unit received a ProCite database with a thesaurus of keywords and descriptors and the procedures for keeping the information current. The database will be kept and maintained at the park unit to ensure accessibility by managers. Upon completion, the databases from all parks will be made available in a central system that will be accessible by all authorized individuals.

Partnerships

Data entry and data conversion are proceeding on schedule under arrangements with the Colorado State University, Idaho State University, University of Northern Arizona, Pennsylvania State University, University of Hawaii, and Rhode Island State University. The North Carolina State University is participating in the coordination of the project.

Program Status

As of December 1996, the databases for all parks in the Southwest and Alaska were complete; databases for parks in the Rocky Mountain and Colorado Plateau areas were nearing completion; and data entry for parks in the West and Southeast will be completed in 1996. Trained data entry teams began entries in New England, the mid-Atlantic, and the Midwest in 1996.

Base Cartographic Data

The systematic monitoring of natural resources requires park-specific maps of surface features and boundaries. Basic cartographic products for each park are at a 1:24,000 scale in digital format that is suitable for import into GIS. Specifically, the basic cartographic data products are:

Digital elevation models - georeferenced arrays of regularly spaced elevations or three-dimensional models of the Earth's surface.

Digital raster graphics - scanned and georeferenced images of the United States Geological Survey topographic maps.

Digital line graphs - separate layers or coverage of linear features on topographic maps, i.e., hydrography (water), hypsography (contour lines), political boundaries, and transportation features such as railways, oil pipelines, and roads.

Digital orthophotos - map-view digital images of aerial photographs from which displacements caused by the camera and the terrain were removed.

Partnerships

The cartographic products are made possible by a cost-sharing arrangement among the National Park Service, the U. S. Geological Survey, other federal agencies, and the states of California, Florida, and New York.

Program Status

Since 1993, complete or partial base cartographic data have been acquired for 130 parks with significant natural resources. Acquisition of data for the remaining such parks is expected by the year 2000.

Geologic Mapping

Maps of selected geophysical features, including bedrock and surficial geology, are produced for the baseline inventory of natural resources in each park. Much of this information can be captured with existing geologic maps (surficial and bedrock), inventories, and bibliographies. Whenever possible, inventories will include the development of maps in GIS-suitable formats.

Partnerships

The I&M Program is completing geology maps by national agreements with other federal agencies, most notably the U.S. Geological Survey. In 1995, scientists of the survey assisted park managers with defining types of geologic mapping and scales for park management. Regional teams of the survey acquainted park personnel with the quality and availability of geologic mapping.

In a partnership with the American Association of State Geologists, information will be gathered from the files of state agencies and compiled into an automated ProCite database of geologic maps, documents, specimen collections, and other related information.

Program Status

Initially, an inventory of geologic information was made of parks with general management plans. Because field mapping of bedrock and surficial geology data theme layers is extremely costly, data must first be obtained from other sources. Database searches were completed in all three regions of the U.S. Geological Survey. Data files were downloaded from GEOINDEX and GEOREF databases and converted into a format that can be uploaded into park-specific ProCite files. Data entry and data conversion are proceeding on schedule under an arrangement with the Colorado State University.

Pilot mapping of surficial geology in the southern portion of Zion National Park began in 1996 in a cost-sharing arrangement with the Utah Geological Survey.

Soil Mapping

Maps of selected geophysical features such as soils are being produced for each natural resource park. The National Park Service is working with the Natural Resource Conservation Service to complete Order 3 soil surveys in all parks, except where more detailed surveys are required for park management.

In addition to the baseline soil survey data, a primary product of the soil mapping program is a digital layer for specific park units. The soils data will be automated to provide flexibility in map design and production and to facilitate data management.

Partnerships

The Inventory and Monitoring Program is completing soil maps through national agreements with other federal agencies such as the Natural Resources Conservation Service and with private contractors. In 1995, I&M Program staff assisted parks with identifying soil mapping needs so that park objectives could be met through appropriate data collection and scale of maps. For example, special strategies are being developed in cooperation with the Natural Resources Conservation Service to handle the large-area mapping for parks in Alaska, beginning with Denali National Park and Preserve.

Program Status

The Natural Resources Conservation Service is conducting soil surveys in 18 parks and will continue to support soil mapping until the project is completed. Soil map digitization in Bighorn Canyon National Recreation Area was completed by the conservation service in 1995 at no cost to the National Park Service. Additional mapping is being conducted by contractors at Pecos National Historical Park.

Fieldwork was completed at Dinosaur National Monument, Hagerman Fossil Beds National Monument, Theodore Roosevelt National Park, in Pecos National Historical Park, Yellowstone National Park, and in the Southern Arizona Group (including the Chiricahua National Monument, Coronado National Memorial, Fort Bowie National Historic Site, Montezuma Castle National Monument, and Tuzigoot National Monument), and the delivery of the maps is expected in 1996. Field mapping will continue in the 1996 field season in Bighorn Canyon National Recreation Area, Glacier National Park, Hawaii Volcanoes National Park, Lake Mead National Recreation Area, Rocky Mountain National Park, and Yosemite National Park.

In addition in 1996, fieldwork was conducted at Craters of the Moon National Monument and in Gateway National Recreation Area, Great Smoky Mountains National Park, and Saint Croix National Scenic Riverway. Soil mapping at Bandelier National Monument is planned under a contractual arrangement similar to that in Pecos National Historical Park.

Vegetation Mapping

In cooperation with other agencies and the Federal Geographic Data Committee's Vegetation Subcommittee, the National Park Service is developing a uniform hierarchical vegetation classification standard. This national vegetation classification standard is based on a system originally developed by The Nature Conservancy through its network of Natural Heritage Programs. To allow for adjustments and refinements, the classification system, field methodologies, and map accuracy assessment procedures are being tested in representative park units across the National Park System. Field data will be maintained in the park in which they were collected to ensure their availability to managers.

Every park unit with significant natural resources will be provided with information on its vegetation. After development and testing of standards and protocols, hard-copy and digital vegetation maps will be generated. Aerial photography and remotely sensed imagery will also be acquired to support vegetation mapping, soil surveys, geologic mapping, and species inventories.

The primary product of the vegetation mapping is a digital vegetation layer. Digitizing of the vegetation data will provide flexibility in map design and production and will facilitate data management. Other products of the program include vegetation class descriptions and keys, hard copy maps, and field data analysis.

Program Status

Through a contract administered by the Biological Resources Division of the U.S. Geologic Survey, standards and protocols for the classification system

were developed in 1995. Progress has been made in developing field sampling methods and procedures for assessment of map accuracy. A completed inventory of existing data in 101 parks is providing the basis of planning for identifying the need for aerial photographs. The Inventory and Monitoring Division of the National Park Service is locating and acquiring from other agencies aerial photographs that meet the requirements and standards of this project. When necessary, contracts will be established for obtaining new imagery. The park units will be mapped in priority order, based on identified needs for vegetation information and the availability of Digital Orthophoto Quarter Quads, which serve as the cartographic basis for the mapping .

Acquisition of Photographs for Vegetation Mapping.

The acquisition of photographs through interagency agreements with the U. S. Bureau of Land Management and the U. S. Forest Service is complete for the following park units: Arches National Park, Colorado National Monument, Canyonlands National Park, Capitol Reef National Park, Glen Canyon National Recreation Area, Natural Bridges National Monument, Bryce Canyon National Park, Rainbow Bridge National Monument, Great Sand Dunes National Monument, Bent's Old Fort National Historic Site, Florissant Fossil Beds National Monument, and Zion National Park. Reprints of photographs were obtained for the Devils Tower National Monument, Great Smoky Mountains National Park, Jewel Cave National Monument, and Mount Rushmore National Memorial. In 1995, photos were acquired under contract for the Fort Laramie National Historic Site (specific areas of interest to the park), Scotts Bluff National Monument, Agate Fossil Beds National Monument, and Tuzigoot National Monument. Pphotographs for the Devils Tower National Monument, Glacier National Park, Rocky Mountain National Park, Sunset Crater Volcano National Monument, Congaree Swamp National Monument, Walnut Canyon National Monument, and Wupatki National Monument and Theodore Roosevelt National Park were acquired in 1996. The acquisition of photographs for Glacier Bay National Park and Preserve and Klondike Gold Rush National Historical Park through partnerships with the U. S. Forest Service, Biological Resources Division of the U.S. Geologic Survey, and National Aeronautic and Space Agency in Alaska is also planned; additional imagery and maps will be acquired under contract.

Pilot Projects

Pilot projects are being conducted in several parks to test the new classification system, field methodologies, and procedures for assessing map accuracy. A summary of the accomplishment in each pilot project is as follows.

Assateague Island National Seashore

Existing aerial photographs (1:12,000) were used on Assateague Island. Field sampling in 114 plots in summer 1995 indicated 25 vegetation types. Photo interpretation was also completed and provided more detail than the cover classes. The classification, vegetation type descriptions, and field key for Assateague Island National Seashore were delivered to the National Park Service by the contractor.

Tuzigoot National Monument

New aerial photography (1:6,000) was completed in fall 1995. Analysis of field sampling in 35 plots indicated 19 vegetation types. Photo interpretation and automation were completed. The classification, vegetation type descriptions, and field key were delivered and are in review.

Scotts Bluff National Monument

New aerial photography (1:12,000) and field sampling were completed at the monument in 1995. Analysis of the vegetation in 100 plots indicated 18 vegetation types. Sampling accuracy was assessed at 150 sites. The classification, vegetation type descriptions, and field key were delivered.

Great Smoky Mountains National Park

Existing aerial photography will be used for the initial sampling in the park. Existing aerial photography and related data to conduct the pilot in the park were reviewed in 1995 and will be the foundation of planning the field sampling.

Vegetation Mapping In Alaska

Mapping of 22 million hectares (54 million acres) of vegetation in the 15 national parks in Alaska is coordinated by the Alaska Regional Office. It is conducted independent of vegetation mapping in parks

elsewhere in the United States, primarily because of the large spatial scale. In national parks in Alaska, vegetation is mapped from satellite imagery, not from aerial photographs. Initially, FirePro field data collected during vegetation mapping over the years in Denali, in Gates of the Arctic, Katmai, Lake Clark, and Wrangell-St. Elias national parks were automated. In Fiscal Year 1996, imagery for vegetation in Denali and Lake Clark national parks and preserves was acquired. Now, vegetation mapping is being conducted in Lake Clark, Noatak, and Wrangell-St. Elias national parks and preserves and in Cape Krusenstern National Monument. A major focus is on acquisition of new imagery for vegetation mapping in other parks in Alaska.

The National Vegetation Classification System by the Nature Conservancy and the Biological Resources Division of the U. S. Geological Survey is also being adapted for Alaska and field tested in one or more of the national parks in Alaska.

Activities in 1996

Priorities in the 1996 field season included:

- continued acquisition of aerial photos for priority parks
- continued field testing of procedures and methods
- review of products from pilot projects.

Field sampling, photo interpretation, vegetation description, and data automation are planned for additional pilot projects in Acadia, Joshua Tree, Yosemite, and Voyageurs national parks and in Congaree Swamp National Monument. Others will be initiated when funding is available.

Training Opportunity

The Biological Resources Division of the U.S. Geologic Survey contracted The Nature Conservancy to conduct a workshop on the standardized national vegetation classification system. The initial class will be held for National Park Service personnel but will probably include representatives from the U. S. Bureau of Land Management, Bureau of Reclamation, Department of Defense, Environmental Protection Agency, U. S. Fish and Wildlife Service, U. S. Geological Survey, and Biological Resources Division of the U.S. Geologic Survey. The purpose of the class is to explain the classification system; identify the data that are necessary to use the system; describe methods for acquiring aerial photographs from other agencies for sampling and analysis of data; and conduct field exercises in gathering data, analyzing results, and producing keys and other products.

Monitoring and Status of Natural Resources

Monitoring Program Overview

National parks have inspired, awed, and brought enjoyment to countless millions throughout this century. In recognition of these national treasures, the Congress gave the National Park Service the mandate of preserving, protecting, and maintaining the health and integrity of park resources for the enjoyment, education, and inspiration of this and future generations. But management of the national parks is an extremely complicated and difficult task. Park ecosystems are complex and vary tremendously over time and space. Managers must be capable of determining whether the changes they observe in park resources are the result of natural variability or the effects of anthropogenic activities. If the latter, then managers must understand park ecosystem processes and mechanisms well enough to know what actions are needed to restore natural conditions. Such knowledge and insights can be obtained only through comprehensive, long-term research and monitoring. Short-term, parochial investigations will not provide the needed knowledge and understanding. In the words of Waldo Emerson, *The years teach much which the days will never know.*

Part III of this report are examples of how prototype ecological monitoring provides the long-term knowledge and understanding that park managers need to protect park resources. Examples include geophysical and biological park resources. In some cases, the examples draw on information that existed before the park began prototype monitoring. Not all of the monitoring programs are at the same stage of implementation. But all hold the promise of enhancing the management and protection of park resources.

Water Quality

Water Quality in Great Smoky Mountains National Park, Tennessee and North Carolina

Water quality affects biota and ecosystem processes in the terrestrial environments through which the water passes. Studies during the past decade demonstrated that the streams in Great Smoky Mountains National Park have extremely low solute concentrations and very low conductivity and are therefore highly susceptible to acidification. Other studies revealed that the park receives higher levels of atmospheric nitrogen and sulfur depositions than other similarly forested ecosystems in North America and Europe. For these reasons, the park monitors the trends in water quality and atmospheric deposition, the variation in water quality among ecosystems across the landscape, and relations between ecosystem processes and water quality.

Water quality in the park is monitored in a high-elevation (1738 m, 5700 feet) stream that drains a spruce-fir (*Picea-Abies*) watershed and in 70 additional sites that represent the entire range of ecosystem conditions in the park. In the high-elevation stream, no trend in any stream-chemistry parameter was apparent during the past 5 years except in calcium, which may have been increasing. Sulfate concentrations in streams are relatively low, except where geologic sources of sulfate, primarily from the Anakeesta Formation, are important. Stream nitrate concentrations are high across the high elevations of the Park. The pH is usually below 6.0 in many stream reaches at high elevations. Across the elevation gradient, pH and the acid neutralizing capacity decrease with increasing elevation and nitrate increases with increasing elevation. Sulfate does not correlate with elevation.

Water Quality in Shenandoah National Park, Virginia

Shenandoah National Park along the crest of the Blue Ridge Mountains in Virginia is the location of the headwaters of three river drainages. Among the many resources of interest to park visitors are the streams that originate high on the ridges and often tumble down the mountain sides in spectacular waterfalls. These cool, clear, and highly oxygenated streams support excellent populations of brook trout (*Salvelinus fontinalis*) that attract many anglers to the park.

As a result of high air pollution levels, atmospheric deposition in Shenandoah National Park is the greatest threat to the protected mountain streams. Acid precipitation, a type of atmospheric deposition that is primarily linked to fossil fuel combustion, is lowering streamwater pH in some extremely sensitive streams. The low buffering capacity of a large percentage of soils in the park provides limited protection from acid depositions. Because of the sensitivity of the streams in the park to acidification, long-term monitoring of stream water chemistry and hydrogeochemical processes is a major component of the I&M Program in the park.

Monitoring of water quality in Shenandoah National Park began as cooperative research with the University of Virginia in 1979 and became known as the *Shenandoah Watershed Study* or SWAS. Continued interest and support for research on watersheds and monitoring lead to further development of SWAS. Except for the collection of quarterly water samples and water quality data associated with biological monitoring, the University of Virginia collects, maintains, and interprets the hydrochemical data. Hydrochemical data are now routinely collected from sites throughout the park. Measured are the quantity and chemical composition of precipitation in 2 sites, the chemical composition of stream water in 14 sites, and stream-water discharge in 5 sites.

As a result of the cooperative research and monitoring associated with the Shenandoah Watershed Study, 89 publications including theses, dissertations, a book chapter, journal articles, and miscellaneous reports have been produced to date. Analyses of trends in ion composition of Deep Run and White Oak Run stream waters through 1987 revealed a significant positive trend in sulfate concentrations and a significant negative trend in acid neutralizing capacity.

During the mid-1980s, defoliation by gypsy moths (*Lymantria dispar*) spread from the north to the south of the park and affected water quality. By the early 1990s, the initial wave of the defoliation had moved through the entire 121-km (75-mile) length of the park, and stream-water nitrate concentrations had increased significantly as a result of the defoliation. Nitrate concentrations in surface waters are normally low because of the demand for nitrogen as a nutrient by growing forests. However, as a result of defoliation, nitrate concentrations in the stream water increased. Because nitrate is derived from anthropogenic emissions and from natural microbial fixation of nitrogen, the increase in nitrates caused difficulty in interpreting nitrate trends. Without previous baseline data on nitrate concentrations, short-term research of nitrate pollution would have been based on artificially elevated concentrations. Ongoing monitoring will probably reveal the recovery of the baseline nitrate levels.

In 1992, research funded by the Natural Resource Preservation Program of the National Park Service was initiated to investigate factors that influence fish distributions in Shenandoah National Park. The project known as the *Fish in Sensitive Habitats* (FISH) project was initiated as a result of the documented increase in stream water acidity. Although the final report is not complete at this time, the study revealed that lowered pH affected two fish species. During runoff episodes when pH values decreased to 5.0, mortality of brook trout fry was significant. Effects on adult blacknose dace (*Rhinichthys atratulus*) were sublethal at chronic pH values of 6.0. The primary cause of mortality and stress was aluminum toxicity from increased aluminum availability at the lower pH levels.

The Dynamic Glaciers of Denali National Park and Preserve, Alaska

One sixth or about 405,000 ha (1 million acres) of Denali National Park and Preserve is covered by glacial ice. The types of glaciers and the landscapes they create are diverse. Some of the largest alpine glaciers in North America are in this park. Surging glaciers are also abundant throughout the park, and surges have occurred in many of them during this century. One is taking place now in a glacier on the northern side of Mt. McKinley, and based on the historical periodicity of these events, more surges are expected to occur throughout the park. Glacial activity has shaped much of the terrain in the park and created excellent recent examples of glacial landforms. The varieties of glacier types and glacial processes in the park provide a unique opportunity to study and monitor glaciers and glaciation in what is essentially a vast glacial laboratory.

Glacier Surging

The phenomenon of glacier surging is a foremost research topic. Surges are sudden and rapid accelerations of glaciers that are thought to occur when the drainage of meltwater beneath these glaciers is disrupted. The dammed subglacial water acts as a lubricant, allowing the glacier to slide downstream at speeds as much as 10 to 100 times greater than normal. Although this mechanism is widely believed to be at work in most surges, it has been proven only once. It also does not explain other curiosities, such as the fact that most surge-type glaciers seem to undergo these dramatic events with consistent frequency. Surges can last anywhere from a few months to a few years, and seem to recur at regular intervals between 10 and 100 years, depending on the glacier. This may be related in some way to climate through the growth that is needed for a glacier to reach a condition that is critical for surging, but that condition is not known. How subglacial hydraulics become disrupted is also not known.

The relation between glaciers and climate is perhaps the most relevant and pressing topic in modern research on glaciers. The indications of climatic change or global warming and its effect on the ecology of the national parks may best be detected in ecosystems at higher latitudes where the effects will probably be greater. Because of its subpolar climate and relatively undisturbed ecosystems, Denali National Park and Preserve is uniquely suited for the detection of the onset and magnitude of these changes. Signals of medium to long-term climate change should be detectable in the glaciers of the park. Changes in the relative health of these glaciers, in terms of the amount of ice that is gained or lost through time (mass balance), are indicators of the changing climatic forces that influence them.

In 1997, monitoring of glacial activity throughout Denali National Park and Preserve will be initiated to determine the regional effects of climate on the glaciers. A regional knowledge of glacier activity is valuable as a measure of the magnitude and duration of climate change. The information will aid in the interpretation of data from other studies on the effects of natural and anthropogenic climate change on the ecology in the park. The focus will be on field study of benchmark glaciers in each climatic region of the park. Most long-term monitoring will be done by remote sensing image analysis of glaciers throughout the park. Data from the benchmark glaciers will be used for verification on the ground. The data will be shared with institutions and agencies such as the U.S. Geological Survey and World Glacier Monitoring Service to expand the understanding of glacial activity and its relation to climate in North America and the world.

Glacier mass balance has been monitored in the park since 1991 when index sites were established on two of the largest glaciers--the Kahiltna Glacier that flows from the southwestern side of Mt. McKinley and the Traleika Glacier that flows from the northeastern side. These glaciers have been losing mass since the monitoring began. These data do not, however, reveal how glaciers throughout the park are responding to climate.

Studies of the Muldrow Glacier (Fig. 7), which last surged in the 1950s, are conducted in the field every summer. Data on the glacier's thickness and longitudinal profile, rate of ice flow, and the chemistry and sediment load of melt waters are collected. The data may help predict the onset of the Muldrow's next surge and will raise the understanding of the changes during a surge. The surge of the Peters Glacier west of the

Muldrow Glacier in 1986 was studied in cooperation with scientists from the University of Alaska. The subsequent publication of a paper added valuable information to the limited body of literature on surging.

A surge in a small glacier on Peters Dome near the north face of Mt. McKinley began in mid-1996 and is still underway. The surge is of particular interest because the glacier is much smaller than most glaciers that surge. The surge is monitored regularly by aerial photography and observation and may reveal information about the times of onset and termination of a surge, the amount of water that triggers a surge, and the extent to which such an amount exceeds the amount of water during different seasons.

Other studies of glaciers in Denali National Park and Preserve are of glacial histories and current glacier terminus positions. Aerial reconnaissance and photography of all glaciated areas in the park are conducted annually. Glacial histories are determined largely with mapping of glacial landforms that are indicators of previous glacial extent. At present this research is conducted by academic institutions. The involvement of the National Park Service is expected to increase soon.

Figure 7. Precise surveys are used to monitor the rate of movement of the Muldrow Glacier, Denali National Park and Preserve, Alaska, 1996.

Air Quality in Shenandoah National Park, Virginia

Good air quality is critical for the protection and preservation of the natural systems and cultural resources in national parks as well as for the enjoyment of parks by visitors. In Shenandoah National Park, Virginia, clean air is necessary to meet the mandates of the park (1) for clear views of natural and cultural environments from Skyline Drive, developed areas, and trails and (2) for the protection and perpetuation of native, rare, endangered, and relict species, habitats, and communities. Air quality in Shenandoah National Park has been monitored for more than 10 years. Donations enabled the park to expand its monitoring with excellent equipment and to measure a diversity of parameters (Table 4).

Table 4. Measured parameters of air quality in Shenandoah National Park, Virginia.

Year	Parameter	Measuring Agency or Program
1981	precipitation chemistry	National Atmospheric Deposition Program
1982	particulates	IMPROVE[a] Program
1983	ozone	National Park Service and EPA[b]
1987	visibility with transmissometer	National Park Service (part of IMPROVE)
1988	meteorology	National Park Service and EPA
1988	particulates	National Dry Deposition Network of EPA
1989	precipitation sulfur isotopes	U. S. Geological Survey
1995	low level sulfur dioxide	National Park Service
1995	nitrogen oxides	National Park Service
1995	carbon monoxide	National Park Service
1995	volatile organic compounds	National Park Service
1996	visibility with nephelometer	National Park Service (part of IMPROVE)

[a] IMPROVE = Interagency Monitoring of Protected Visual Environments

[b] EPA = U. S. Environmental Protection Agency

Total pollution levels are expected to increase in Virginia. In northern Virginia, the number of registered vehicles is 1.63 times greater than the population increase between 1980 and 1990. In Albemarle County alone, hydrocarbon emissions increased 44% between 1980 and 1987. Projections of statewide emissions in Virginia by the U. S. Environmental Protection Agency show that even with the implementation of the 1990 amendments to the Clean Air, emissions will increase.

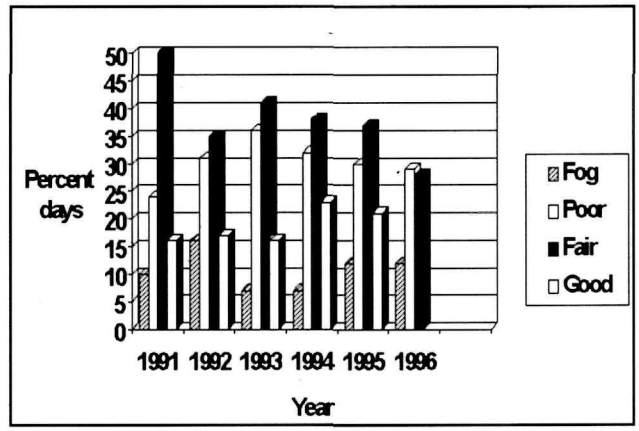
Poor visibility is indeed the most frequent complaint by visitors to Shenandoah National Park. The ability to see long distance and atmospheric clarity have diminished by an annual average of 60% since the late 1940s. High humidity, frequent air stagnations, and region-wide pollution impair visibility in Shenandoah National Park. The Federal Land Manager's 1990 *Federal Register* notice referenced a letter from the Department of the Interior to the U. S. Environmental Protection Agency, dated 14 November 1985, that stated scenic views in the park were impaired by anthropogenic pollution more than 90% of the time (Figs 8a-b). In 1996, visitors could see distances of only 10 miles or less 29% of the time (Fig. 9). Good visibility into distances of more than 30 miles prevailed 31% of the time, which was a significant improvement from previous years. Only long-term monitoring can reveal whether weather patterns in 1996—an unusually wet year—caused unusually good visibility or long-term improvements began.

Figure 8a. Clear air in Shenandoah National Park, Virginia, 1996.

Light extinction is another measure of visibility and is caused by particulate matter in the air. The effect of extinction is analogous to a sheer curtain in front of a window--clarity and color of a vista become muted. A comparison of sulfur emissions and extinction during 1940-80 revealed that in the Southeast, light extinction increased with emissions. The Interagency Monitoring of Protected Visual Environments has monitored particulate levels in Shenandoah National Park since 1982. In the East, sulfate particles were identified as the primary cause of light extinction and have been increasing during summer and fall in the park at a rate of 2%-3%/year during 1982-95. Before 1990, an upward trend of around 5%/year was noticed, but since 1990, a constant trend of sulfate concentrations has been observed.

Figure 8b. Air pollution in Shenandoah National Park, Virginia, 1996.

Figure 9. Range of visibility (percent days; May - October) in Shenandoah National Park, Virginia, 1991-1996.



Coral Reefs in Virgin Islands National Park

Most coral reefs around the islands of St. Croix, St. John, and St. Thomas in the U. S. Virgin Islands are shallow fringing reefs that parallel the islands' coastlines. Many are true coral reefs on frameworks of coral skeletons that have been deposited over thousands of years. Elsewhere, coral reef organisms grow on submerged boulders and rock ridges near shore. Submerged bank reefs—some with spur and groove formations—also occur in deeper water. Reefs grow on the walls of Salt River Canyon, a drowned river valley (i.e., an estuary) on the northern shore of the St. Croix island. Extensive barrier reefs with well-defined lagoons do not occur around St. John and St. Thomas. However, Buck Island Reef National Monument north of the St. Croix island is named for a barrier reef. In some locations, fringing reefs extend from rocky headlands at bay entrances. They cut off back-reef areas and may lead to the formation of salt ponds. More than 40 species of scleractinian corals have been found on reefs of the U. S. Virgin Islands. The total cover of living coral on the reefs is typically less than 40% but more in some reef zones.

Coral reefs in the U. S. Virgin Islands are facing the same pressures as reefs elsewhere in the Caribbean. Hurricanes and other major storms, higher than normal water temperatures, coral diseases, boat anchors and boat groundings, careless land use, dredging, pollution, and excessive fishing cause reef deterioration. Within the last 15-20 years, the amount of live coral declined, and the abundance of algae increased. The increase in algae probably reflects the increase in substrate from the death of the coral and the inability of the herbivorous fishes and sea urchins to keep the algal growth in check.

Perhaps the most conspicuous change on the coral reefs in the U. S. Virgin Islands during the last few decades is the decline in elkhorn coral (*Acropora palmata*), the primary reef-building coral in the Caribbean. Elkhorn coral forms shallow crests near the water's surface that create physical barriers to ocean waves and reduce coastal erosion. In the late 1970s, the elkhorn zone on the eastern end of the Buck Island's barrier reef was described as perhaps the best in the Virgin Islands, and entire stands and isolated, impressive colonies of this species were still seen around Buck Island and St. John. Only few large, living colonies can be found now. The primary culprit seems to have been white band disease, first observed in the U. S. Virgin Islands in the early 1970s. The disease, which has yet to be related to pollution or any other human activity, generally kills the colonies it infects, although occasionally patches of live tissue survive.

At Buck Island, white band disease and physical destruction from Hurricane David and Tropical Storm Frederic in 1979 reduced the live cover of elkhorn from 85% to 5%. Hurricane Hugo in 1989 caused further declines. Numerous new colonies of this species that had developed from sexually produced larvae and from branch fragments were seen at Buck Island in summer of 1995. A few months later, Hurricanes Marilyn and Luis destroyed several of them.

In 1987, a study of 50 elkhorn coral colonies in Hawksnest Bay off the northern shore of St. John indicated that only 10 had remained undamaged 7 months after initial observation. Heavy ground seas and damage from snorkelers and boats were responsible for the observed decline. The elkhorn coral population in the bay seemed to be recovering when it suffered damage from Hurricanes Luis and Marilyn in September 1995. Although little quantitative information exists, staghorn coral (*Acropora cervicornis*) and finger coral (*Porites* spp.) also seem to have declined substantially around the the U. S. Virgin Islands.

During 1988-96, the U. S. Virgin Islands were hit by 4 hurricanes and numerous tropical storms. Some of the most severe damage was associated with Hurricane Hugo in 1989. This category 4 storm flattened reefs off the southern side of Buck Island and created widespread areas of rubble. Transport of rubble and coral resulted in movement of the southern reef crest 30 m (98 ft) toward the island. In contrast, little damage from Hurricane Hugo was noted off the northern shore of the island.

In long-term monitoring sites around St. John and Buck islands, coral cover that was initially less than 30% dropped by 8%-18% after Hurricane Hugo. The dominant coral species, *Montastrea annularis*, declined about 35% in Lameshur Bay. Studies revealed that in spite of coral recruitment, total coral cover has not substantially recovered. Decreases in the amount of living *M. annularis* are of particular concern because this is now the major reef-building species in the Caribbean.

During Hurricane Hugo, gorgonians and sponges were torn apart and ripped from their bases. Many collected in sand channels and other depressions on the reefs, and piles of them washed up on the beaches. Along long-term transects in Lameshur Bay, the number of species and sizes of colonies of gorgonians and sponges increased between 1991 and 1992. Although the number of sponge colonies decreased slightly during this period, gorgonian colonies increased. These results may indicate ongoing recovery of the sponge and gorgonian communities from Hurricane Hugo.

In September 1995, two hurricanes, Luis and Marilyn, hit the U. S. Virgin Islands within 10 days. Reefs off the northern side of Buck Island and the southern side of St. John suffered severe damage. Although damage was conspicuous in Lameshur Bay, the percent live coral cover along the permanent study transects did not decrease, perhaps because of the uneven nature of hurricane damage or because so little coral remained to be damaged. In some bays on the northern shore of St. John, more physical destruction was associated with boats that broke loose and dragged across coral colonies than from the storm itself. Large coral colonies, some perhaps more than 100 years old, were split into pieces by boat keels. On the long-term study site in Newfound Bay, little damage from Hurricane Marilyn was observed, and total living coral cover has remained at about 23% for the last 6 years.

Although the physical destruction from hurricanes and white band disease produced the most drastic changes of the U. S. Virgin Islands reefs, other stresses are also taking their toll. Probably the greatest potential threat to the reefs is sedimentation associated with runoff from coastal development. The steepness of the islands exacerbates this problem. A theoretical study of sediment runoff indicated that reef distribution around St. John is a function of watershed size, bay exposure and bathymetry, distance from sources of land-derived sediments, and storms. Cores from large coral colonies off St. John give some clues about the sedimentation regime before, during, and after extensive clearing of vegetation for sugar cane plantations in the eighteenth and nineteenth centuries. Growth data from these cores suggest gradual declines during the last 200 years. Limited data from cores in Hawksnest Bay indicate that upland construction in the early 1980s led to significant decreases in annual growth rates, presumably a response to increased sedimentation rates. Current development of private land inside and adjacent to boundaries of Virgin Islands National Park and construction of new roads increased the flow of sediment into nearshore waters. Scientists of the Colorado State University are currently conducting research on this issue.

Black band disease has been reported on several species of hard corals, including *Montastrea annularis* and *Diploria strigosa*, around St. John and at Buck Island Reef National Monument. This disease has not been conclusively linked to human activities. One researcher found that less than 1% of the corals in Lameshur Bay were infected. Although the effects of black band disease are less serious than effects from other stresses, it should not be ignored because it infects primary reef building species. Like coral bleaching, which was observed in the the U. S. Virgin Islands in 1987 and 1990, this disease seems to correlate with higher seawater temperatures. If algae grow on the bare substrate, which becomes available after the infected coral tissue dies, recolonization by hard corals and other reef organisms will be inhibited.

The abundance of algae on the long-term transects in Lameshur Bay has fluctuated between 2% and 32%; the highest amounts were observed in fall of each year. Increases in algal biomass result from nutrient input and reductions in herbivory, but no direct correlations have been documented. In spite of some excellent early studies on herbivorous fishes in Lameshur Bay, further research is needed to unravel the complex relation between herbivorous fishes and invertebrates and the species of algae (primarily *Dictyota*) that predominate on the reefs around St. John. Some fishes and sea urchins graze on algae and open up new space on the reef for colonization by non-algal reef organisms. How the decline in predatory fishes has affected these herbivores is not clear.

The difficulty with the protection of natural resources in national parks increases with the number of visitors. Virgin Islands National Park attracts close to 1 million visitors a year, most of which arrive on cruise ships or smaller boats. A single anchor drop from a cruise ship in 1988 led to the destruction of almost 300 m^2 (3230ft^2) of reef. Monitoring at this site reveals no significant recovery of hard coral 8 years later. A survey of 186 boats in 1987 revealed that 32% were anchored in seagrasses and 14% in coral communities. About 40% of the anchors in coral and 58% in seagrass beds caused damage. Small boats continue to run aground on reefs in Buck Island Reef National Monument and Virgin Islands National Park. The installation of mooring buoys and limits on the size of vessels allowed in park waters lessened the pressure on these reefs, but in some areas, little coral is left to protect.

Coral reefs are highly diverse and complex ecosystems. The understanding of the ecological processes in and among reefs and associated mangrove and seagrass bed systems is limited. Interactions among these systems include transfer of nutrients and the movements of organisms (primarily fishes). Seagrass beds and prop roots of red mangroves (*Rhizophora mangle*) provide critical feeding and nursery areas for reef fishes. The degradation of reefs in the the U. S. Virgin Islands is a result of a combination of stresses that sometimes acts synergistically. Without doubt, the reefs have suffered serious declines from hurricanes and white band disease. The hurricanes scoured out large portions of the seagrass beds around St. John and, in combination with a severe drought in 1994-95, killed extensive mangrove areas. The full effects of the changes on the associated reefs are impossible to quantify.

Sedimentation, excessive fishing, and damage from boats continue to degrade the U. S. Virgin Islands reefs. On reefs off the northern coast of Jamaica, similar stresses caused a drastic, probably irreversible, decline in the amount of live coral cover to less than 5% and increases in algal biomass of as much as 90%. Only time will tell whether the amount of living coral on the reefs in the the U. S. Virgin Islands will drop to these levels and lead to further increases in algae. Future hurricanes combined with anthropogenic stresses may tip the balance such that recovery becomes impossible.

Prairie Restoration on Wilson's Creek National Battlefield, Missouri

At the time of the Civil War, the rolling hills surrounding Wilson's Creek in Missouri were covered with a mosaic of prairie, savanna, and limestone glade vegetation. The restoration of this historic landscape at Wilson's Creek National Battlefield is a long-term goal. During the early 1990s, park resource specialists planted almost 81 ha (200 acres) of former agricultural land with native prairie grasses and forbs. Because the seed of many forb species is scarce and expensive, effective planting techniques are important. The 19 species of prairie forbs that were planted in 1992 (Table 5) are being monitored, and the information will be used to assess planting methods, to develop future management for each area, and to evaluate the establishment potential of individual species.

Table 5. Establishment of prairie forbs 1 year after planting, Wilson's Creek National Battlefield, Missouri.

Common Name	Species Scientific Name	Establishment Rate (1993 density/1992 planting rate)
lanceleaf tickseed	*Coreopsis lanceolata*	68.0%
pinnate prairie coneflower	*Ratibida pinnata*	21.0%
wild quinine	*Parthenium hispidum*	21.0%
sweet coneflower	*Rudbeckia subtomentosa*	17.0%
wildbergamot beebalm	*Monarda fistulosa*	14.0%
compassplant	*Silphium laciniatum*	13.0%
largeleaf wild indigo, white wild indigo	*Baptisia leucantha*	6.4%
prairie rosinweed	*Silphium terebinthinaceum*	6.1%
purple coneflower	*Echinacea* spp	5.3%
stiff goldenrod	*Solidago rigida*	3.9%
purple prairieclover	*Dalea purpurea*	2.6%
bigfruit or Missouri eveningprimrose	*Oenothera macrocarpa*	0.9%
western silver aster, silky aster	*Aster sericeus*	0.7%
azure blue sage	*Salvia azurea*	0.6%
Missouri orange coneflower	*Rudbeckia missouriensis*	0.3%
Missouri orange coneflower	*Eryngium yuccifolium*	0.1%
tall gayfeather	*Liatris aspera*	0.06%
cattail gayfeather	*Liatris pycnostachya*	0.0%

Initial forb establishment from the 1992 plantings was high (mean density of 31.2 forb plants/meter^2), and establishment rates varied considerably by species (Table 6; Fig.10). The rates of lanceleaf tickseed (*Coreopsis lanceolata* L.), pinnate prairie coneflower (*Ratibida pinnata* (Vent.) Barnh.), wild quinine (*Parthenium integrifolium* var. *hispidum* (Raf.)), sweet coneflower (*Rudbeckia subtomentosa* Pursh), wildbergamot beebalm (*Monarda fistulosa* L.), and compassplant (*Silphium laciniatum* L.) were highest.

Table 6. Change in prairie forb density in Wilson's Creek National Battlefield, Missouri, 1993-1996

Common Name	Species Scientific Name	Change in Density
azure blue sage	*Salvia azurea*	466.0%
prairie rosinweed	*Silphium terebinthinaceum*	108.0%
stiff goldenrod	*Solidago rigida*	108.0%
purple coneflower	*Echinacea* spp.	54.9%
wildbergamot beebalm	*Monarda fistulosa*	48.5%
largeleaf wild indigo, white wild indigo	*Baptisia leucantha*	27.4%
compassplant	*Silphium laciniatum*	25.6%
wildquinine,wild bergamot	*Parthenium hispidum*	19.8%
Missouri orange coneflower	*Rudbeckia subtomentosa*	-4.5%
pinnate prairie coneflower	*Ratibida pinnata*	-24.5%
lanceleaf tickseed	*Coreopsis lanceolata*	-71.1%

Four years after planting, the mean forb density declined (21.0 forb plants/m^2). The decline was primarily the result of self-thinning of lance-leaf coreopsis, a species that was initially abundant in the plantings. At the same time, increases in the densities of some species, most notably azure blue sage (*Salvia azurea* Michx. ex Lam.), prairie rosinweed (*Silphium terebinthinaceum* Jacq.), and stiff goldenrod (*Solidago rigida* ssp. *L. rigida*), were striking. Most species that increased in density between 1993 and 1996 were species that required specific treatments to overcome seed dormancy. Increased density 4 years after planting suggests that the plantings were only partially successful in breaking dormancy and may need to be modified.

The overall progress of new forb plantings is apparent from the change in the frequency distributions of all species. One year after planting, five forb species dominated the plantings, and most of the remaining species occurred in less than 10% of the sampling plots. Three years later a more even distribution of species was evident. Although the same five species dominated the plantings in 1996, half of the remaining species occurred in 10% or more of the plots. The rates of establishment in some species were consistently low during 4 years of monitoring. Most notable among these were the bigfruit or Missouri primrose (*Oenothera macrocarpa* Nutt.), western silky aster (*Aster sericeus* Vent.), cattail gayfeather (*Liatris pycnostachya* Michx.), and tall gayfeather (*Liatris aspera* Michx.). Direct seeding of these species may not be the most efficient method of introduction.

Figure 10. Prairie forb establishment in Wilson's Creek National Battlefield, Missouri, 1996.

Terrestrial Vegetation

Effects of Global Warming on Vegetation at Treeline in the Rock Creek Watershed, Denali National Park and Preserve, Alaska

In the past, the location of the transition zone between boreal forest and tundra—often referred to as *treeline*—shifted in response to climate change. Scientists predict that global warming will have a major effect on this ecotone within several decades, when the boreal forest will expand into areas that are now upland tundra.

The vegetation in Alaska's largest national parks and preserves—Denali, Gates of the Arctic, Katmai, and Wrangell St. Elias national parks and preserves and Noatak National Preserve—is dominated by boreal forest and upland tundra. The predicted expansion of the boreal forest into the upland tundra would have major effects on the distributions and population sizes of plant and animal species. Monitoring vegetation parameters that can be used to predict and document this shift as it occurs will be a useful adjunct to the monitoring of other resources in the park.

Vegetation monitoring in the initial phase of long-term ecological monitoring in Denali National Park and Preserve was designed to detect responses to global warming in the boreal forest-upland tundra ecotone against the background of natural variation. Specific objectives were:

- the determination of the compositions and structures of major plant communities in the Rock Creek watershed and the documentation of natural changes from, for example, wildfire, flooding, and climatic change;
- the determination of the growth rate and reproduction of white spruce (*Picea glauca* (Moench) Voss), the major treeline species in many parks in Alaska; and
- a comparison of data with other boreal forest sites to amplify monitoring power.

Study design is based on and compatible with the Bonanza Creek Long-Term Ecological Research site near Fairbanks, where boreal forest communities at a lower elevation are monitored. In the Rock Creek watershed, monitoring is focused on four major vegetation types that on an elevational gradient extend from riparian broad-leaved forest and coniferous forested slopes through treeline to alpine tundra. The early snowfall in 1992 damaged and killed trees region-wide in the park and at Bonanza Creek. Although the annual growth of diameter in white spruce was similar in the forest and at treeline, it was less in a comparably aged stand at low elevation at Bonanza Creek. Crops of white spruce cones have been small to moderate, and only a few viable seeds dispersed each year. Data from several more years are needed to evaluate the relation between climatic measurements and white spruce growth and reproduction.

Terrestrial Vegetation in Great Smoky Mountains National Park, Tennessee and North Carolina

The goals of monitoring vegetation in a park-wide network of permanently marked plots in Great Smoky Mountains National Park are the detection and assessment of the degrees of change in the vegetation over time, particularly those from anthropogenic disturbances such as exotic insects and diseases, atmospheric pollution, invasive exotic plants, and suppression of natural fires. The information is imperative for sound management of natural resources and for designing long-term ecological studies.

Flowering dogwood

Flowering dogwoods (*Cornus florida* L.) provide a reliable crop of high protein berries for wildlife, especially migratory birds. They also provide calcium to upper soil layers and are valued for floral display in spring and for foliage display in fall.

However, flowering dogwoods in the park are affected by an exotic foliar blight disease, dogwood anthracnose (*Discula destructiva*), that can cause heavy mortality in moist forests. The disease, believed to be originally from Asia, was first found in Great Smoky Mountains National Park about 1988.

Since 1978, when flowering dogwood in the park was first examined, the number of trees and basal area of the tree declined by 50%.

Increases in flowering dogwood in few monitoring plots seem to be attributable to significant tree fall that permitted the penetration of sunlight. The increase in sunlight is believed to suppress the anthracnose and enhance the survival of the dogwoods. The results, although not unexpected, revealed that natural processes like tree falls may help the survival of the dogwoods.

Figure 11. Blue Ridge catchfly, *Silene ovata* Pursh.

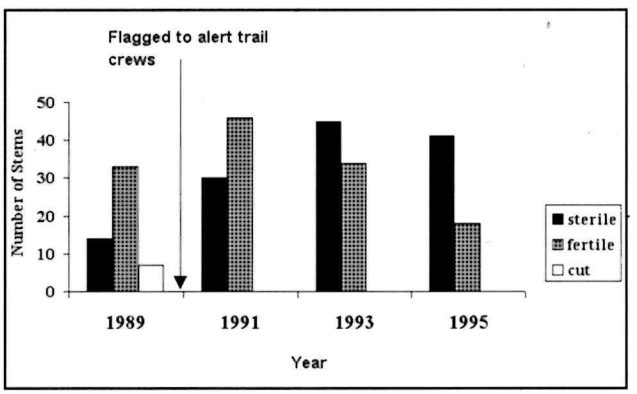
Blue Ridge Catchfly

The Blue Ridge catchfly (*Silene ovata* Pursh; Fig. 11), a member of the Pink family (Caryophyllaceae), is listed as a federal species of special concern. The Blue Ridge catchfly is a rhizomatous perennial with 1-16 stems/plant. It occurs primarily on rich slopes in mesic oak communities where its survival is believed to depend on disturbances that create light gaps in old-growth forests and fires. Ten depauperate populations occur in Great Smoky Mountains National Park, about four of which consist of only 1-3 individuals.

Four populations of the Blue Ridge catchfly in the park are monitored. After they were flagged to prevent losses from trail maintenance, no cut stems were reported in subsequent years (Fig. 12), and the numbers of sterile and fertile stems increased until 1993. However, in 1993 and 1995, the number of fertile stems declined, and in 1995 the number of sterile stems also declined.

By curtailing direct damage to the Blue Ridge catchfly stems, sympatric species have competed with the catchfly. To reduce competition, the stems of sympatric species will be selectively cut until the planned reintroduction of fire to these communities is initiated. Monitoring of this species reinforces the critical importance of maintaining ecological processes like fire to maintain biological diversity in national parks and other reserves.

Figure 12. Number of stems of a Blue Ridge catchfly, *Silene ovata* Pursh, population in Great Smoky Mountains National Park, Tennessee and North Carolina, 1989-1995.



American Ginseng

Ginseng (*Panax quinquefolius* L.), a formerly abundant perennial, has been harvested throughout its range for more than two centuries. Great Smoky Mountains National Park is the largest protected reserve of the species because collections of natural resources are not permitted in national parks. Elsewhere in Tennessee and in North Carolina, the collection of ginseng roots (Fig. 13.) is legal and regulated by the states. Although the extent of poaching in the park is not known, it is considered a long-term threat because the price per pound increases each year. For instance, in 1995, the price per pound of dry roots hovered around $500. The survival of replanted seized roots in the park has been monitored since 1991. To date, 7786 roots have been weighed and aged, and about 5000 replanted. The

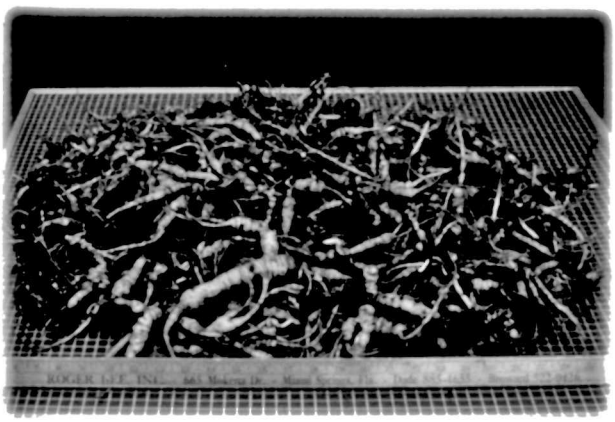


Figure 13. Seized poached American ginseng, *Panax quinquefolius* L., roots in Great Smoky Mountains National Park, Tennessee and North Carolina, 1990.

roots, planted in the watershed from which they were believed taken, are monitored and recorded in a database by watershed and can be summarized as totals in the park. Survival of the roots and age structure (size-classing by leaf number) are recorded.

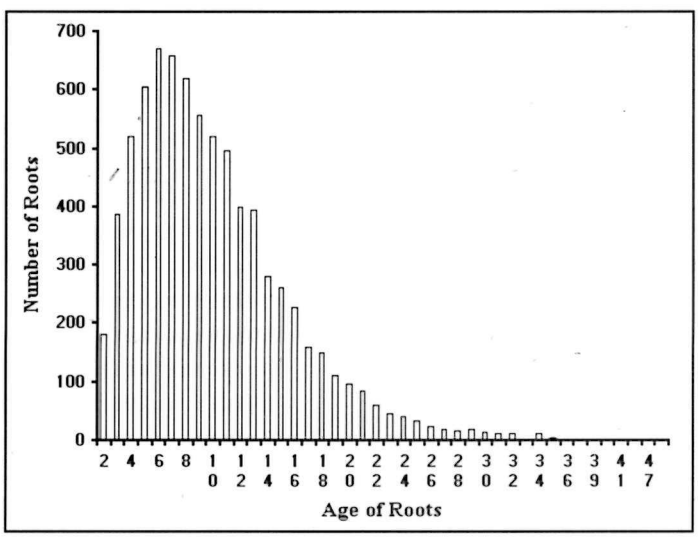
Preliminary results from monitoring indicate that more emphasis must be given to the survival of this species. Eight of 20 replanted populations were again measured during the past 2 years. Four populations were poached. Two of these populations were subsequently seized and replanted a second time.

An analysis of the data did not reveal a correlation between age and weight because growing conditions, not age, determine root size. The data revealed that roots taken from the park are most commonly 6-8 years old (Fig.14). Because this species can live 50 or more years, many of the populations in the park seem to be young.

Continued monitoring is expected to provide sufficient data for a better understanding of natural population variations and for the extent of poaching (by watershed and by proximity to roads, trails, and park boundary) and root age (an indicator of reduced population numbers). Monitoring revealed needs for research on habitat preference, increased coordination by law enforcement, and greater involvement of the state agencies in the coordination and enforcement.

Based in part on the data from monitoring, the Southeast Regional Office of the National Park Service provided short-term funding for an extensive inventory of American ginseng, for marking plants, and for better detection equipment for law enforcement by rangers in Fiscal Years 1997 and 1998

Figure 14. American Ginseng, *Panax quinquefolius* L., roots by age in Great Smoky Mountains National Park, Tennessee and North Carolina, 1991-1996.



Forest Insects and Diseases in Great Smoky Mountains National Park, Tennessee and North Carolina

The diverse forests of Great Smoky Mountains are subject to biotic stressors that have existed for centuries. The influx of new insects and diseases from outside the region and from other continents during the last two centuries has overwhelmed the reaction strategies of some tree species. Populations of several uncommon tree species and unique forest types drastically declined because of introduced pests. The extent of the decline may not be known for years. Annual monitoring, however, reveals trends in abundance for the timely development and implementation of management and prevention of further drastic losses.

Balsam Woolly Adelgid

About 74% (about 15,390 ha or 38,000 acres) of all existing spruce-fir (*Picea-Abies*) forests in the southeastern United States are in the Great Smoky Mountains of North Carolina and Tennessee. Fraser's firs (*Abies fraseri* (Pursh) Poir.) occur only in the high elevations of the southern Appalachian Mountains. The species tolerates the extreme conditions on the windward slopes that exclude other species. A small insect, the balsam woolly adelgid (*Adelges piceae*) was accidentally transported from Europe to North America in the early 1900s. The insects feed on the bark and inject a substance that causes abnormal cell growth in the trees. The abnormally large cells restrict the flow of nutrients and can kill the trees. Balsam woolly adelgids have killed about 90% of the mature Fraser's firs in the Great Smoky Mountains (Figs 15 and 16). Attempts to control the insect have been unsuccessful, and the U. S. Fish and Wildlife Service listed the Fraser's fir as a species of special concern.

Figure 15. Fraser's fir, *Abies fraseri* (Pursh) Poir., killed by balsam woolly adelgids, *Adelges piceae*. Great Smoky Mountains National Park, Tennessee and North Carolina.

Figure 16. Fraser's fir, *Abies fraseri* (Pursh) Poir., killed by balsam woolly adelgids, *Adelges piceae*. Great Smoky Mountains National Park, Tennessee and North Carolina.

In the Great Smoky Mountains National Park, the balsam woolly adelgid is monitored on four mountain peaks. Populations of the insect in areas on two of these mountains are monitored and managed. The density of the insect and the number of fir cones are determined to provide information about trends in the insect population size that can be used to predict changes in host stress and future mortality of the firs (Figs 17a-b). Insecticidal soap is applied in small areas when populations warrant control. Control is supported by Forest Health of the U. S. Forest Service.

The massive decline of the Fraser's fir placed plants and animals of the spruce-fir plant association in jeopardy. Twenty-seven species of mosses and liverworts frequently occur on the bark of Fraser's firs and eight of them occur exclusively on the bark of firs. A small tarantula and a lichen, which are federally listed endangered species, and two salamander species are among the native species that occur only in spruce-fir forests.

Figure 17a. Mean number of balsam woolly adelgids, *Adelges piceae*, and mean number of Fraser's fir, *Abies fraseri* (Pursh) Poir., cones on Mount LeConte in Great Smoky Mountains National Park, Tennessee and North Carolina, 1987-1996.

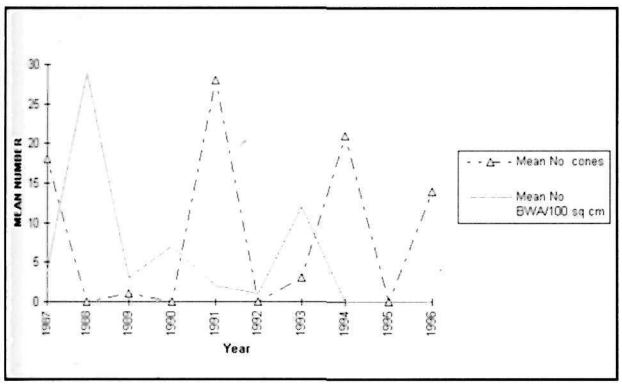
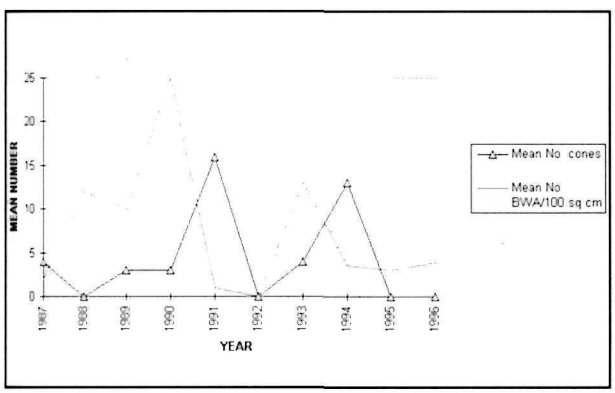


Figure 17b. Mean number of balsam woolly adelgids, *Adelges piceae*, and mean number of Fraser's fir, *Abies fraseri* (Pursh) Poir., cones on Mount Sterling in Great Smoky Mountains National Park, Tennessee and North Carolina, 1987-1996.



Beech Bark Disease

In Great Smoky Mountains, American Beech (*Fagus grandifolia* Ehrh.) occurs in mixed forests and as the dominant species in gaps at elevations as high as 1769 m (5800 feet). Beech can tolerate damaging strong winds and is the only deciduous, hard-mast-producing tree species at high elevation. Soils in beech gaps are less acidic and contain more organic matter than soils in the spruce-fir forests that surround them. The different soil conditions allow the proliferation of herbaceous species that do not occur in spruce-fir forests. These islands of diversity provide habitats for rare invertebrate species.

The presence of the introduced European insect-fungus complex known as beech bark disease was confirmed in Great Smoky Mountains in 1993. A small white-covered scale insect (beech scale insect [*Cryptococcus fagisuga*]) is the first sign of the disease. The insect inflicts a wound that provides the entrance into the tree for the *Nectria* fungus (*Nectria coccinea* var. *faginata*, *N. galligena*), the killing agent.

The detection of the disease in the park was a surprise because the next nearest infestation was in West Virginia. Between 1994 and 1996, the percent of infested beeches increased from 55% to 96%, and in one area, the mortality of beeches increased from 71% to 87%. Isolated pockets of beeches at all elevations are becoming infested (Fig. 18).

Figure 18. Beech, *Fagus* spp., that are dying from beech bark disease in Great Smoky Mountains National Park, Tennessee and North Carolina, 1996.

Although the disease has spread from New England and northeastern Canada since its accidental introduction 75 years ago, no forest-wide control of the disease has been found. Reproduction of beeches in gaps at high elevantions is almost exclusively from root sprouts, and the genetic variation of the trees is therefore restricted. Research in the northern United States revealed that less than 1% of the affected trees are resistant. The resistant trees occur in groups and are probably clones or closely related to nearby resistant parent trees. Tissue culture screening of beeches for resistance to the beech bark disease is being developed by the U. S. Forest Service. In the park, beech stands are monitored for changes in vegetation and for resistant individuals for future regeneration.

Butternut Canker

The butternut or white walnut (*Juglans cinerea* L.) is an uncommon tree throughout its range in the eastern United States and southeastern Canada. In the late 1960s, a new canker disease (*Sirococcus clavigignenti juglandacearum*) that affects the butternut was discovered in Wisconsin. Little is known about the origins of this disease, but it is suspected to have originated outside North America. Mortality of the butternut in the southeastern United States during the last 30 years has been attributed to butternut canker. The severity of the disease and the relative scarcity of the tree resulted in the federal designation of the tree as a species of special concern.

The longest survey of butternut canker was initiated in 1987 in Great Smoky Mountains National Park. A survey in 1996 revealed a 25% mortality in monitored trees since the survey began. The healthiest trees are those that receive full sunlight. These trees are growing rapidly, heal their cankers, and produce nuts on a regular basis. The cankers of trees in the understory where plants must compete for light heal slower and thus render the trees susceptible to other debilitating fungi. The number of trees with numerous (more than 11) cankers has declined.

The healthiest trees produce the most seeds. Although some trees produce hundreds of nuts on a cyclical basis, regeneration is limited. Butternut seedlings survive only in areas that receive full sunlight. These conditions limit reproduction to stream sides, road sides, and tree-fall areas where light reaches the forest floor. Natural disturbances such as floods, storms, and fires are essential for creating openings for the regeneration of the butternut.

Control of the canker is currently not possible. Park managers are focusing on protection of the trees such as screening nuts for resistance, modeling distribution in the park and in adjoining national forests, an – in collaboration with U. S. Forest Service – identifying mature trees with apparent resistance.

Western Prairie Fringed Orchid in Pipestone National Monument, Minnesota

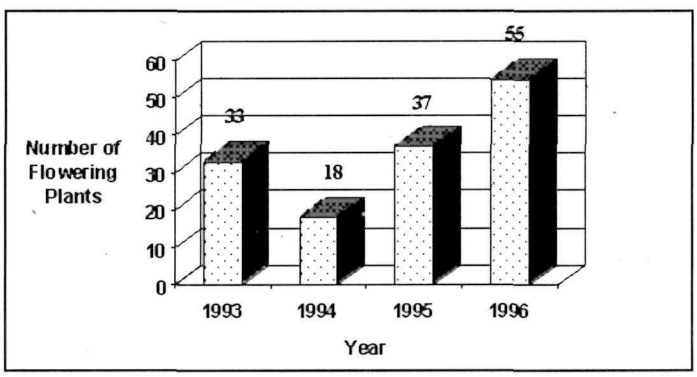
The western prairie fringed orchid or Great Plains white fringed orchid (*Plantanthera praeclara* Sheviak & Bowles; Fig. 19) was placed on the federal list of threatened plants in 1989. It occurs in scattered, usually small populations (fewer than 250 individuals) in mesic prairies in Iowa, Kansas, Nebraska, Minnesota, Missouri, and North Dakota. In Pipestone National Monument, Minnesota, the western prairie fringed orchid occurs in a wet prairie-sedge meadow community. Fire seems to be important in the flowering dynamics of the orchid, but fire's long-term effect on survival of the plant is unknown. A fire in late spring may reduce flowering in the orchid population by removing inflorescences or by creating drier habitats where plants abort inflorescences. However, fire may be important for recruitment to the population because of subsequent seed germination and seedling survival. Results of flower counts in July 1993-96 revealed a large variation in the number of flowering plants (Table 7; Fig. 20). The counts were compared to climate variables, such as May precipitation, which are suspected to affect orchid population size, and to time since last prescribed fire. Only time since the last fire was a significant predictor variable, accounting for about 98% of the variation in the number of flowering plants.

Figure 19. Western prairie fringed orchid, *Platanthera praeclara* Sheviak & Bowles, in Pipestone National Monument, Minnesota, 1996.

Table 7. Number of flowering western prairie fringed orchids (*Platanthera praeclara* Sheviak & Bowles) by year and by date of previous fires. Pipestone National Monument, Minnesota, 1992-1996.

Year	Number of Flowering Plants	Date of Previous Fire	Number of Years Since previous Fire
1993	33	May 1992	1
1994	18	May 1994	0
1995	37	May 1994	1
1996	55	May 1994	2

Figure 20. Number of flowering western prairie fringed orchids, *Platanthera praeclara* Sheviak & Bowles, in Pipestone National Monument, Minnesota, 1993-1996.



Threatened and Endangered Fishes in Great Smoky Mountains National Park, Tennessee and North Carolina

The natural reproduction (as opposed to artificial propogation in hatcheries) and recruitment of reintroduced threatened and endangered species in a creek in the park seem to be successful. Evidence suggests natural reproduction and an expansion of range in the dusky darter (*Percina sciera*) in 1996. Snorkelers observed eggs and young-of-year dusky darters in several stream pools. Sightings of nesting pairs of smoky madtoms (*Noturus baileyi*) by snorkelers increased. Monitoring of smoky madtoms and spotfin chubs (*Cyprinella monacha*) indicates little natural reproduction.

Brown Pelicans in Channel Islands National Park, California

Brown Pelicans (*Pelecanus occidentalis*; Fig. 21) are on the federal list of threatened and endangered birds. On the West Coast of North America, colonies of Brown Pelicans are located in Channel Islands National Park and on islands off the coast of Baja California. Therefore, the only breeding colonies of Brown Pelicans in the western United States are supported by Channel Islands National Park in California. In the 1970s, the number of breeding birds in the colonies had severely declined because of high levels of DDT/DDE in the marine environment. The contaminant caused the thinning of eggshells that could not withstand the pressure of the incubating adults that incubate their eggs by standing on them.

Since then, DDT/DDE levels have declined and the number of birds in the breeding population has steadily increased. The estimated yearly nesting attempts in the park increased from 100 in the early 1970s to 4000-6000 in 1996. On one of the islands, the number of nests has ranged from 400/year to 700/year.

Although breeding attempts by the pelicans seem to have stabilized, human disturbance and pollution remain large threats to these birds. Management of the pelicans consists of restricted access to West Anacapa Island. A closure keeps boats well offshore to protect fledglings in the vicinity of the nesting colony.

Figure 21. Brown Pelican, *Pelecanus occidentalis*, in Channel Islands National Park, California.

Piping Plovers on Cape Cod National Seashore, Massachusetts

Cape Cod National Seashore constitutes about 87 km (54 miles) of beaches on the outermost portion of the arm of Cape Cod, a glacial outwash plain that juts about 97 km (60 miles) seaward from mainland Massachusetts. Seventy-one kilometers (44 miles) of the beaches are managed by the National Park Service; 16 km (10 miles) are owned and managed by towns. Recreational developments on these beaches include public parking and off-road vehicle trails on nearly all town-owned beaches and on 14 km (8.5 miles) of the beaches that are managed by the service. Beach nourishment and erosion control are mininal on outer Cape Cod. Shoreline developments include small groins at Herring Cove Beach, a breakwater inside Wood End, and a small dredging project at Aunt Lydia's Cove in Chatham. Sixteen kilometers (10 miles) of town-owned sand spits exist on Nauset Beach in Orleans and Chatham. Sand spits on Coast Guard Beach in Eastham, Jeremy Point in Wellfleet,

and Race Point, Wood End, and Long Point in Provincetown are in the care of the service. The remainder of the beach is backed by high bluffs or dunes that do not provide access to bays or harbors. Cape Cod National Seashore receives about 5 million visitors annually, and during the 15 April - 15 November season, the National Park Service issues 2500 permits for off-road vehicles.

The Atlantic Coast population of the Piping Plover (*Charadrius melodus*) became a federally listed threatened species in 1986. Annual monitoring of the Piping Plover on Cape Cod National Seashore began in 1985. Data on habitat selection; population dynamics; relation between human recreation, foraging ecology, and survival of chicks; and brood home-range characteristics have been collected annually.

Protection of the Piping Plover on the seashore consists of temporal and spatial restrictions of off-road vehicles, seasonal restricted access by visitors of areas where the plovers nest, control of avian and mammalian predators by protecting nests with mesh-topped or string-topped welded-wire exclosures, and raising of public awareness of the status and the management of the plover.

Hatching success and productivity of the Piping Plover on the seashore began to increase in 1988, when predator exclosures were first used. Since 1990, the nesting populations on town-owned beaches and on beaches in the care of the National Park Service has substantially increased. Nests have been observed in sites where none had been seen before 1990, even in the 14-km (8.5-mile) off-road vehicle corridor.

Seventy-seven pairs or about 16% of the total breeding population of Piping Plovers in Massachusetts were monitored in 9 sites on Cape Cod National Seashore during 1996. Although the number of nesting plovers in the 9 sites decreased by 8% since 1995, it is nevertheless 427% of the number of nesting plovers in 1985 when monitoring began. Hatching success (total number of hatched eggs/total number of eggs) in all sites combined was 38% and ranged from 0% to 79%. Overall, hatching success was the lowest recorded since wide-scale use of predator exclosures was initiated. Fledging success (total number of fledglings/total number of hatched eggs) decreased by 15% since 1995. Productivity (number of fledglings/nesting pair) decreased by 50% since 1995. In fact, it was the lowest productivity on Cape Cod National Seashore since 1988.

Not even 1 chick was hatched from 64% (75 of 116 nests) of the initiated nests. The leading cause of the failure (27%) was predation by crows (*Corvus brachyrhynchus*). Abandonment of the eggs by the hen (16%) and predation by red foxes (*Vulpes vulpes;* 13%) were the second and third leading causes.

Predator exclosures were installed around 73 of the 116 (63%) nests. Chicks hatched in 34 (46%) nests. Chicks did not hatch in 10 (14%) nests because of predation by crows, in 10 (14%) other nests because of abandonement by the hen, in 6 (8%) nests because of predation by red foxes, and in 14 (19%) nests because of other factors. Mesh-topped exclosures protected nests from predators better than string-topped exclosures. The number of enclosed nests in which chicks hatched was greater than the number of unprotected nests in which chicks hatched. Mesh-topped exclosures did not, however, prevent mammalian predation. In fact, taller, mesh-topped exclosures may have contributed to increased loss of clutches from abandonment by the hen. In several instances, exclosure height was increased to 152-183 cm (5-6 ft) above ground and depth to which the enclosures were buried was increased to 20 cm (8 inches).

The determination of causes of chick mortality factors was difficult because of lack of indices. Three dead chicks were found in 1996. The presumed cause of death was exposure. Additionally, 1 chick from a brood of 3 was observed being taken by a Great

Black-backed Gull (*Larus marinus*). Red foxes and fox tracks were routinely observed in several sites. In contrast to previous years, birds of prey such as American Kestrels (*Falco sparvarius*) and Merlins (*F. columbarius*) did not seem to contribute substantially to chick mortality. In fact, few were seen on the beaches during the chick-rearing stage. Adult mortality was not observed on Cape Cod National Seashore in 1996.

In summary, the number of nesting pairs of piping plovers on Cape Cod National Seashore increased steadily from 15 to 83 during 1990-95 but declined to 77 pairs in 1996 (Table 8). The increase suggests that control of off-road vehicles and restricted access of nesting areas by visitors since 1990 have been effective. However, a satisfactory explanations for the substantial reduction in the average number of fledglings per pair from 2.6 in 1990 and 1991 to 0.9 in 1996 has yet to be found.

Table 8. Piping plovers, *Charadrius melodus*, on Cape Cod National Seashore: number of nesting pairs and average number of fledglings/pair, 1985-1996.

Year	Number of Pairs	Average Number of Fledglings/Pair
1985	18	0.7
1986	16	0.3
1987	15	0.4
1988	13	0.9
1989	15	1.4
1990	15	2.6
1991	28	2.6
1992	43	2.4
1993	60	2.1
1994	72	2.5
1995	83	1.8
1996	77	0.9

INVERTEBRATES

Aquatic Macroinvertebrates in Great Smoky Mountains National Park, Tennessee and North Carolina

Monitoring of aquatic macroinvertebrates in Great Smoky Mountains National Park is designed to provide data on the health of streams and on the aquatic biodiversity and to determine relations among macroinvertebrates, fishes, and water quality. Macroinvertebrates are the insects, crayfishes, worms, and other large invertebrates that live in streams. Annual samples are taken from 25 permanent sites to permit comparisons of the health of these sites from year to year. Annual samples are taken from another 15 sites on a rotating basis to provide wider coverage of streams in the park. Complete coverage of the more than 3400 kilometers (2100 miles) of streams in the park is a long-term objective.

In 1995, more than 16,000 specimens that represented more than 300 species of invertebrates were taken in 40 samples. The Diptera or true flies were represented by 92 species, the Trichoptera or caddisflies by 62 species, the Ephemeroptera or mayflies by 47 species, and the Plecoptera or stoneflies by 30 species. The number of taxa in each sample ranged from 27 to 95 (average=44 taxa/sample). From the total of 378 taxa, 246 taxa occurred in 10 or fewer collections; 127 occurred in 11-74 collections; and 5 taxa occurred in 75-89 collections. No one taxon occurred in all collections. On the other hand, every collection included at least one species that had not yet been collected elsewhere in the park, including several collections from locations that were only a few hundred meters apart in the same stream and collections from the same site in different years. These data indicate that many more species of aquatic invertebrates remain to be discovered in the park.

The status of a site is determined with a *biotic index*, which consists of the abundance value of each species and the tolerance value of each species. Tolerance values are determined in large-scale studies of species in a range of water quality conditions. A species that is found only in pristine, unpolluted water is considered intolerant, whereas a species that occurs in polluted waters is considered tolerant. A value is assigned that ranges from zero (most intolerant) to ten (most tolerant). The combined values are summed over all species and converted to a site value.

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 in the park by more than a full pH unit. Thus, the biota of streams are subject to high levels of pollution. Impairments of the health of the streams will be seen in the responses of the aquatic biota. As intolerant species are replaced by tolerant species, the trend in the biotic index will begin to slant downward. Such trends may be among the earliest indications of biotic effects of pollution in aquatic ecosystems in the park.

Monitoring Aquatic Macroinvertebrate Assemblages to Detect Changes in the Water Quality of Prairie Streams, Great Plains Prairie Cluster.

The streams in small prairie parks are primarily influenced by changes in watersheds outside park boundaries. High turbidity, pesticides, and nutrient loading from agricultural pollution reduce the biological diversity in many prairie streams. Near urban centers, water quality of the streams is threatened by industrial pollution. Natural resource managers increasingly use data from analyses of aquatic macroinvertebrate communities to determine the status and trend of water quality in streams. In 1988, the National Park Service began to monitor water quality in six prairie parks by sampling stream macroinvertebrates (Fig. 22). During 1988-89, intensive sampling was conducted to provide baseline water quality data, resource managers were trained in sampling techniques, and monitoring methods were standardized. During 1990-95, data were collected intermittently.

When long-term monitoring was initiated in the Great Plains Prairie Cluster, the effectiveness of previous monitoring of macroinvertebrates was evaluated. An initial review revealed that, although monitoring of water quality with aquatic macroinvertebrates provided data of consistent quality, the data were not readily available to park managers to address water quality issues. Although the initial monitoring protocol included routines for data summary, interpretation of the data was difficult because of the high variance of invertebrate density among sampling sites and dates. Therefore, in 1996, a study was initiated to (1) identify the main sources of variation in invertebrate community structure in park streams, (2) devise the most cost efficient sampling strategy, and (3) develop biological criteria for detecting changes in water quality.

Figure 22. Sampling aquatic macroinvertebrates to monitor water quality in prairie streams. Great Plains Prairie Cluster, 1996.

Within year variance was assessed with data from 1989, the most complete data set. Within season variance was assessed with data from streams at Wilson's Creek National Battlefield, the only data set with multiple sampling dates in a season. All data were used for an examination of long-term trends. Results indicated that between season variance accounted for most of the variation in macroinvertebrate densities. Sampling efficiency could be improved by modifying the protocol to include the collection of five replicate samples on three dates during a single season (June-August). Trend analysis of all data suggested a significant decline of water quality in Wilson's Creek during 1988-95 and an improvement of water quality in streams in Pipestone National Monument during 1989-95. Managers of Wilson's Creek National Battlefield are using data from monitoring water quality with macroinvertebrates to prevent the placement of a sewage treatment plant in the Wilson's Creek watershed.

Collapse of the Black Abalone Population in Channel Islands National Park, California

Black abalone (*Haliotis cracherodii*) are slow growing, long-lived, herbivorous gastropod mollusks that until recently dominated much of the rocky intertidal habitat of Channel Islands National Park. For thousands of years, beginning with the Chumash Indians, black abalone have played an important role in a large and valuable fishery in California. During 1972-88, they were a major component of the commercial harvest, comprising 32%-60% of the total abalone landings.

Rocky intertidal monitoring in the park was begun in 1982 to monitor the health of the intertidal ecosystem, provide baseline information, and document size trends in populations. A variety of techniques was used to measure population dynamics of selected organisms. Fixed photoplots were used to determine percent cover of certain attached animals and algae. Densities and size frequencies of black abalone and owl limpets (*Lottia gigantea*) were measured inside fixed plots. Empty abalone shells were counted as an additional measure of mortality in some sites. As abalone densities declined, methods were modified to include a timed search to document dwindling populations.

In the mid-1980s, monitoring of the rocky intertidal zone from the islands in the park revealed mass mortality of black abalone. As much as 99% of the populations in some areas was lost. The term *withering*

syndrome (WS) was coined because of the emaciated state of the moribund abalone. Park staff worked closely with the California Department of Fish and Game to document the population decline and to determine the cause of what seemed to be an infectious disease. Histological and pathological analyses of moribund abalone were done. Research into the relations of temperature and feeding was conducted. Bacterial infection is the leading suspect as the cause of the mass mortality, but proof seems to be elusive. Monitoring data supported the closure of all black abalone harvest to protect resistant stock.

Rocky intertidal monitoring is conducted twice annually at 15 permanent sites around the park islands. It is an ongoing program of indefinite duration. Expanding pinniped and seabird populations have made it difficult to access some areas during the breeding season and monitoring has been reduced to those areas.

The Reef Fishes on St. John in the U. S. Virgin Islands

Of the 24,618 known fish species in the world, more than 400 reef-associated or inshore-ranging pelagic species occur in the nearshore waters surrounding St. John in the U.S. Virgin Islands. Many species such as the foureye butterflyfish (*Chaetodon capistratus*) and butter hamlet (*Hypoplectrus unicolor*) depend on coral reefs for shelter from predation, for a source of food, or for a place to spawn. Juvenile fishes of many species--for example, barracudas (*Spyraena* spp.) and gray snappers (*Lutjanus griseus*)--find shelter amidst red mangrove prop roots. Other species--for example, the bucktooth parrotfish (*Sparisoma radians*) and the fringed filefish (*Monacanthus ciliatus*)--spend their lives in seagrass beds, whereas others use the grass beds as nurseries--for example, the French grunts (*Haemulon flavolineatum*)--or for nocturnal feeding--for example, many snappers and grunts (Lutjanidae and Haemulidae). Even habitats dominated by gorgonians (soft corals), sand, or algae and sponges are essential for some fishes--for example, the scrawled filefish (*Aluterus scriptus*) feeds on gorgonians, the spotted snake eel (*Ophichtus ophis*) lives in sand, and the chalk bass (*Serranus tortugarum*) on the algal plain.

Figure 23. Wire-mesh fish trap reinforced with a wooden frame. Virgin Islands National Park, 1996.

Natural events and human activities can directly kill fishes and degrade habitats. When Hurricane Hugo swept through the Virgin Islands in September 1989, the total abundance of fishes and number of species on two St. John reefs decreased significantly for 2-3 months. The number of blue chromis (*Chromis cyanea*) declined sharply; the abundance of surgeonfishes (*Acanthurus* spp.) increased (feeding on the increased amount of algae); and squirrelfishes (*Holocentridae*) appeared in the open, probably because of extensive damage to the reef. When Hurricanes Luis (6 September 1995) and Marilyn (15 September 1995) hit St. John, no changes were observed in either the number of species or the number of fishes. In the Virgin Islands today, several anthropogenic activities are damaging coral reefs, seagrass beds, and mangroves, and the long-term effects on the reef fish assemblages are not yet fully understood. Fishing damages habitats when anchors and traps are set on the reef and lines become entangled on the bottom; and fishing can directly affect the abundance, average size, and species composition.

Since approximately 800 B.C., human inhabitants of the Virgin Islands have harvested a variety of reef fishes for consumption. Early on, fishes were gleaned by hand in the shallows. Today, most fishing in the Virgin Islands is with traps or pots made of 3.2-5.1 cm (1.25-2.00 inch) wire mesh that is reinforced with a wooden or steel frame (*Fig. 23*). Small reef fish species escape through the mesh, but most larger species are contained. Some species are trapped frequently, whereas others are seldom caught, independent of their absolute abundance. Groupers (*Serranidae*) in particular tend to be attracted to traps, perhaps by the lure of a meal from the concentration of prey inside. Most trapped fish species in the Virgin Islands are eaten, which places pressure on a large number of species. Even the unpalatable species that escape the dinner plate and are discarded (bycatch) usually do not survive. After the larger fishes are removed from an intensely fished area, immature fishes comprise an increasing pro-

portion of subsequent catches. *Recruitment overfishing* results and seriously compromises the future abundance of the species.

The rapid growth of coastal human populations has fueled the increased demand for marine resources worldwide; St. John is no exception. The 1929-30 Virgin Islands census revealed that 765 people of 22,012 in the U. S. Virgin Islands lived on the 52 km^2 (20 $mile^2$) island of St. John. Today, the island has 3,500 permanent residents and more than one million visitors per year. This 55 fold increase in the number of people increased the demand for local fishes. As a consequence, the economic incentive to catch more fishes has became so compelling that the local spawning aggregation of the Nassau grouper (*Epinephelus striatus*) has been fished out of existence. Pressure from fishing continues to increase. In 1987, the Virgin Island Division of Fish and Wildlife reported the following trends in the fishery: a continuing decline in the average size of trapped fishes, an increase in fishing without a significant increase in landings, and pre-spawning juveniles comprising a majority of the catch. Whereas groupers and snappers were 33% of the catch in 1967-68, parrotfishes dominated the fishery in 1987. Now parrotfishes are beginning to exhibit signs of excessive fishing, the average size of trapped parrotfishes is decreasing.

In 1992, the Research Division (now the Biological Resources Division of the U. S. Geological Survey) of Virgin Islands National Park commenced a 3-year study of the effects of fishing (primarily by traps) on the reef fishes in the waters of St. John and of the trends in species composition, abundance, and sizes of fishes. Park regulations allow fishing in park waters by trap, hook and line, and cast net. No other fishing methods or types of gear are permitted. Thus, another objective of the study was the evaluation of the effectiveness of fishing regulations in preserving and protecting the reef fishes. The research involved several interrelated studies that were completed through the cooperative efforts of several agencies and universities: U.S. Geological Survey, National Park Service, the Virgin Islands Department of Planning and Natural Resources, the Florida Marine Research Institute, and the Universities of Rhode Island, Richmond, and Hawaii.

The research included experimental trapping, general trapping, and visual censuses of fish traps. A comprehensive view of the state of the reef fishes and fishery resource of St. John is emerging from the analyses of historical data and the results of the research. The information to date is exciting and disturbing.

The study revealed that fish traps decreased the number of fishes and changed the relative abundance of species on St. John reefs. Throughout 6 months of experimental trapping on a single reef in the park, the number of groupers, snappers, squirrelfishes, surgeonfishes, and total number of fishes caught in traps declined significantly. During the same period, visual census data also showed a decrease in the numbers of grunts, parrotfishes, piscivorous (fish-eating) fishes, snappers, squirrelfishes, surgeonfishes, and total number of fishes.

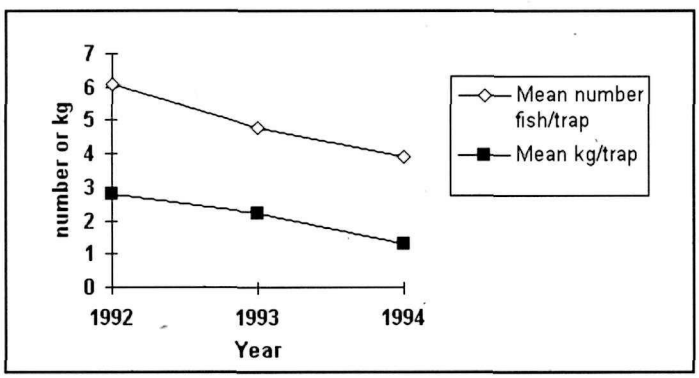
A comparison between fishes trapped on the same reef in 1982-83 and fishes trapped in 1993-94 clearly revealed the decline in numbers and percentage of grunts, porgies, groupers, snappers, goatfishes, and boxfishes (Table 9). The mean length of most species decreased. Eleven of the species present in 1982-83 were not observed or trapped during the 1993-94 study; 4 of the 11 were groupers (rock hind [*Epinephelus adscensionis*], mutton hamlet [*E. afer*], red grouper [*E. morio*], and black grouper [*Myctoperca bonaci*]).

Another study revealed that in visually censused fish traps set by fishermen in 1992-94, the average number and length of fishes declined (Figs 24a-b). The average catch was 4.7 fishes/trap and the mean length was 25.0 cm (10 in.). More blue tangs (*Acanthurus coeruleus*) than any other species were trapped (an average of 15.4% of the catch). Porgies (*Sparidae*) were the second (11.7%) and gray

Table 9. The ten numerically most abundant fish families in one trap in 1982-83 and in one trap in 1993-94 at the Yawzi Point reef, St. John, Virgin Islands National Park.

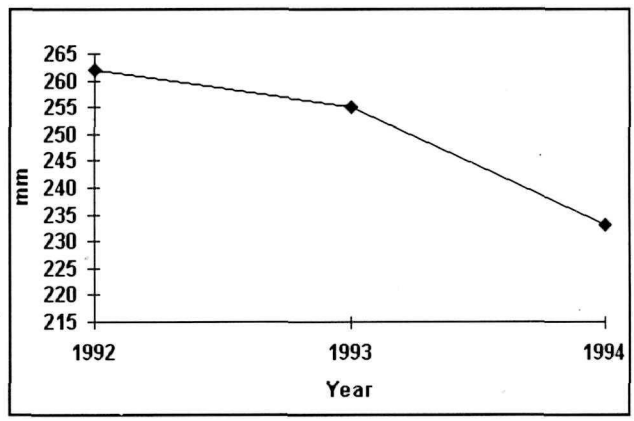
Common Name	Scientific Name	1982-83	1993-94 %
surgeonfishes	*Acanthuridae*	25.7	45.2
grunts	*Haemulidae*	23.1	11.3
porgies	*Sparidae*	10.0	3.5
snappers	*Lutjanidae*	8.1	5.5
goatfishes	*Mullidae*	5.6	3.7
parrotfishes	*Scaridae*	5.4	15.4
boxfishes	*Ostraciidae*	2.5	0.6
squirrelfishes	*Holocentridae*	2.0	5.4
angelfishes	*Pomacanthidae*	1.1	2.2

Figure 24a. Mean number of fishes per trap and mean weight (kg) per trap on St. John, Virgin Islands National Park, 1992-1994.



angelfishes (*Pomacanthus arcuatus*) were the third (9.4%) most abundant trapped fishes. The highly prized food fish, the Nassau grouper, comprised only 0.1% of the catch. In terms of catch by fish family, the surgeonfishes (Acanthuridae) were 19.5% of the trapped fishes, increasing from 8.6% in 1992 to 34.6% in 1994. The surgeonfishes, butterflyfishes (*Chaetodontidae*), angelfishes (*Pomacanthidae*), and boxfishes (*Ostraciidae*) were 50% of the catch. The increase in the percentage of herbivorous fishes and the decrease in fish-eating (piscivorous) fishes is noteworthy (Table 10).

Figure 24b. Mean length (mm) of fishes in traps on St. John, Virgin Islands National Park, 1992-1994.



Catch rates (used here as number of fishes/trap), species composition, and sizes of fishes were similar on reefs inside and outside park waters. The results seem to indicate that neither park regulations nor enforcement are protecting a natural resource that the park is mandated to protect.

In waters inside Virgin Islands National Park, 86% of the traps were set on living organisms (live coral, soft-corals, seagrasses) on the sea floor. Damage to the live substrate has far reaching negative effects on the marine ecosystem because the available abundances of shelter and food often decrease with damage.

Forty-nine percent of the traps in the park (35% of all traps) did not have a functioning biodegradable panel. This panel ensures that the trap loses its ability to hold fishes after a short time. Without the required panel, lost traps continue to kill fishes for years.

In summary, analyses to date have shown the following direct effects from the trap fishing of reef fishes in the waters surrounding St. John: a change in the relative abundance of reef fish species, a change in the species composition, a decrease in the number of many fish species, and a decrease in the size of fishes.

Table 10. Percentage of fishes by trophic level in visually censused traps on St. John in Virgin Islands National Park, 1992-1994.

Trophic Level	1992 %	1993 %	1994 %	All Years %
Herbivores	23.5%	22.8	41.7	28.1
Omnivores	18.7%	19.1	9.5	16.4
Insectivores	41.0%	44.1	36.2	41.2
Piscivores	16.8	14.0	12.5	14.3

Fish Populations in Shenandoah National Park, Virginia

Some of the greatest concentrations of native brook trout (*Salvelinus fontinalis*) in the East occur in streams in Shenandoah National Park. Among them, the Rapidan River (Fig. 25) is one of the most popular streams for trout fishing in Virginia. In 1982, park management began to monitor fishes because of concerns over harvestable populations in view of the close vicinity of the park to densely populated urban areas, concomitant intense legal and illegal angling, and effects of weather and acidification. By 1984, fish populations were regularly sampled in 46 streams.

Fish populations in moderate to high-gradient mountain streams are influenced primarily by variations in water flow rates, particularly during flood events, and a range of other factors such as habitat quality, water temperature, and water chemistry. Floods from heavy rains can cause profound losses of fish populations (as much as 100%) in heavily affected stream reaches.

Population loss was evidenced in two watersheds in Shenandoah National Park after a 500-1000 year flood in late June 1995. Whereas species diversity and the associated biomass of primarily nongame species were high before the flood in the lower reach of the Rapidan River in the park, sampling after the flood in mid-July revealed only 19 fishes of three species. Most of the surviving trout (*Salvelinus* spp.) in the stream were adults. Population stability was greater upstream and greatest in the uppermost reaches in the watershed.

The most drastic effects of the flood in 1995 were seen in the lower Staunton River, a major tributary to the Rapidan River. Whereas the sizes of brook trout populations had been stable and four other fish species had been routinely observed in the lower reaches before the flood, sampling after the flood in mid-July revealed no fishes in the lower reaches. All fishes in these reaches were destroyed. Most surviving trout elsewhere in the stream—as in the Rapidan River—were adults.

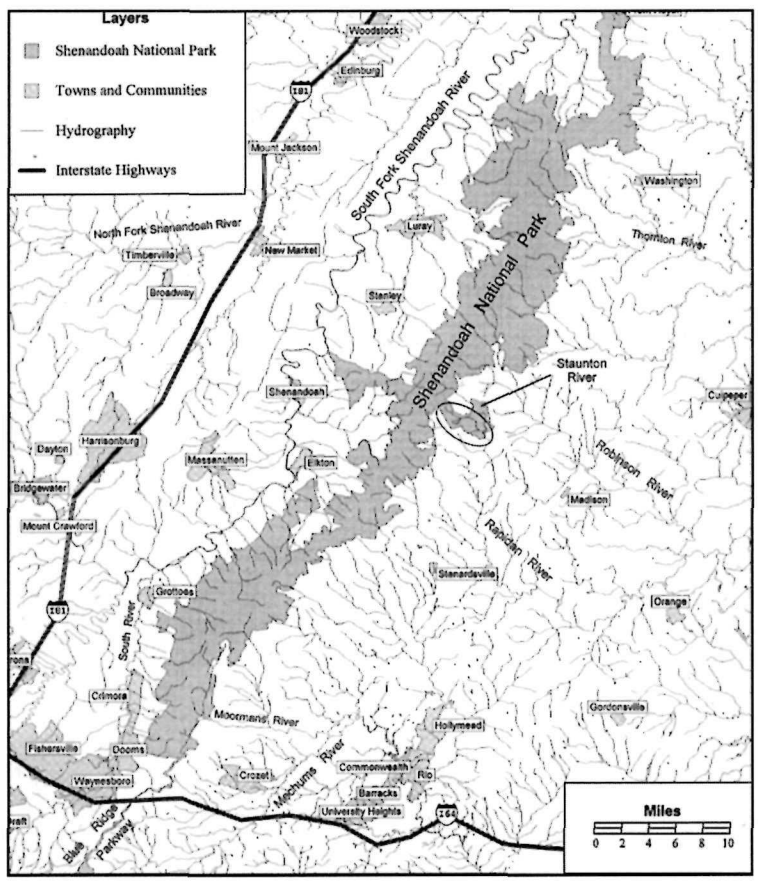


Figure 25. Streams in Shenandoah National Park, Virginia.

Most fish species that inhabit streams are highly prolific and, therefore, highly resilient to sudden, profound losses. For example, before the flood in June 1995, a sample of 824 fishes that represented 13 species was captured in a lower reach of the North Fork of the Moorman's River in the park. After the flood in July, a sample of only 6 fishes that represented 4 species was taken from the same reach with the same technique. However, a sample from the same reach in July 1996—1 year later—consisted of 1859 fishes that represented 10 species.

The number of blacknose daces (*Rhinichthys atratulus;* 1153) alone numerically exceeded the number of fishes in the entire sample taken before the flood in June 1995. Similar increases were observed in the lower Rapidan River. A sample in July 1996 consisted of 2030 fishes that represented 13 species, and as in the North Fork of the Moorman's River, blacknose daces (1188) prevailed.

Fish Communities in Large Streams of Great Smoky Mountains National Park, Tennessee and North Carolina

Game and nongame fish populations in Great Smoky Mountains National Park have been monitored since the establishment of the park in 1936. During 1930-50, the objectives of fishery management were the maximization of harvests and angler use. Beginning in the late 1970s, the U. S. Fish and Wildlife Service began sampling fishes in the larger streams in the park and permanently marked and recorded the sampling sites. The work provided an updated list of the fishes and the first evidence that previous surveys with toxicants had extirpated approximately 30 fish species. However, sampling had not been designed to monitor aquatic systems but to provide an estimate of population size and diversity.

In 1983, a sportfish management plan was drafted that called for the rotational monitoring of 6 streams: Abrams Creek, Cataloochee Creek, Deep Creek, Hazel Creek, Little River, Oconaluftee River (Fig. 26). The primary objectives were the acquisition of baseline data on species composition and abundance, the identification of current and future threats to the park, and the collection of data that could be used for management. In 1986, biologists of the National Park Service began annual surveys with standardized sampling techniques at standardized sampling sites on Abrams Creek, Cataloochee Creek, and the Little River.

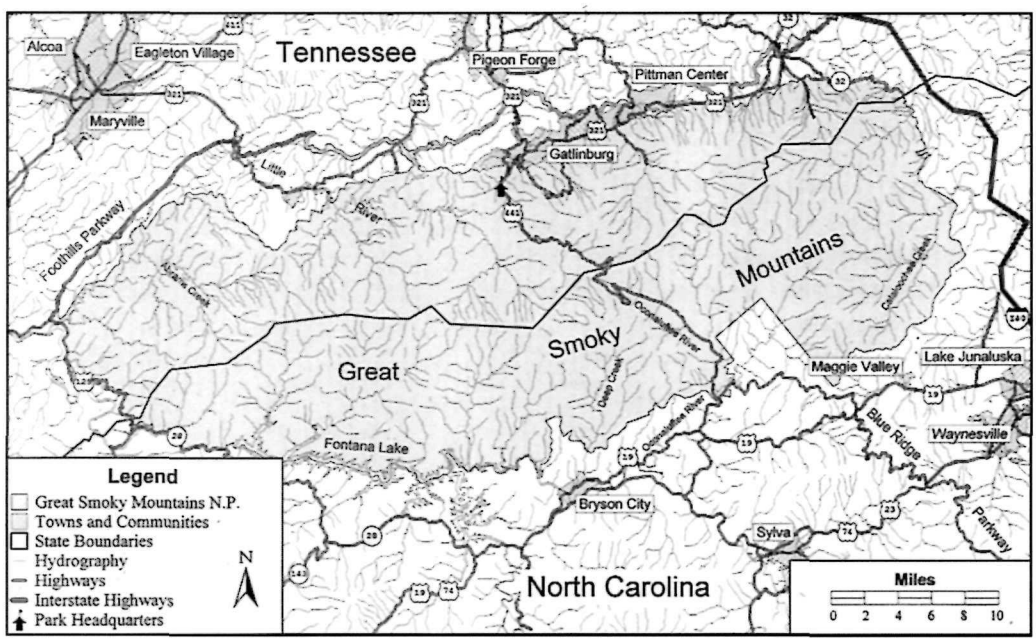


Figure 26. Streams in Great Smoky Mountains National Park, Tennessee and North Carolina.

Figure 27b. Densities of brown trout, *Salmo trutta*, in the Little River in fall, Great Smoky Mountains National Park, 1986-1995. Flooding in 1990 precluded the collection of data.

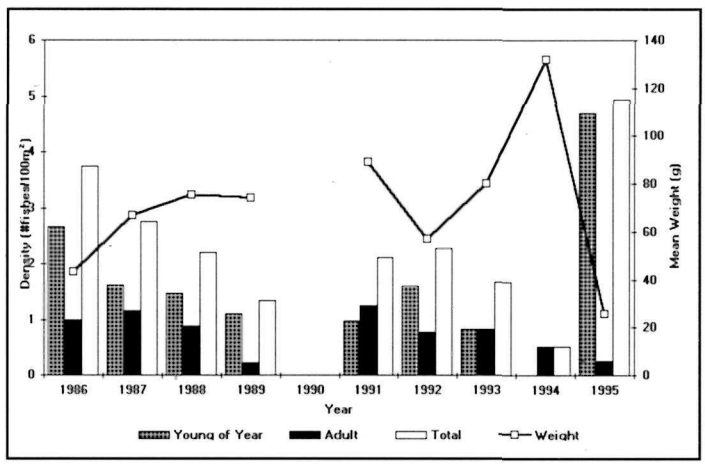
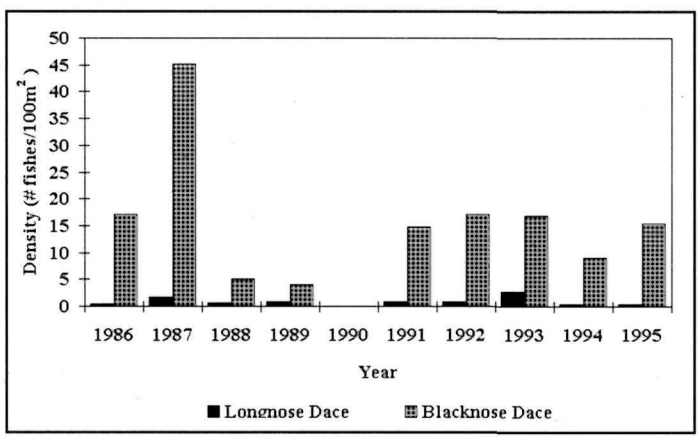


Figure 27c. Densities of the longnose dace, *Rhinichthys cataractae*, and the blacknose dace, *R. atratulus*, in the Little River in fall, Great Smoky Mountains National Park, 1986-1995. Flooding in 1990 precluded the collection of data.



1994 flood affected, however, all sizes of many nongame species and thus reduced their fecundity and the rate with which their abundances returned to many streams in the park.

Annual changes in density and biomass indicate that the annual variations in fish populations is largely due to abiotic events such as droughts and floods. The production of young-of-year salmonids is reduced by large floods with greater than 28,317 L/sec (>1000 feet3/sec) flows. The annual mortality of 1-4 year old rainbow trout and brown trout in Great Smoky Mountains National Park ranges from 60% to 70%.

Current sampling techniques in large streams have been reviewed by biologists from the National Park Service and from other agencies. The nongame fish protocol will be improved by sampling individual lengths and weights from a subset of individuals of each species. The improved protocol will permit a finer examination than traditional mass measurements of condition and size structure of nongame populations over time.

Brook Trout in Great Smoky Mountains National Park, Tennessee and North Carolina

The brook trout (*Salvelinus fontinalis*) is the only native salmonid in Great Smoky Mountains National Park. In the Southeast of the United States, the range of the brook trout has been profoundly reduced since 1900. In the park, brook trout disappeared from more than 256 km (159 miles) of 679 km (422 miles) of streams where the species was believed to have been common until heavy logging was done prior to the establishment of the park in 1934. Distribution surveys in the 1950s and in 1970 indicated that the number of kilometers of streams occupied exclusively by brook trout had declined by about 224 km (139 miles) since the 1930s.

The difficulty with conducting park-wide surveys has precluded a determination of changes in fish populations since 1970. Since then, allopatric exotic rainbow trout (*Oncorhyncus mykiss*) encroached into streams that were once exclusively inhabited by brook trout. Current information suggests that encroachment of rainbow trout has slowed because the species has difficulty moving in high gradient streams. However, increasing acidification of headwater streams threatens the persistence of brook trout populations.

Protocols for monitoring brook trout, aquatic macroinvertebrates, and water quality have been geographically and temporally integrated to determine population trends and provide data for management. In 1996, distribution surveys were conducted in the west, middle, and east prongs of the Little River watershed. The distributions of allopathic and sympatric brook trout populations were determined and sampling sites for the determination of annual variations in fish populations from abiotic or biotic factors were selected in the eight streams that in turn were selected for long-term monitoring.

Brook trout population dynamics are monitored annually in 25 sites in 11 streams and 7 watersheds. These sites include allopatric and sympatric populations, so that variations in populations can be evaluated and attributed to either biotic or abiotic factors or to the effects of nonnative salmonids. Population density seems to be most affected by droughts and floods. Spring floods that scour substrate wash eggs from the gravel and lower the density of young-of-year trout by as much as 90%. The adults of the population do not seem to be seriously affected by floods but, by droughts. Overall, the data to date suggest that the brook trout populations are stable and near the carrying capacity in each stream.

Land Birds in Denali National Park and Preserve, Alaska

Birds from all over the globe come to Denali National Park and Preserve to breed (Fig.28). Indeed, migratory birds—many of which winter in Central and South America—strongly dominate the avian community in the park. However, concern among ornithologists about the population trends of neotropical migratory birds (i.e., species that winter in the tropics and breed in the Nearctic) has been growing. Evidence of declining abundances of several species is strong, but the exact reasons for the declines are unclear. The pristine boreal habitats of interior Alaska provide researchers with the opportunity to determine whether problems on the breeding grounds affect migrants on their wintering grounds.

Figure 28. Songbirds captured in Denali National Park and Preserve, Alaska, are measured and banded before release.

Since 1992, the Alaska Bird Observatory has tested a variety of techniques for surveying landbirds. The primary objective is to develop protocols that quantify annual variation in relative abundances of migratory and resident species. The methods that are developed in the park should be transferable to other areas in Alaska to gain a broad picture of the status of songbirds throughout the subarctic.

Systematic surveys revealed 86 taxa of birds in 1994, 80 taxa in 1995, and again 86 in 1996. Species richness was greatest on the western side of the park, which is characterized by a wide variety of habitat types including extensive marshes and ponds. The relative abundance of most species also was similar between years. The abundances of species that were rare tended to fluctuate widely between years; often these birds were absent. In contrast, the annual variation in the population sizes of species that were common and widespread was small, which is a pattern that previous studies in this region of Alaska also brought to light.

Cooperative Monitoring of Productivity and Survivorship of Migratory Land Birds in Denali National Park and Preserve, Alaska

Migratory land birds may be sensitive indicators of regional and global environmental changes. Trends in population sizes suggest that the abundances of many species of land birds are severely declining. Trends provide, however, no information on primary demographic parameters—productivity and survival—for determining when in the life cycles of land bird species problems are occurring or to what extent observed population-size trends are being driven by factors of natality and mortality. Without data on productivity and survival, key ecological processes that drive the population-size trends cannot be identified and management that reverses the declines cannot be developed.

Since 1989, the Institute for Bird Populations has coordinated the cooperative monitoring of avian productivity and survivorship (MAPS) by public and private agencies and bird banders who maintain a North American network of stations where birds are captured with mist nets and banded. The objectives are the making of estimates of adult survival and of recruitment into the adult population and the determination of indices of population size and post-fledging productivity in land bird species. The estimates and indices can be used to investigate temporal, spatial,

and between-species patterns in primary demographic parameters to identify proximal causes of population changes, to identify management for reversing declines, and to evaluate the effectiveness of management.

The Institute for Bird Populations established five stations in Denali National Park and Preserve in 1992 and operated these stations during the past 5 years. Field and analytical techniques were tested, refined, and formalized. During 1992-96, the operation revealed that:

The total adult population size tended to be higher in habitat of primarily willow scrub than in habitats of primarily spruce (*Picea* spp.) or alder (*Alnus* spp.) forests. Productivity, however, tended to follow the opposite trend. Such information suggests that in Denali National Park and Preserve, the natural mosaic of habitats is most conducive for high population levels and high productivity in land birds.

Productivity indices (proportion of young in the catch, which averaged 0.6-0.7) tended to be higher than productivity indices of the same and similar species in the lower 48 states (which averaged 0.2-0.6). This supports the notion that birds that breed at higher latitudes produce more young, presumably because of a combination of a greater temporal concentration of food resources, more daylight hours for foraging and feeding young, and lower rates of predation on eggs and nestlings and of brood parasitism.

Productivity was relatively constant in 1992, 1993, and 1995 despite pronounced differences between the times when breeding started in those years. Productivity in 1994, however, was substantially lower than in the other three years, especially in ground nesting species. Heavy rains during the latter half of June 1994 may have destroyed nests or caused desertions of broods by females. In 1995, productivity rebounded strongly to pre-1994 levels, particularly in ground nesting species.

Adult population sizes of most species, especially ground nesters, was lower in 1995 than in 1994, seemingly because of the low productivity in 1994.

The population sizes of three species—the Arctic Warbler (*Phylloscopus borealis*), Swainson's Thrush (*Catharus ustulatus*), and Common Redpoll (*Carduelis flammea*)—declined substantially during 1992-95. The population sizes of two less common species—the Alder Flycatcher (*Empidonax alnorum*) and Varied Thrush (*Ixoreus naevius*)—also seemed to have declined during 1992-95. Population levels of these species should be monitored closely.

The population levels of three species—the Orange-crowned Warbler (*Vermivora celata*), Yellow-rumped Warbler (*Dendroica coronata*), and Dark-eyed Junco (*Junco hyemalis*)—increased substantially during 1992-95. Short-term increases were also noticed in the population levels of less common species, Gray Jay (*Perisoreus canadensis*), Ruby-crowned Kinglet (*Regulus calendula*), Gray-cheeked Thrush (*Catharus minimus*), Hermit Thrush (*Catharus guttatus*), and Fox Sparrow (*Passerella iliaca*). In general, the abundances of species tended to increase rather than decrease during 1992-95, suggesting that the bird populations in the park are healthy.

Estimates of annual adult survival of seven migratory species were lower than analogous estimated adult survival of same or similar species in the western United States. The differences may have been due to the longer migration routes of birds that breed in Alaska or different ecological conditions on the winter ranges, which are not the same winter ranges of species that breed in the western United States.

Species-specific biases in productivity indices were small, and indices and estimates of primary demographic parameters can provide useful information for management at the scale of a single national park. These conclusions were drawn from predictions by a simple demographic model of mean annual productivity indices and from estimated survival.

The productivity indices, estimated survival, and population-size trends of the seven species suggest that poor productivity was the primary cause of the short-term declines in the abundances of the three species with the lowest productivity indices: Arctic Warbler, Swainson's Thrush, and Common Redpoll. Moreover, the estimated survival of the Swainson's Thrushes was not lower in Denali National Park and Preserve than elsewhere in the western United States. Adult survival and productivity indices of the Arctic Warbler were low and may have contributed to the short-term decline in the abundance of this species. In contrast, the three species with short-term increases in abundances were characterized by high productivity and relatively high survival.

Changes in the Reproductive Success of Golden Eagles in Denali National Park and Reserve, Alaska

Denali National Park and Preserve provides valuable nesting habitat for many species of birds, including for such predatory birds as the Golden Eagle (*Aquila chrysaetos*). Each year, tens of thousands of visitors are thrilled to see these majestic birds nesting within full view of the Denali Park road.

The National Park Service has been monitoring Golden Eagles in Denali National Park and Preserve since 1987. Currently, this study is the only long-term ecologically based study of migratory Golden Eagles in the northern latitudes of North America. During the past decade, long-term studies in the western United States revealed yearly declines in the number of Golden Eagles in fall migration. Because most Golden Eagles are resident at more southern locations, many of the fall migrants are probably from northern latitudes. Results from the study in the park, therefore, have broad-scale implications for the conservation of Golden Eagles throughout the western United States.

More than 50 years ago, Adolf Murie studied the food habits of nesting Golden Eagles in Denali National Park and Preserve. Murie suggested that at least 25 pairs of Golden Eagles were nesting in the northeastern portion of the park. Decades later, through extensive surveys from 1987 to 1996, biologists discovered that the largest known breeding population of Golden Eagles in Alaska is in the park. Since 1988, the occupancy and reproductive success by Golden Eagles in 75 nesting territories have been monitored each year. The data are used to make inferences about the population status of Golden Eagles in the park and to compare the reproductive success of this Golden Eagle population with those of eagles in other areas throughout the world.

Since 1988, the occupancy of nesting territories has remained stable. However, the eagles were not marked, and whether subsequent occupancies of a territory were by the same individual cannot be determined. Furthermore, the lack of mortality data precludes evaluations of turnover rates and the extent of recruitment required for population stability. However, based on occupancy data, the territorial population has remained stable during the study period.

Overall productivity of the population (measured as the number of fledglings per monitored nesting area) has drastically varied during the study period. The proportion of pairs that laid eggs decreased steadily each year from 90% in 1989 to 33% in 1994. However, incubating rates began to increase in 1995 and 1996. The hatching rate also varied greatly, ranging from 42% to 83%. Overall population productivity varied from a low of 0.13 fledglings/nest in 1994 to a high of 0.88 fledglings/nest in 1989. Despite changes in hatch rate and overall population productivity, median brood sizes of 1.13-1.68/nest remained stable during the study period (Table 12).

Without anthropogenic factors, much of the variation in the reproductive success of birds of prey can be related directly to food supply. Egg-laying highly correlates with observed highs and lows in the popula-

tion cycles of snowshoe hares (*Lepus americanas*) and willow ptarmigans (*Lagopus lagopus*) in the study area. The correlation suggests that prey availability before egg-laying plays a major role in determining how many eagles lay eggs each year. When eagles return to the park in late winter (March), the diversity of available prey species is low. Based on observations, snowshoe hares and willow ptarmigans are the two most common available prey species for eagles during March. At that time, other common prey species of Golden Eagles in summer such as the hoary marmot (*Marmota caligata*) and the arctic ground squirrel (*Spermophilus parryii*) are still hibernating.

Research in Denali National Park and Preserve has only begun to uncover some factors that regulate the reproduction of Golden Eagles. So far, biologists have not detected direct relations between weather conditions and reproductive success. The relation between weather and prey availability has not yet been examined.

Research during 1997-99 will be concentrated on environmental factors that may affect the population productivity of the Golden Eagle. The role of habitat quality (including prey availability) in relation to occupancy of the nesting territory and reproduction and the role of wintering habitat and its relation to future reproductive efforts will be examined. Researchers determined that prey availability and weather during winter can influence reproduction in Golden Eagles. Because Golden Eagles in the park spend nearly 4 months on their wintering grounds annually, locating and assessing these areas in relation to reproductive success is important information about the ecology of the Golden Eagle. Satellite radio telemetry will be used to determine the annual movements of adult eagles. The studies will be conducted cooperatively by the Alaska Support Office of the National Park Service and the Forest and Rangeland Ecosystem Science Center of the Biological Resources Division, U.S. Geological Survey. The studies will be funded by the Natural Resource Protection and Preservation program of the National Park Service.

Table 12. Reproductive success of Golden Eagles (*Aquila chrysaetos*) in a study area, Denali National Park and Preserve, Alaska, 1988-1994.

Year	Occupancy Rate[a]	Incubating Rate[b]	Success Rate[c]	Fledglings/Area	Median Brood Size at Fledging
1988	85.71	77.08	75.68	0.68	1.36
1989	75.76	90.00	77.78	0.88	1.66
1990	69.70	82.61	73.68	0.71	1.68
1991	77.27	68.63	82.86	0.65	1.48
1992	81.43	63.16	52.78	0.37	1.37
1993	80.88	45.45	68.00	0.34	1.35
1994	85.29	32.76	42.11	0.13	1.13
1995	85.29	46.55	70.37	0.37	1.32
1996	87.50	42.86	88.89	0.43	1.30
Mean	80.98	61.01	70.24	0.51	1.40

[a]occupancy rate = number of occupied nests in the study area

[b]incubating rate = number of nests in which an incubating adult, eggs, or fresh eggshell fragments in fresh nesting material were observed

[c]success rate = number of nests in which one or more nestlings reached the age of 51 days; at that age, nestlings are assumed to be fledglings

The Island Fox on the Channel Islands, California

The island fox (*Urocyon littoralis littoralis*; Fig. 29) occurs only on the Channel Islands of California. Listed as threatened by the state of California, the fox is a diminutive relative of the mainland gray fox (*U. cinereoargenteus*) and inhabits the six largest of the eight Channel Islands. Island foxes are relatively abundant generalist predators that probably affect a variety of other species. The species' unknown population status, vulnerability to disease, and status as the largest native mammal on the islands justify monitoring the fox.

Figure 29. Island fox, *Urocyon littoralis littoralis*.

From 1994 to 1996, the size of the island fox population on San Miguel Island severely declined (Fig. 30). The decline may reflect a natural fluctuation in the size of the population in response to changes in food availability because of weather. Alternatively, the downward trend in the abundance of the fox on San Miguel Island may have been due to a virus in the population. Previous testing of the foxes on San Miguel Island revealed past exposure to canine parvovirus and canine adenovirus. No antibodies to canine distemper were found in any of the fox populations on the Channel Islands, although canine distemper was identified as a factor in periodic declines of the abundance of the gray fox on the California mainland. It is also possible that island foxes on San Miguel Island were exposed to the San Miguel Sea Lion Virus. The virus is a member of a group called the caliciviruses, which commonly cross species barriers. It is always present in sea lions (*Eumetopias jubatus, Zalophus californianus*) and northern fur seals (*Callorhinus ursinus*) on San Miguel Island, where it causes vesicular lesions on the flippers of pups. Thus far it has not been linked to mortality in sea lions, but the virus seemingly mutates annually and creates new varieties, some of which are more virulent than others. Antibodies for the virus have been found in the island foxes and feral pigs on Santa Cruz Island. Whether foxes on San Miguel Island have ever been exposed to the virus (perhaps from feeding on pinniped carcasses) and whether exposure to the disease affects the health of the foxes are not known. If disease was the agent, the direction of the decline in the population size of the foxes on San Miguel Island suggests a disease outbreak that originated at the western end of the island near Point Bennett, the largest pinniped rookery on the island.

The park is currently seeking funding to investigate possible causes of the observed decline in the abundance of island foxes on San Miguel Island and causes that may drive fox population dynamics. The

Figure 30. Density of the island fox, *Urocyon littoralis littoralis*, on San Miguel Island, California. 1993-1996.

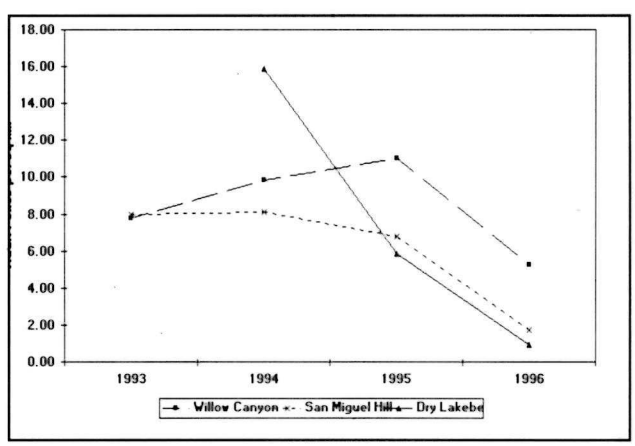


Figure 31. Radio-collared wolves, *Canis Lupus*, provide information about predator-prey interactions that affect wolves, caribou, *Rangifer tarandus*, and moose, *Alces alces*, populations. Denali National Park and Preserve, Alaska.

proposed study will be focused on the role of disease in the ecology of the fox as indicated by seroprevalence to various diseases before and after decline and on the influence of weather and prey availability, as indicated by studies of prey availability and selection of prey by the foxes.

Population Trends of Wolves and Caribou in Denali National Park and Preserve, Alaska

Management of gray wolves (*Canis lupus*) and their prey (Figs 31 and 32) in interior Alaska has been a subject of great controversy during the last three decades. Recently, a heated debate was rekindled by renewed interest in controlling wolves to bolster two populations of caribou (*Rangifer tarandus*) adjacent to Denali National Park and Preserve . Research in the park provides information about the declines of caribou populations and some of the possible causes. The fluctuating populations of both species illustrate the complex requirements for managing these species to meet a diverse array of public interests.

Wolves and caribou are two components of the large mammal community of Denali National Park and Preserve. Concomittant with the 1980 park expansion to more than 18,900 km^2 (>7300 mi^2) of central Alaska, the relation between these large mammals became the only one of its kind that is virtually unaffected by human harvest. Therefore, the park provides a unique opportunity for the study of the natural interactions of these species. The findings may provide basic information for the management of wildlife elsewhere.

Since 1986, researchers from the National Park Service and the U. S. Fish and Wildlife Service (now the Biological Research Division of the U. S. Geological Survey) have studied wolves and caribou in Denali National Park and Preserve. The objectives were the determination of the numbers and status of the species and the gathering of information about the interactions of the two species in the protected subarctic ecosystem.

Figure 32. Caribou, *Rangifer tarandus*, are fitted with radio collars to monitor survival. Denali National Park and Preserve, Alaska, 1996.

Snowfalls had been light (about 100 cm/year or 39 in/year) in winters of 1976-86 before the studies began but have been above average since then. During winters 1990-91 and 1992-93, snowfalls set records. More than 390 cm (154 in) of snow fell or four times as much as in the early years of the study. This change in snowfall had profound effects on the wildlife in central Alaska. The trends in the population sizes of the caribou and wolves in the park are strong evidence of the natural fluctuations in a dynamic and variable environment.

The Denali caribou herd increased from about 1000 animals in 1975 to 2600 in 1986 during the decade of mostly below-average snowfalls and increased at about 7% per year in 1986 when the research began. Approximately 46 wolves inhabited the 10,000 km^2 (3900 mi^2) range of the caribou herd in the early years of the study. The number of wolves was lower than expected from the abundance of large prey species in the park. Light snowfalls were favorable to caribou, and few died. Wolves preyed primarily on moose (*Alces alces*) and preyed on only a few very young and very old caribou. The reproduction of wolves was low, and the dispersal of young wolves was high. Several wolves died in fights between packs.

When winters became more severe again in 1988-89, the number of wolves increased rapidly to 74 within only 2 years. Reproduction increased, and the dispersal of young wolves decreased. In the deep snow, caribou were vulnerable to predation and replaced moose as the most important prey species for wolves. Losses of adult female caribou increased eight-fold to nearly 20%/year. Between 1990 and 1991, nearly half the adult males (about 500 animals) died. The caribou herd stopped growing in 1990 at about 3300 and plummeted to 1700 by 1993—-a 50% decline in only 3 years. At the same time, the number of wolves in the range of the caribou herd also declined to about 60 individuals—a 23% reduction between March 1990 and March 1993.

Subsequent to the reduced availability of forage on the alpine ridges and the increased energy costs of getting to forage under deep snow, the production of calves decreased. Coincident with the increased snowfall, the age at which adult females first reproduced increased from 2 years to 3 years, fewer adult females were pregnant, the birth weight of young was 28% lighter, and stillbirths were noted for the first time in the study. Survival of 4-month-old young substantially declined from nearly 56% in the early years to about 9% in the later years. When young were born large, the few that died were killed by predators primarily within the first 10 days of their lives. The smaller young that were born in later years died in greater numbers during the early 10 day period but also continued to be killed throughout the year, indicating that they were more vulnerable to predation than the larger young.

The fluctuating abundances of wolves and caribou in Denali National Park and Preserve are probably indicative of normal adjustments to the highly variable winter weather of the region. In the short space of 8 years, the caribou herd increased by 36% and declined by 50%. At the same time, the number of wolves almost doubled but then declined to one and one-half times of its size at the beginning of the study.

Information about the wolves and caribou in Denali National Park and Preserve provides a framework for managing game in the care of the National Park Service elsewhere as well as throughout Alaska and Canada. Understanding the roles of natural factors is essential to recognizing effects of hunting and other anthropogenic changes. The trends in the size of the caribou herd in the park are representative of population-size trends of several other herds throughout central Alaska, including the caribou in the Wrangell-St. Elias National Park and Preserve and the Yukon-Charley Rivers National Preserve. Reductions of hunting of these herds have led to clamorous debates over the merits of control of wolves to provide more caribou for human harvest. The study in Denali National Park and Preserve revealed information about naturally regulated predator-prey relations that has already benefited the management of caribou and wolves in these and other areas of Alaska and Canada. Although the future of wolves and caribou in interior Alaska is secure, natural fluctuations like those observed in the park will generate continued controversy over the management and allocation of these important wildlife species in and outside of Alaska's national parks and preserves.

Black Bears in Great Smoky Mountains National Park, Tennessee and North Carolina

Great Smoky Mountains National Park provides refuge for a significant portion of the black bear (*Ursus americanus*) population in the Southern Appalachian region. In the park, the bear population seems to be near the carrying capacity but is threatened by increasing demands for timber and recreation on national forest lands surrounding the park, increased development on adjacent private land, and illegal hunting.

Long-term monitoring of the black bear in Great Smoky Mountains National Park with mark-recapture techniques and aerial telemetry serves to determine changes in sex and age structure, mortality, natality, and movement patterns. The relative changes in the density and distribution of the bears are estimated from population indices at bait stations. Hard mast is surveyed to determine the availability of important foods such as acorns in fall and its influence on black bear population dynamics.

Monitoring from December 1995 through March 1996 included the location of 13 of 16 radio-collared sows in their winter dens. Ten of them were visited in their dens. The production of at least eight cubs was documented. Two yearlings were radio-collared for future tracking of their dispersals. Data on capture, mortality, and natality are used to estimate the population size, survival, and capture probabilities.

From 23 May to 2 August 1996, 63 bears were captured—4 were captured twice. Fifty of the captured bears were males. The average age of the males and the females was 5.6 years. The mean ages of the males (5.3 years) and females (6.6 years) were about the same. The average weight of all captured bears was 71.2 kg. The average weight of males was 77.1 kg and of females, 49.4 kg. These weights were 14-22% higher than the average weights of bears captured in 1995.

The bait-station survey was conducted from 10 July to 24 July 1996. The results suggested only a slight decline in the bear population since 1995, which may simply indicate a variation in the survey technique. The bait-station survey may not be very sensitive when bear populations are relatively high. The number of bear visits was lower at high elevations than at low elevations. The difference may reflect the distribution of available foods.

Hard mast—notably oaks (*Quercus* spp.), which are the most important mast-producing trees in the park—was surveyed during 9-29 August 1996 to determine the availability and distribution of hard mast. The results suggested a fair production of mast by all oaks and a good production by white oaks that should benefit black bears. After years of abundant white oak mast, sows nearly always respond with high productivity. Therefore, the number of cubs in 1996-97 is expected to be high.

Dall Sheep in Denali National Park and Preserve, Alaska

From the end of the nineteenth century until establishment of McKinley National Park in 1917, market hunters who provided meat for railroad and mining camps, extirpated several local populations of Dall sheep (*Ovis dalli*). Concern about the preservation of the sheep was a major factor for the establishment of the park. Inside the park boundaries, wildlife has been protected. Hunting is permitted only in areas that in 1978 were combined with McKinley National Park to form Denali National Park and Preserve.

Dall sheep are easily visible from the park road and are a major attraction of visitors. They are also a vital component of the Alaskan Range. During the past 62 years, biologists conducted surveys to estimate the sizes and sex and age compositions of Dall sheep populations throughout the park. Adolf Murie began a study of the relation between the timber wolf (*Canis lupus*) and Dall sheep in 1939. He accumulated extensive data on each species, including age and sex compositions, from ground surveys during 3 years. On 4 August 1934, park personnel conducted the first aerial census of wildlife in the park and

counted 2280 Dall sheep during a 4 hr flight. The second aerial census of sheep was conducted in 1947. Thereafter through 1968, aerial surveys were conducted approximately every 2-3 years.

Throughout the 1970s and 1980s, the National Park Service and the Alaska Department of Fish and Game conducted surveys of Dall sheep in the park. Information about the populations and their habitat use during 20 years was collected from ground and aerial counts. However, the survey methods were not standardized and the survey areas were not always the same. Therefore, determinations of the status and population-size trends of the Dall sheep populations were difficult.

Now, aerial surveys are conducted yearly over a smaller section of sheep habitat in the eastern area of the park and on the southern side of the Alaska Range, which was not included in previous surveys.

In 1996, a significant portion of sheep habitat in the park was surveyed during winter and summer as part of a study of seasonal migration in sheep. During the survey in summer, 1873 sheep were counted in areas over which previous surveys had been conducted, and 379 sheep were counted inside park boundaries on the southern side of the Alaska Range.

Giant Coreopsis

The giant coreopsis (*Coreopsis gigantea*) is a member of the Sunflower Family (Compositae) that responds quickly to winter rains with bright green carrot-like leaves and yellow composite flowers. It is a fleshy plant that is vulnerable to grazers. Although giant corepopsis once covered much of Santa Barbara Island, its occurrence was reduced to sites in canyons after the introduction of the Old World rabbit (*Oryctolagus cuniculus*) in the 1940s. After the eradication of the rabbit from Santa Barbara Island by 1982, the distribution of the giant coeopsis seems to be expanding slowly. However , recruitment of young coreopsis has been low and may be hindered by the foraging by deer mice (*Peromyscus* spp.)

In 1995, the location and compilation of data from all ground and aerial surveys of sheep in the park were implemented. Summaries from surveys in 1934 and 1947 provided only a total count of sheep and general descriptive information about the geographic extent of the survey. Information from other early surveys consisted of only the number of animals in each group. However, locations of sighted groups were plotted on topographic maps. Surveys since the 1970s have provided information on age and sex compositions of groups and recordings of locations of sheep on topographic maps. Data from most surveys have been located and entered into a computer database. Locations of sheep groups are being digitized into the GIS database of the park.

The long-term data will enable researchers and resource managers to analyze trends in population sizes, to monitor productivity from estimated yearly ewe:lamb and ewe:yearling ratios, and to determine changes, if any, in habitat use over time. Currently, the effect of the park road and vehicle traffic on the seasonal migrations of the Dall sheep are being studied. Examinations of historic and recent uses of seasonal ranges may help researchers determine whether migration patterns have been disrupted.

Adolf Murie included other predator and prey species in his landmark study of sheep, so that decisions about management of wolves would be based on the interactions of wolves with other organisms in a large natural system. The continued long-term monitoring of several predator and prey species will provide important data for understanding the natural variations of population sizes of species in the park.

The Significance of Deer Mice in the Channel Islands Ecosystem in California

The population-size trend of deer mice (*Peromyscus maniculatus anacapae, P. m. elusus, P. m. streatori*) in the Channel Islands ecosystems is monitored because the mice are dominant components of island communities. They are abundant generalist granivores with a significant influence on plants and terrestrial invertebrates on the islands. The estimated densities on the islands in 1995 ranged from 47.2 mice/ha (117 mice/acre) on the Middle Anacapa Island to 419.8 mice/ha (1037 mice/acre) on the San Miguel Island. The influence of the mice is particularly pronounced on Santa Barbara Island. On that island,

Figure 33. Giant coreopsis, *Coreopsis gigantea* (Kellogg) Hall. Channel Islands National Park, California.

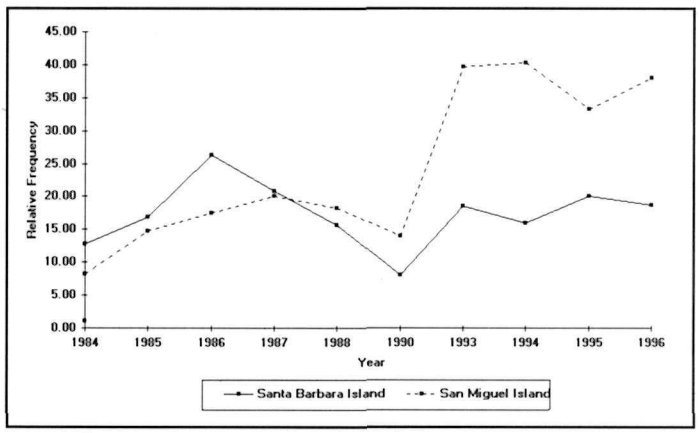
predation by deer mice on the eggs of the burrow-nesting Xantus' murrelet (*Synthliboramphus hypoleuca*) may be a primary factor that limits the recruitment of this rare seabird; the consumption of seeds and seedlings of the giant Coreopsis (*Coreposis gigantea*; Fig. 33) by deer mice is hindering the recovery of this native shrub (Fig. 34); and the number of wintering and breeding owls that feed on mice is largely determined by the abundance of deer mice.

Small Mammals of Rock Creek in Denali National Park and Preserve, Alaska

Voles in Denali National Park and Preserve play a significant role in the trophic structure of the park. They consume plant material and in turn are food for the furbearers and avian predators in the park. To develop a better understanding of the role of small mammals in the park, monitoring was initiated in the Rock Creek watershed.

Small mammals are monitored in two habitat types: riparian habitats and open canopy shrub habitats. Three species of voles (*Clethrionomys rutilus, Microtus oeconomus, M. miurus*), one lemming (*Synaptomys borealis*), and two species of shrews (*Sorex cinereus, S. palustris*) were captured in the Rock Creek watershed. Monitoring revealed that small mammal populations in the watershed substantially fluctuated during 1991-96. A sixfold increase within 2 years has been observed. The greatest influence on the fluctuating abundances of small mammals that do not hibernate seems to have been the degree of winter severity.

Figure 34. Relative frequency of the giant coreopsis, *Coreopsis gigantea* (Kellogg) Hall, on Santa Barbara and San Miguel Islands, Channel Islands National Park, California. 1984-1996.



By far the largest segment of the small mammal community in the Rock Creek watershed in numbers and in biomass has been the northern red-backed vole (*Clethrionomys rutilus*) whose demographic patterns have been the focus of documentation. Within-year variation in abundance was substantial. Remnant survivors of one winter reached peaks of abundances at the onset of the next winter. Between years, variations in abundance in fall were substantial. In 1992 and 1994, abundance was low; in 1993 and 1995, abundance was high; and in 1996, abundance was intermediate. In 1993 and 1995, when abundance was high in both habitats, survival and recruitment patterns were substantially different between years but not between habitats. This finding demonstrates that different demographic processes can give rise to similar abundance patterns. Polymorphism in the red-backed vole has also been noted during the study, and the incidence of the dark morph has increased during the study.

The study of voles in Denali National Park and Preserve unexpectedly assisted with the inventory of fungi in the park. Fungi—grown from spores—in fecal samples of the voles were species that had not been detected by staff during inventories of fungi.

Black-tailed Prairie Dogs in Seven Prairie Parks

Before European settlement of the Great Plains, the black-tailed prairie dog (*Cynomys ludovicianus*; Fig. 35) may have occupied 20% of the short- and mixed-grass prairies. Although the species now occurs in only 2% of its historic range, states generally still consider the black-tailed prairie dog a pest species. During the past 20-40 years, the black-tailed prairie dog has been extirpated from 5 of the 12 units in which it occurred in the Great Plains Prairie Cluster. In the remaining parks in the Great Plains, active colonies remain in only four units. These colonies are smaller than 50 ha. Long-term monitoring of the species and its ecosystems was implemented in 1995 to evaluate the current status of the species.

During summer 1995, inventory protocols and digital mapping technologies were developed to determine the distribution and abundance of the black-tailed prairie dog populations in seven parks in the Great Plains. In each of the seven parks, permanent plots for visual monitoring of prairie dogs and permanent plots for determining the compositions of vegetative communities were also established.

Figure 35. Black-tailed prairie dog, *Cynomys ludovicianus*, in the Great Plains Prairie Cluster, 1996.

Inventories of the prairie dogs were made in six units. In the Badlands National Park, South Dakota, prairie dogs were monitored as part of the recovery of the endangered black-footed ferret (*Mustela nigripes*). During summer 1996, the monitoring protocols were tested in Scotts Bluff National Monument, Nebraska.

Results of the inventories in 1995 indicated that park managers have inaccurately estimated prairie dog colony sizes and population abundance by 100%-250% (Table 13). Four parks host prairie dog populations of fewer than 400 individuals; the other three parks host populations that are smaller than the estimated minimum viable population size. Vegetation analyses suggested that, although the parks with prairie dogs are roughly aligned along a north-south transect from northern mixed-prairie of North Dakota to shortgrass prairie of southeastern Colorado, low successional weedy vegetation and moderate species richness are characteristic of all colonies (Table 14).

Park-specific handbooks with protocols for inventories and long-term monitoring of black-tailed prairie dogs are expected to be ready for distribution in time for implementation of the surveys in summer 1997.

Table 13. Distribution and abundance of the black-tailed prairie dog (*Cynomys ludovicianus*) in seven units of the National Park System, 1995.

	Distribution (ha)		Abundance (pd[a]/ha)		
National Park System Unit	**Actual[b]**	**Estimated[c]**	**Actual[b]**	**Estimated[c]**	**Actual Population[d]**
Scotts Bluff Nat'l Monument, Nebraska	1.2	2.4	15.3	12.0	18.0
Bent's Old Fort Nat'l Historic Site, Colorado	6.5	16.2	10.6	12.0	69.0
Fort Larned Nat'l Historic Site, Kansas	6.9	16.2	39.5	unknown	273.0
Devils Tower Nat'l Monument, Wyoming	10.9	16.2	36.1	12.0	393.0
Theodore Roosevelt Nat'l Park, North Dakota	226.8	356.4	42.7	62.0	9,685.0
Wind Cave Nat'l Park, South Dakota	437.4	506.3	52.4	unknown	22,920.0
Badlands Nat'l Park, South Dakota	1,660.0	--	49.0	--	81,340.0

[a] Prairie dogs
[b] Derived from digital mapping of colony size or visual count estimates of population abundance.
[c] Derived from estimates by park managers in a survey in spring 1995.
[d] Derived from actual distribution x actual abundance.

Table 14. Percentage plant cover in black-tailed prairie dog (*Cynomys ludovicianus*) colonies in Scotts Bluff National Monument, Nebraska. 1995.

Species			Cover
Common Name	**Scientific Name**		
Grasses:			
cheatgrass	*Bromus tectorum* (L.)[a,b]		28%
western wheatgrass	*Pascopyrum smithii.* (Rydb.) A. Love		19%
		Subtotal	47%
Forbs and Half-shrubs:			
longleaf groundcherry	*Physalis longifolia Nutt.*[b]		10%
common sunflower	*Helianthus annus* (L.)[b]		3%
common kochia	*Kochia scoparia* (L.) Schrad[a]		3%
common kochia	*Lactuca serriola* (L.)[a,b]		2%
Canadian horseweed	*Conyza canadensis* (L.) Cronq.[b]		2%
showy milkweed	*Asclepias speciosa* Torr.[b]		tc
nodding plumeless thistle	*Carduus nutans* (L.)[a,b]		tc
		Subtotal	20%
Total Live Plant Cover			68%
Bare Ground			7%
Litter			9%
Species Richness + 95% C.I.			11.85 + 4.1
Shannon Diversity Index			1.58
Evenness			0.54
Graminoid/Forb Cover Ratio			2.23
Native/Exotic Cover Ratio			0.86

[a] *Considered exotic to North America*
[b] *Considered weeds by Whitson , T.D., L.C. Burill, S. A. Dewey, D. W. Cudney, B. E. Nelson, R.D. Lee, and R. Packer. 1992. Weeds of the west. University of Wyoming Cooperative Extension Series, Laramie, Wyoming. 630 pp.*
[c] *trace of <1%*

Data Management in the I&M Program

The Inventory and Monitoring Program must manage the gathered information and must therefore develop policies, standards, and software to document and describe the collected data, to exchange and distribute data to others in and outside the service, and to archive and store data for ready access. The service must also make its spatial databases accessible on the information superhighway (i.e., on the Internet). Therefore, the I&M Program, the service's GIS Program, and others are jointly developing standards and guidelines to document natural resource data sets (i.e., metadata) and to acquire the hardware, software, and technical expertise for maintaining the data sets and making them available on the Internet.

The data management goal of the I&M Program is the development and implementation of multilevel strategies for planning, integrating, and preserving natural resource data for present and long-term information needs and for National Park Service management. The program is approaching this goal in several ways: Staff are (1) working with parks to develop uniform data management protocols and tools, (2) developing a servicewide I&M data management and inventory archiving plan, and (3) implementing Internet service via the World Wide Web with up-to-date information on I&M Program activities and accomplishments.

Data Management Protocols

Data Management Protocols were drafted with assistance from park data managers. The document features chapters with instructions for developing and writing a park-based data management plan, a database structure and software for cataloging ongoing and legacy data sets (*Dataset Catalog*), and generalized data handling procedures. The instruction chapter includes sections on the current status of resources, on data management strategies, on data management accomplishments, on activities and goals, and on implementation strategy and budget. The catalog is a database of natural resource data sets that incorporates abbreviated metadata for general use. It is park-based but can be aggregated for servicewide needs. The database was implemented via Microsoft Access with an automated data input form, links to other data and information, and an automated one-page report form. The chapter about procedures includes general guidelines for managing natural resource data sets. The guidelines are for tasks such as the entry, verification, validation, back-up, and editing of data or for more complex tasks such as the documentation, archiving, and dissemination of data. An appendix features several associated documents and examples.

The draft *Data Management Protocols* is presently under review by park data managers and I&M coordinators. The final document will be disseminated to the parks. Copies of the latest draft and the *Dataset Catalog* are available by request.

Servicewide I&M Data Management Plan

A plan for efficiently managing and archiving servicewide inventory data and products is currently being developed by I&M staff. Extant and future inventories generate a wide variety of data and require comprehensive planning of protocols and facilities that ensure long-term, efficient flow, archiving, distribution, and retrieval of data.

I&M Internet Service

I&M staff developed a worldwide web home page (http://www.aqd.nps.gov/natnet/nrid/im/index.htm) that features the *Natural Resource Inventory and Monitoring in National Parks* brochure. The brochure contains general information about the natural resource inventories and long-term environmental monitoring in the National Park Service. Fact sheets describing the status of each inventory will be added to the web pages in the near future. The pages maintain links to partners and other National Park Service entities associated with inventory and monitoring. I&M staff is also considering the feasibility of providing online access to selected inventory data in the future.

The I&M Training Program

The conservation of critical resources in parks requires comprehensive, interdisciplinary inventory and monitoring at the ecosystem level. The principles of that approach are described in NPS-75 *Servicewide Natural Resources Inventory and Monitoring Guideline*, and training in appropriate designs and implementation of inventory and monitoring is provided in the *Natural Resources Inventory and Monitoring* course.

The Natural Resources Inventory and Monitoring course presents a systematic and holistic approach to inventory and monitoring and is designed to: (1) provide an overview of the servicewide I&M Program, including staff roles and functions; (2) describe the step-down processes for conducting studies at park level; (3) identify major ecosystem components useful for inventory and long-term monitoring; and (4) provide data administration and reporting guidelines.

Figure 36. Harold Smith, Superintendent (retired) of Organ Pipe Cactus National Monument, giving an inspiring account of the critical need for long-term inventory and monitoring data sets and their roles in park management and resource protection.

The course was developed primarily by Dr. Gary Williams, the National Inventory and Monitoring (I&M) Program Manager, and by the regional I&M coordinators Dr. Sarah Allen, Patricia Patterson, and Lyman Thorsteinson. The course meets the needs of personnel who are responsible for developing or coordinating the design of I&M programs in their parks and for supervising the implementation of these programs. Thus, a major focus of the course is to ensure that participants will be able to develop and implement inventory and monitoring that provide park-specific information for planning, management, and decision-making.

Specific objectives of the developers were:

- the presentation of a systematic approach to developing an integrated, holistic I&M program;
- the introduction of the concepts of ecology as applied to an integrated I&M program;
- an explanation of the major steps in the I&M process outlined in NPS-75 and the development of a strategy for designing an integrated I&M program that meets specific park needs;
- a discussion of the ecological components, experimental design, statistical analyses, quality control, and assurance needs of an I&M program;
- a discussion of the role and methods of information management in an I&M program;
- a presentation of alternatives and methods for accomplishing I&M;
- and a presentation of a diversity of I&M case studies from parks.

When the 36-hr course was last conducted during 9-13 September 1996 in Ventura, California,

several prominent scientists from the National Park Service and various universities presented lectures. Dr. Dave Graber from Sequoia-Kings Canyon National Park gave a philosophical introduction to the concept of inventory and monitoring. Dr. James Quinn from the University of California, Davis, offered a session on database development and oriented students in the application of NPFAUNA and NPFLORA. Leslie Armstrong trained students in the I&M geographic information system databases such as soils, vegetation maps, and digital orthophoto quads. Dr. Robert Bernstein from Ecological Consulting, Inc., led a session on I&M data quality assurance and quality control. Students also were given background in ongoing monitoring of fire, water resources, and threatened, endangered, and sensitive species.

Harold Smith (Fig. 36), Superintendent at Organ Pipe Cactus National Monument, gave an inspiring account of the critical need for long-term inventory and monitoring data sets and their roles in park management and resource protection. Presentations of case studies were an important component of the course, and it included a one-day field trip to have the participants observe some of the long-term ecological monitoring projects that are parts of the Prototype Ecological Monitoring Program in Channel Islands National Park. In addition to observing first hand some of the monitoring in Channel Islands National Park, the participants were introduced to similar monitoring in Shenandoah and Virgin Islands national parks and at Montezuma Castle and Organ Pipe Cactus national monuments.

Tentative plans are to offer *Natural Resources Inventory and Monitoring* again for 25-30 participants in Ventura, California, during September 1997.

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