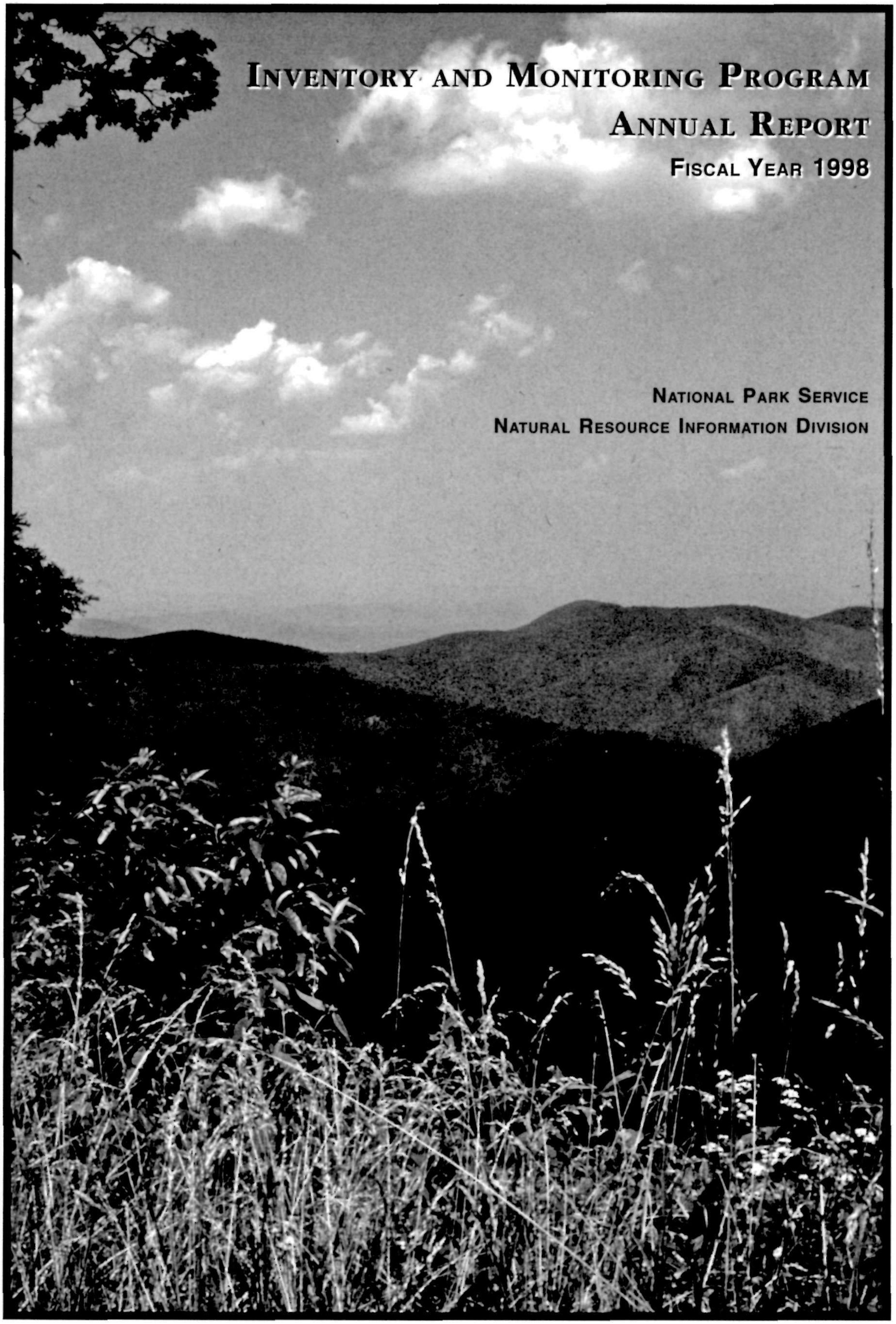
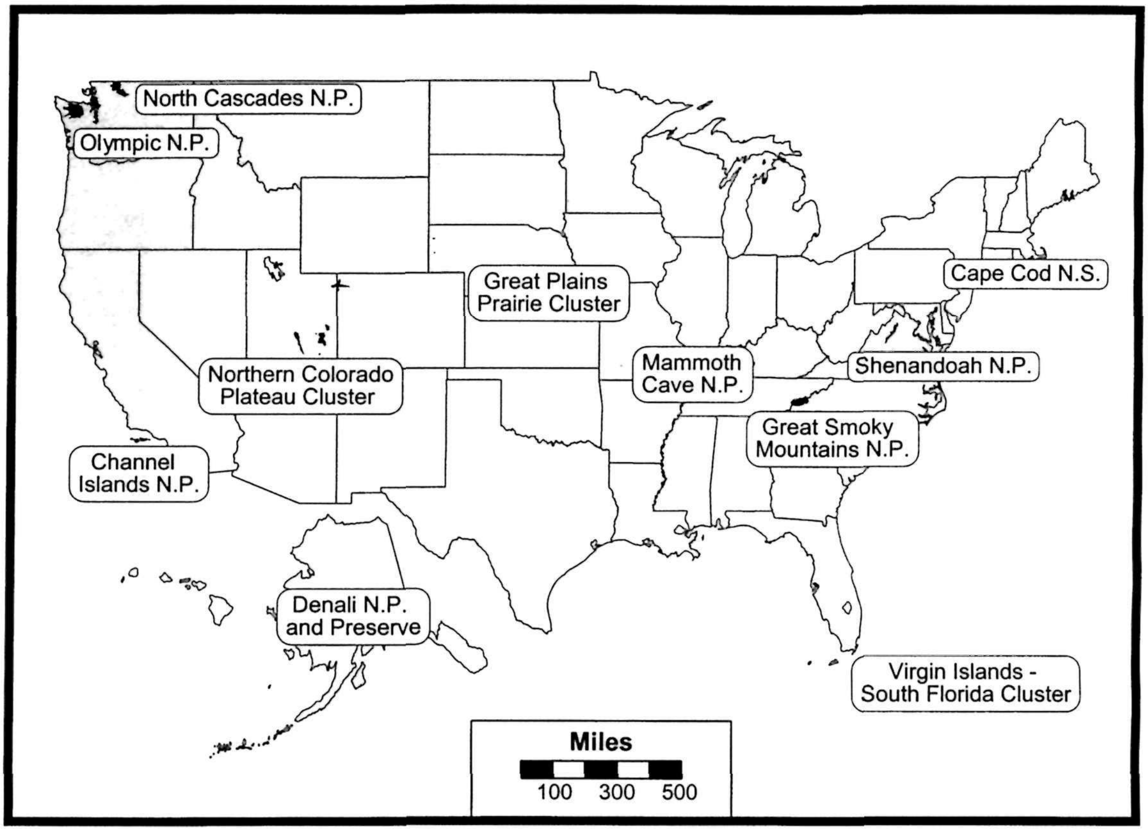


Inventory and Monitoring Program
Annual Report
Fiscal Year 1998

National Park Service
Natural Resource Information Division

COVER: VIEW FROM SKYLINE DRIVE, SHENANDOAH NATIONAL PARK, VIRGINIA. *PHOTOGRAPH BY DAVID DEMAREST.*



National Park System Units Selected for
Prototype Long-Term Monitoring of Natural Resources
Map by J. Gregson

Inventory and Monitoring Program

Annual Report

Fiscal Year 1998

National Park Service
Natural Resource Information Division

1201 Oak Ridge Drive, Suite 350
Fort Collins, Colorado 80525-55589

Natural Resource Information Division

The Natural Resource Information Division provides information that advances the management, protection, and understanding of natural resources in the national parklands and in associated ecological communities.

Inventory and Monitoring Program

The five goals of the Inventory and Monitoring Program are (1) the completion of baseline inventories of biological and geophysical natural resources in all National Park System units with natural resources, (2) the development of long-term monitoring of the status and trends of ecosystems at various spatial scales, (3) the application of geographic information systems and other means to identify and evaluate management of natural resources, (4) the integration of inventory and monitoring with park operations, and (5) the coordination of inventory and monitoring with other governmental agencies to further cost-sharing and to avoid duplication of effort.

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A limited number of copies of this report may be obtained from the Manager of the Inventory and Monitoring Program. The report may also be accessed from the World Wide Web at http://www.nature1.nps.gov/pubs.

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

PREFACE

The Natural Resource Information Division provides information that advances the management, protection, and understanding of natural resources in the national parklands and in associated ecological communities. In keeping with this mission, the division has published comprehensive illustrated annual reports of its Inventory and Monitoring Program and in 1997 gained approval by the U.S. Department of the Interior for publication of the reports as a national series.

Each report features five major sections. The first section describes the mission and structure of the I&M Program. The second section provides an account of the current status of natural resource inventories that are sponsored by the I&M Program. The lengthiest section is a comprehensive account of the monitoring and status of natural resources in 13 National Park System units that conduct prototype long-term ecological monitoring under the I&M Program. Data management in the I&M Program and the I&M Training Program are described in two other sections. Appendixes provide directories of staff, the I&M National Advisory Committee, and the I&M regional coordinators. The report material is technical but presented for a general audience.

Printed copies of the report are distributed to about 270 National Park System units with significant natural resources, to divisions, regions, and support offices, to partners of the I&M Program, and to depository libraries. Electronic copies of the reports are posted on NatureNet (http://www.nature.nps.gov/pubs), one of the World Wide Web pages of the National Park Service. A limited number of printed copies is available from the editor.

The chief of the Natural Resource Information Division, the manager of the I&M Program, and the editor of the annual report welcome comments about the report content and suggestions for its improved presentation.

Elizabeth Rockwell
Editor

Executive Summary

Natural resources in the National Park System are threatened by a variety of anthropogenic causes. Conservation in accordance with the mandates of the National Park Service and implementation of corrective management require early detection of changes and the quantification of trends in the conditions of natural resources. Therefore, the service established the 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 and strategies for monitoring the ecological communities in the National Park System.

In 1998, the I&M staff consisted of the service-wide program manager, a monitoring specialist, and an information management specialist. A national advisory committee and *ad hoc* working groups provided technical and policy assistance. The program maintained an I&M coordinator in each of 4 parks that conducts prototype ecological monitoring. Basic inventories and prototype monitoring were conducted in close partnership with the Biological Resources Division of the U.S. Geological Survey. Air quality is monitored with a system-wide National Park Service gaseous air pollutant monitoring network and by participation in the IMPROVE (Interagency Monitoring of Protected Visual Environments) national visibility monitoring network that is jointly funded and operated by the U.S. Environmental Protection Agency, the National Park Service, states, and other land management agencies. Wet deposition (precipitation chemistry) is monitored through the service's participation in NADP/NTN (National Atmospheric Deposition Program/National Trends Network). The Fiscal 1998 I&M Program budget was $6.19 million.

Prototype monitoring of natural resources continued to be conducted in Cape Cod National Seashore—Atlatic-Gulf coast biome—and in Channel Islands National Park—Pacific Coast biome, Denali National Park and Preserve—arctic and subarctic biome, the Great Plains Prairie Cluster—prairie and grassland biome, Great Smoky Mountains National Park—deciduous forest biome, and Shenandoah National Park—deciduous forest biome. Implementation of prototype monitoring continued in the Virgin Islands-Southern Florida Cluster—tropical-subtropical biome. Inventory and monitoring have also been implemented in Olympic National Park albeit without funding under the I&M Program.

Progress in inventories of bibliographies, base cartography, vegetation, and soils was significant in 1998. Baseline assessments of water quality in all parks with significant natural resources (~260) were funded. Baseline assessments of geology have been initiated and have not been fully funded. The assessment of baseline water quality was funded jointly with the Water Resources Division.

On Cape Cod National Seashore, reproduction of the federally listed endangered Piping Plover has not significantly changed. Air quality improved. Monitoring of other natural resources has not been implemented.

In Channel Islands National Park, sea star populations declined in kelp forest but remained stable in the rocky intertidal zone. Withering syndrome was still present in black abalone, and the abundance of the species continued to decline. The abundance of owl limpets dropped to alarming levels. The number of nesting pairs of all cormorant species decreased substantially, however, productivity of the birds improved. The breeding population of the Western Gull increased, and fledging success and productivity in this species were higher in 1998 than in any other year since 1994. The site occupancy by the Xantus' Murrelet decreased in some areas, but productivity in this species has remained relatively constant and even increased in 1998. The abundance of the island fox continued to decline, possibly from a combination of predation and diseases. The natality of the California sea lion and northern fur seal significantly declined in 1998.

In Denali National Park and Preserve, air quality remained unchanged, and weather was normal. An acceleration in the speed of ice motion on the Muldrow Glacier in 1997 did not continue in 1998. Changes in the mass balance of the East Fork Toklat Glacier in 1998 were significant. Melting near the glacier's terminus caused a profound drop of the ice surface. The glacier is being closely monitored in anticipation of a surge. Spruce cone production was four times larger than in previous years, and its relation to weather is under investigation. The breeding population of Golden Eagles in the park seems to be stable. The frequency of occurrence of most land-bird species remained relatively constant. The abundance of adult migratory land birds increased during 1997-98, and the population-size trends tended to be more positive in the park than in seven national forests in the Pacific Northwest. The abundance of voles was the lowest in 7 years, and these species seem to be at the trough of their population cycles. During the last few years, the Denali herd of caribou stabilized but recruitment of calves was low. The number of wolves was lower than earlier in the decade because the abundance and vulnerability of ungulate prey had decreased.

In the Great Plains Prairie cluster, restoration of native prairie vegetation continued in all six parks. The population density of the federally listed endangered Missouri bladderpod continued to fluctuate. No flowering western prairie fringed orchids, a federally listed threatened species, were sighted in Pipestone National Monument. Protocols are still being developed, and baseline data for other natural resources are being collected.

In Great Smoky Mountains National Park, air quality deteriorated. The number of rosettes of the Rugel's ragwort—an endemic species in the park—continued to decline. The number of American beech that died from beech bark disease increased. American mountain-ash produced abundant seeds after minimum defoliation and crown dieback from the mountain-ash sawfly. The abundance of the wood frog and spotted salamander declined. Populations of the brook trout remained unchanged from previous years. Fish species composition in large streams of the park has not changed since the 1970s. The abundance of breeding birds remained unchanged. An increase in the bear population in the park was attributed to maturation of the forest and a concomitant greater abundance of mast. The number of deer in Cades Cove did not change.

In Shenandoah National Park, air quality may have improved. Ice storms in February caused significant crown damage in chestnut-oak forests, and crown damage from the woolly adelgid continued to increase in eastern hemlocks. Shrub cover increased in Big Meadows, a native opening with rare plant populations and the only large non-forested area in the park. Sword-leaved phlox, a rare perennial endemic to mountainous areas of West Virginia and Virginia, continued to recover from earlier declines. Amphibians seemed to maintain breeding populations. Fish abundance was lower in 1998 than in previous years because of a small yearling class. Exotic trout continue to perpetuate themselves despite annual removals. The abundance of many adult land birds in the park decreased, but their productivity increased.

In Buck Island Reef National Monument in the Virgin Islands-Southern Florida cluster, coral reefs sustained damage from Hurricane George. However, species richness and cover increased in open spaces that previous hurricanes created. Coral bleaching from warm water temperatures during September-November was significant. In sea turtles, the number of recruit and returning migrant breeding females did not change significantly.

The 36-hour training course in inventory and monitoring of natural resources was held during Aug-Sep 1998 in Shenandoah National Park and is expected to be given again in Sep 1999 in Gatlinburg, Tennessee.

ACKNOWLEDGMENTS

Comments by S. Fancy and an anonymous reviewer improved the quality of the report. Cat Hoffman provided material from Olympic National Park. The design of the report benefited from a critique of the layout and enhancement of photographs by J. Selleck. Assistance from D. Joseph and E. Eisenhower improved the presentation of graphs. Nancy Keohane and D. Sanders helped respective park I&M coordinators with the assembly and coordination of material from Great Smoky and Shenandoah national parks.

The Inventory and Monitoring Program

Section cover. Photographs counter-clockwise from top right: Cape Cod National Seashore, Denali National Park and Preserve, Virgin Islands National Park, Great Smoky Mountains National Park, Shenandoah National Park, Channel Islands National Park, Great Smoky Mountains National Park. *Photographs courtesy of the respective National Park System units.*

Overview

The National Park Service is mandated to conserve the natural resources in the National Park System (National Park Service Organic Act, 16 U.S.C. 1 et seq., ch. 408, 39 Stat. 535). Significant natural resources occur in more than 265 of the 378 units of the system, 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 and strategies 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 (1) the identification of links between changes in resource condition and the causes of changes and (2) the elimination or mitigation of such causes. Inventory and monitoring provide important feedback about natural resource conditions to management, trigger specific management, and permit an 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. The integration will 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.

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 of selecting parks in which *prototype experimental monitoring* of each of 10 major biomes could be conducted. To ensure that the broad range of managerial situations is adequately represented, three of the prototypes were selected as *clusters*, i.e., groupings 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.

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

Staffing

In 1998, the service-wide I&M Program Manager and two support staff members of the Natural Resource Information Division in Colorado coordinated the I&M Program goals and objectives. A monitoring specialist, Dr. Steven Fancy, joined the immediate staff of the I&M Program Manager in Aug 1998. His principal function is support of natural resource monitoring by parks. A National Advisory Committee—which consists of park superintendents, natural resource management specialists, program managers, and research scientists of the Biological Resources Division (US 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 of Natural Resource Stewardship and 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

U.S. Geological Survey

Prototype monitoring and basic inventories are being implemented in 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 operational staff are provided by the Biological Resources Division. After completion of research and protocol designs, monitoring is considered operational. From then on, funding and full-time employees become the responsibilities of the National Park Service.

IMPROVE, NADP/NTN, and States

Air pollution is affecting natural resources in parks. To determine background conditions and track changes in air pollution and their effects on the resources, the National Park Service monitors visibility, ambient concentrations of particulate matter, gaseous air pollutants, and wet deposition in many parks. Visibility is monitored as part of the IMPROVE (Interagency Monitoring of Protected Visual Environments) national visibility monitoring network that is jointly funded and operated by the U.S. Environmental Protection Agency, the National Park Service, states, and other land management agencies. Wet deposition (precipitation chemistry) is monitored through the service's participation in NADP/NTN (National Atmospheric Deposition Program/National Trends Network). Gaseous air pollutants are also monitored by networks operated by the National Park Service and states. The networks provide data that are critical for understanding the effects of air pollution on ecosystems in parks.

Budget

The I&M Program is funded by annual line-item appropriations from the U. S. Congress. The Fiscal 1998 I&M Program budget was $6.19 million.

The Selected National Park System Units

Prototype monitoring of natural resources was implemented in 7 of 11 selected parks (Tables 1 and 2). The 7 parks represent 6 biomes; deciduous forest is represented by 2 parks. Monitoring in the remaining 4 parks will be implemented as soon as funding is appropriated.

Cape Cod National Seashore
Atlantic-Gulf Coast Biome

Cape Cod is a large glacial peninsula that extends 96.5 km (60 mi) into the Atlantic Ocean from the coast of Massachusetts. Cape Cod National Seashore on the outer cape was established in 1961 and consists of 18,063 ha (44,600 A) of marine, freshwater, and terrestrial ecosystems. During the past three centuries, the ecosystems were profoundly altered by humans. Many habitats on the seashore are globally uncommon, and the species that occupy them are correspondingly rare. Development of prototype monitoring of five major ecological communities was initiated in 1996: (1) shoreline margins; (2) barrier islands, spits, and dunes; (3) estuaries; (4) freshwater kettle ponds and vernal pools; and (5) maritime heathlands and forests. Information from monitoring in each community will be used in natural-resource management that is specifically related to the seashore and to other Atlantic coastal parks.

The seashore and its partner, the Biological Resource Division of the U.S. Geological Survey at the University of Rhode Island, are in the early phases of research, development, and testing of protocols. Monitoring on the seashore is by a multivariate approach that combines physical, chemical, and biological information to examine patterns of ecological changes. In 1998, development and testing of field techniques and protocols for monitoring estuarine water quality, coastal ecosystems, hydrology kettle pond water quality, kettle pond macrophytes, and estuarine nekton were continued. Full implementation of monitoring and integration of monitoring with natural resource management are immediate goals.

Table 1. The seven National Park System units in which prototype monitoring has been implemented and the biomes that the units represent.

Prototype	Biome
Cape Cod National Seashore, Massachusetts	Atlantic-Gulf Coast
Channel Islands National Park, California	Pacific Northwest
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 and subtropical

Table 2. 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 Service Complex, Washington	Rivers and lakes
Northern Colorado Plateau Cluster, Colorado and Utah	Arid lands

Channel Islands National Park
Pacific Coast Biome

Channel Islands National Park off the coast of California has conducted prototype ecological monitoring since 1992. Monitoring is based on the belief that organisms exhibit the effects of a vast array of ecological factors, including predation, competition, and other environmental factors that are expressed in changes in population dynamics such as abundance, distribution, growth rate, and mortality. 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 fully operational. The natural-resource management staff of the park conducts the monitoring and manages related data.

Denali National Park and Preserve
Arctic-Subarctic Biome

Denali National Park and Preserve was selected for prototype ecological monitoring of communities and ecosystems by watershed in large Alaskan parks. Techniques that are developed in one watershed are eventually replicated in other watersheds to track resource trends in major terrestrial habitats, aquatic systems, and climate regimes in the park. The structures of vegetative and aquatic communities, the dynamics of vegetative communities, and chemical and geophysical parameters, including water and soil characteristics, are monitored in a series of permanent plots in the Rock Creek watershed. Data are also collected from weather stations in associated plots and from grids and stations where the productivity of small mammals and birds is sampled.

Great Plains Prairie Cluster
Prairie and Grassland Biome

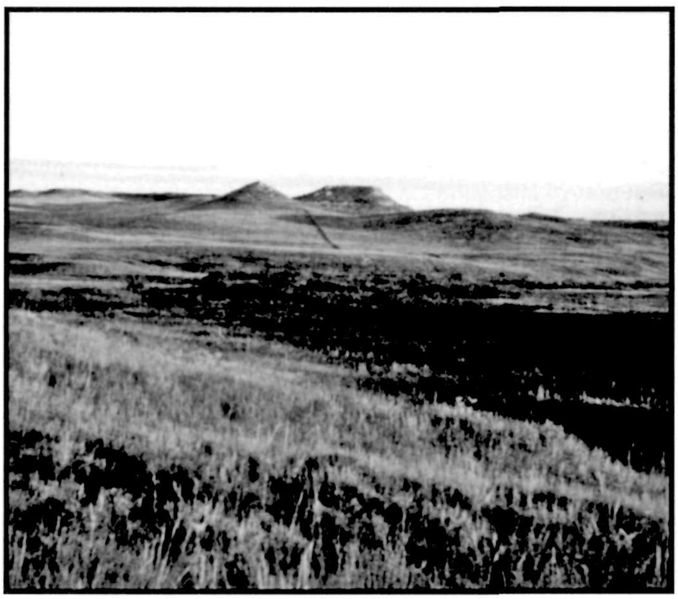
The Great Plains Prairie Cluster initiated prototype long-term ecological monitoring to meet the needs of small parks. Monitoring is conducted in a group of six small prairie parks that are widely scattered throughout the central grasslands. A team of resource specialists stationed in Wilson's Creek National Battlefield collects data there and in Agate Fossil Beds, Scotts Bluff, and Homestead national monuments in Nebraska, in Pipestone National Monument in Minnesota, and in Effigy Mounds National Monument in Iowa.

North American prairies once extended across the mid-continental region from Canada to Texas and from the Rocky Mountains to the Appalachian forest. The vast landscape was nearly continuous grassland, transitioning gradually from shortgrass steppe in the west to tallgrass prairie and savanna in the east. Today, Great Plains grasslands are fundamentally altered by the conversion of prairie to cropland and pasture, the removal or disappearance of native ungulates, drainage of wetlands, and an increase in woody vegetation from plantings and fire suppression. Estimates of the loss of native prairie range between 80% and 99.9%. Fragmentation of the tallgrass prairie ecosystem has left the national parks with a unique opportunity to help preserve many of the features of this almost vanished habitat.

Although each park in the Great Plains Prairie Cluster has a unique mission and represents a distinctive component of regional biotic diversity, the parks share many resource management issues. All include high-quality prairie remnants, sites in need of complete restoration, and a continuum of resource conditions between these two extremes. Restoring prairie vegetation to disturbed sites and managing prairie communities with prescribed fire are common resource management practices. The small size of the parks makes them particularly susceptible to external threats. Agricultural, residential, and industrial development are prominent land uses adjacent to the parks. Because small parks are often inadequately buffered against edge effects, invasion by exotic species is a pervasive problem. Water pollution may be the most urgent external threat. Because the parks are small, their springs, creeks, and ground water are particularly vulnerable to pollution from external sources and cannot be insulated by buffer zones or resource management inside the parks. Most of the parks must also protect unique habitats and manage state or federally listed rare and endangered species.

Monitoring a tern colony on Cape Cod National Seshore

On Anacapa Island in Channel Islands National Park



Agate Fossil Bed in the Great Plains Prairie Cluster

Agate Fossil Beds National Monument was previously a working cattle ranch owned by Captain James Cook. The monument preserves paleontological sites with some of the world's best deposits of mammalian remains of the Tertiary Age. The park also has historical significance as the summer campsite of the Lakota Sioux leader, Chief Red Cloud, who was a friend of Captain Cook. Two-thirds of the monument's 1215 ha (3000 A) consist of mixed grass prairie. The Niobrara River, originating 97 km (60 mi) to the west, flows through the monument. The associated wetlands provide important habitat for prairie birds and wildlife.

Effigy Mounds National Monument was established in 1949 to preserve earth mounds created by the Mound Building Culture of Prehistoric American Indians between 500 BC and 1300 AD. The steep slopes of the monument are primarily eastern hardwood forest. Prairie openings on the ridge tops and bluff edges overlook the Mississippi River. Several rare plant species are associated with undisturbed mesic forest and algific talus slopes on north-facing slopes. The monument also includes floodplain forests along the Sny Magill Creek and the Yellow River.

Homestead National Monument of America 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 woodlands were cut over and heavily grazed. In 1939, the National Park Service began restoring prairie vegetation, and today the Homestead Prairie represents the second oldest prairie restoration in the Midwest. 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 was established in 1937 to preserve and manage the pipestone quarries in their natural tallgrass environment and to provide American Natives with free access to quarry pipestone. The most significant natural resources of the park include the Sioux Quartzite rock formation, 8.1 ha (20 A) of associated Sioux Quartzite prairie, 64.8 ha (160 A) of virgin tallgrass prairie, 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*. 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.

Scotts Bluff National Monument 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 park's goal is to restore and maintain the native prairie landscape to the conditions that were seen by overland emigrants of the 1840-70s. The vegetation of the monument is primarily mixed-grass prairie, dominated by needle-and-thread grass *Stipa comata*, blue grama *Bouteloua gracilis*, and black-root sedge *Carex filifolia*. The monument also includes Rocky Mountain juniper *Juniperus scopulorum* woodland in the steep upland draws, badlands, and riparian communities along the North Platte River. A black-tailed prairie dog *Cynomys ludovicianus* colony occurs on the park.

Wilson's Creek National Battlefield commemorates the battle that occurred there on 10 Aug 1861. It is unique as a Civil War battlefield because the historic landscape consisted primarily of pre-settlement savanna, prairie, and glade communities and a few farms scattered along the creek. In addition to restored prairie grasslands, the battlefield includes oak woodland on the steeper slopes and some of Missouri's best examples of limestone glade vegetation. Four populations of the federally listed endangered plant Missouri Bladderpod *Lesquerella filiformis* occur on the limestone glades. Several caves and sinkholes on the battlefield are associated with rare fauna. Wilson's Creek flows through the park.

Overall goals of the monitoring are identification of early warning of resource decline and assessment of the effectiveness of resource management. Sampling protocols address three high-priority management issues: (1) sustainability of small remnant and restored prairie ecosystems, (2) effects of external land use and watershed changes on small prairie preserves, and (3) effects of fragmentation on biological diversity in small prairie parks. Protocols are currently being developed for monitoring prairie plant communities, rare plants, stream macroinvertebrates (as indicators of water quality), butterflies, grassland birds, and black-tailed prairie dogs *Cynomys ludovicianus*. Plans are underway to develop protocols for monitoring invasive exotic species and changes in adjacent land use.

Protocol design and development began in 1995 and has been funded primarily by the Biological Resources Division of the U.S. Geological Survey. Scientists with the Northern Prairie Wildlife Research Center anticipate that most of the protocols will be completed in 2000. In 1997, the National Park Service began funding a gradual transition to an operational program. Three staff positions, (program coordinator, data manager, and botanist) are currently filled. A full staff complement is anticipated by 2000.

Great Smoky Mountains National Park
Deciduous Forest Biome

Great Smoky Mountains National Park, which encompasses approximately 211,026 ha (521,053 A) in 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 invasion 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 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

Great Smoky Mountains National Park

level primarily serves to determine the effects of air pollution and climatic change on the structure and dynamics of the forests. Also monitored in the park are water quality, rare plants, aquatic macroinvertebrates, exotic forest insects, effects of disease on forests, brook trout *Salvelinus fontinalis* populations, and the population dynamics of the black bear *Ursus americanus* and the white-tailed deer *Odocoileus virginianus*.

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 program.

Olympic National Park
Coniferous Forest Biome

In 1993, Olympic National Park was selected for conducting prototype ecological monitoring of coniferous forest systems. Although not yet funded by the Inventory and Monitoring Program, the park is developing monitoring protocols in partnership with the Olympic Field Station and the Forest and Rangeland Ecosystem Science Center of the U.S. Geological Survey. The park and the Olympic Field Station are identifying objectives, selecting ecological indicators of the condition of the biome, and testing protocols.

The broad objectives are the integration of monitoring in the park with needs by other land management agencies on the Olympic Peninsula, requirements by the President's Northwest Forest Plan, and a regional approach to monitoring by other parks in the Pacific

RAINFOREST IN OLYMPIC NATIONAL PARK

Northwest. Park-specific objectives are an understanding of the mode of change by components of the park ecosystems over time, identification of early warning of anthropogenic change that requires managerial intervention, and development of a benchmark for comparison with altered landscapes.

During 1997, Olympic National Park staff and other Olympic Peninsula resource managers (agency, tribal, and private) identified the resources of greatest concern for monitoring. In a workshop for resource managers of other agencies, the Olympic Field Station determined that at least 4 federal agencies, 4 state agencies, 4 tribal governments, and 2 private timber companies already conduct monitoring (~150 projects) on the Olympic Peninsula. In another workshop, the Olympic Field Station and the Forest and Rangeland Experiment Station used the Olympic National Park as a case study for the selection of indicators in ecological monitoring. Eighteen experienced scientists of federal agencies and universities addressed the application of ecological theory to designing monitoring programs and selecting effective ecological indicators.

During 1997-98, the Olympic Field Station and park staff completed an initial screening of coniferous forest indicators in three categories, indicators that respond to management concerns, focal species indicators (e.g., charismatic, threatened, or endangered), and indicators of ecosystem status or health. Scientists of the Olympic Field Station initiated testing of pilot protocols for each indicator type.

In Jan 1999, the park assembled 50 scientists to expand the scope of monitoring to the intertidal zone and the glaciers of the alpine zone. Results of the workshop will provide comprehensive long-term ecological monitoring in the park. Implementation of the plan is anticipated in Fiscal Year 2000.

Shenandoah National Park

Deciduous Forest Biome

Shenandoah National Park in the northern Blue Ridge Mountains of Virginia is the largest protected area in the mid-Atlantic region (79,380 ha; 196,000 A) and the site of the scenic Skyline Drive. Because of its vicinity to Washington, D.C. and other large eastern metropolitan areas, the park is a popular tourist destination. The park has a diverse flora of northern and southern plants whose showy display of blooms in spring and flaming colors in fall are renown nationwide. Many Neotropical birds migrate through the park or even nest there, and the large mixed mesophytic forest provides important habitat for many species of wildlife.

High ozone levels and sulfate deposition; invasions by exotic forest insects, diseases, and plants; and destruction of habitats from development on adjacent lands threaten the natural resources in the park. Protection of the resources is challenging because of the long narrow shape of the park.

In response to legislation or recognizeded threats, Shenandoah National Park began long-term ecological monitoring of water quality, air quality, brook trout, and black bears in the 1980s. In 1992, prototype ecological monitoring in a deciduous forest biome was continued under the auspices of the I&M Program and is now fully integrated into the resource management program of the park. Since 1992, monitoring has been expanded to rare plants, forest health, aquatic insects, other fishes, and Neotropical birds. Studies or funding of studies by cooperating agencies such as the U.S. Geological Survey, U.S. Forest Service, state agencies, universities, and others contribute important information to the conservation of geophyscial and natural resources. In 1998, the park hosted the national I&M training class.

Virgin Islands-Southern Florida Cluster *Tropical-Subtropical Biome*

The Virgin Islands-Southern Florida Cluster consists of Virgin Islands National Park and Buck Island Reef National Monument in the Greater Antilles and Dry Tortugas National Park in Florida. In 1998, further development of monitoring and monitoring in accordance with plans developed in 1997 continued in Virgin Islands National Park.

Buck Island Reef National Monument was designated in 1961 for the bank-barrier coral reef surrounding the islands' east end. This uninhabited island lies 2.4 km (1.5 mi) northeast of the island of St. Croix in the U.S. Virgin Islands (17°47' N, 64°37' W) and includes 71 ha (176 A) of land and 285 ha (704 A) of water and coral reef system. Most of the water (220 ha, 544 ac) is designated *marine garden* that is closed to fishing and all collecting. The monument is a nesting site for several endangered and threatened species including the green sea turtle *Chelonia mydas*; the hawksbill *Eretmochelys imbricata*, the leatherback *Dermochelys coriace*, the brown pelican *Pelecanus occidentalis*, and the least tern *Sterna antillarum*. The surrounding coral reef system provides developmental habitat for juvenile hawksbills. The monument is also the most popular tourist destination on St. Croix where visitors enjoy the sand beaches, picnic areas, and overland hiking trails. They snorkel on the underwater interpretive trail in the beautiful turquoise waters. The trail leads snorkelers through the coral reef to large elkhorn coral patch reefs that rise to the surface from as deep as 12 m (40 feet).

Dry Tortugas National Park, formerly Fort Jefferson National Monument, was built in 1846-66 to help with the control of the Florida Straits. It is the largest all-masonry fortification in the western world and occupies about 26,200 ha (64,700 A) of the Dry Tortugas Banks. The remarkable bird and marine life of the area has been world-renowned. Louis Agassiz conducted the earliest documented research there in 1858, the Carnegie Institution established a marine laboratory on the Loggerhead Key in 1904, and 35 volumes of research had been published by the Tortugas laboratory by 1939.

The park has the only colonies of Magnificent Frigatebirds *Fregata magnificens* and Masked Boobies *Sula dactylatra* and the only significant Noddy Tern *Anous* spp. and Sooty Tern *Sterna fuscata* colonies in the continental United States. A large variety of passerines and birds of prey migrate through the park during spring and fall.

Information from monitoring natural resources in Dry Tortugas National Park will be used to (1) determine and evaluate the levels of nutrients in waters around the park, (2) determine and manage the effects of high levels of visitation on natural resources, and (3) maintain the fish assemblages and traditional fisheries in the park.

Inventories of Natural Resources

SECTION COVER. PHOTOGRAPHS CLOCKWISE FROM BOTTOM LEFT: SURVEY OF THE EAST TOKLAT GLACIER IN DENALI NATIONAL PARK AND PRESERVE, VEGETATION SAMPLING IN SCOTTS BLUFF NATIONAL MONUMENT, AQUATIC MACROINVERTEBRATE SAMPLING IN WILSON'S CREEK NATIONAL BATTLEFIELD, VEGETATION SAMPLING IN SHENANDOAH NATIONAL PARK. *PHOTOGRAPHS COURTESY OF THE RESPECTIVE NATIONAL PARK SYSTEM UNITS.*

Overview

The I&M Program is committed to conducting inventories in about 260 National Park System units with significant natural resources. Since 1992, the program has funded 560 inventories of various natural resources and verified species lists from 95 units. Progress in inventories of bibliographies, base cartography, vegetation, and soils has been significant. Baseline assessments of water quality and geologic bibliographies 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 (Table 3). The I&M Program will complete the basic resource data sets for each National Park System unit with natural resources. 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 other resources, for example, invertebrates or fossils, are the responsibility of parks.

Table 3. The 12 natural resource data elements or core set of minimum information for park management, planning, and natural resource protection.

Air-quality-related values
Base cartographic data
Geology map
Location of air quality monitoring stations
Natural resource bibliography
Precipitation and meteorological data
Soils map
Species distribution and status of vertebrates and vascular plants
Species list of vertebrates and vascular plants
Vegetation map
Water-body location and classification
Water-quality data

In addition to a description of the objectives, documentation, and status of species inventories in parks, a collection of six facts sheets about inventories in the I&M Program are provided here. The information in the fact sheets was updated by staff of the Natural Resource Information Division between December 1998 and January 1999. Hard copies were distributed to various entities of the National Park Service, including all parks with significant natural resources. Electronic copies were posted on the Natural Resource and INTOUCH bulletin boards and on the Natural Resource web site of the National Park Service (www.nature.nps.gov/facts/findex.htm). Each distributed or posted fact sheet provides the name and address of at least one person who may be contacted for further information about a specific topic.

Species Inventories

The objectives of the species inventories are the documentation of 80% of all vascular plant and vertebrate species within the boundaries of National Park System units and the production of maps of the distribution of species of special management concern, notably threatened, endangered, and nonnative species. Species lists of the units in the southwestern region are verified and validated. Many species lists that are now stored in two different versions of the NPFlora and NPFauna databases will eventually be stored in an I&M database system that is under construction. Updating of the species lists and the generation of distribution maps are future tasks.

Relations with Data Standards and Programs

The I&M Program is charged with producing inventories of species lists of vascular plants, amphibians, reptiles, fishes, birds, and mammals in all National Park System units with significant natural resources (about 265 units). A need to collect and maintain information about other species such as macroinvertebrates, insects, and fossils that are outside of the I&M Program purview has also been expressed by resource managers and scientists of the National Park Service.

In the past, National Park System units used various nonstandard methods, protocols, and record-keeping systems to generate and maintain species lists of their plants and animals. Much of the information was logged into the NPFlora and NPFauna databases but often without verification and validation. However, these databases have not been universally adopted, and systematic validation and updating have not been standardized. Consequently, the service-wide data are neither systematically validated nor updated. Use of NPFlora and NPFauna has been further subverted by the evolution of incompatible software and data issues from successive generations of the databases outside of the National Park Service. New species inventories and the new database system seem to be the most economically and logistically feasible solutions of the problems.

Automated Natural Resource Bibliographic Database

(Fact Sheet 98-6, Dec 1998, by M. Ostergren)

The comprehensive inventory of parks with significant natural resources involved cataloging information from all the natural resource studies in parks. All historical scientific material including unpublished reports, journal articles, maps, photograph collections, and other sources of natural resource information are incorporated into an automated database.

Program History

In 1994, compilation of the databases with the Pacific Northwest bibliography project as a prototype was initiated. The first three funded regions were the Southwest Region (under a cooperative agreement with the University of Idaho), the Rocky Mountain Region (under a cooperative agreements with the Northern Arizona University and Colorado State University) and the Alaska Region (under an agreement with the library of the Bureau of Land Management in Anchorage).

In 1995, the remaining six regions received funding and began to compile their information. The Western Region was funded under cooperative agreements with the Northern Arizona University, the University of Idaho, and the University of Hawaii. The Midwest and Southeast regions were funded under cooperative agreements with the University of Idaho. The Mid-Atlantic and National Capital regions were funded under agreements with Penn State and the North Carolina State University. The North Atlantic Region was funded under an agreement with the University of Rhode Island. The general approach was to travel to parks, search their collections, and catalog appropriate documents on laptop computers.

Program Status and Future

As of October1998, the preponderance of in-park work was completed and the project has been moving into a maintenance phase. To support this, the I&M Program has funded an *NRBIB Coordinator* position. The incumbent—stationed in the library of the NPS Columbia Cascades Support Office in Seattle—is responsible for providing the support and guidance to keep the databases current, make them accessible online, address concerns about sensitive information in the databases, and provide assistance to users (data entry, searching, etc.).

Base Cartographic Data

(Fact Sheet 99-03, Jan 1999, by L. Armstrong)

The systematic monitoring of natural resources requires park-specific maps of surface features and boundaries. The scale of basic cartographic products is 1:24,000 for NPS units in the lower 48 states and 1:163,360 for units in Alaska. All products are in digital format that is suitable for import into a geographic information system (GIS).

Partnerships

The cartographic products are made possible by a cost-sharing arrangement with the U.S. Geological Survey and by procurement contracts.

Program Status

Since 1993, complete or partial base cartographic data from more than 240 parks with significant natural resources have been acquired. A status database of all cartographic data by park and 7.5-minute quadrangle is maintained on the Intranet at http://aqsun.aqd.nps.gov:82/quad/quad.html.

Baseline Water Quality Status and Trends

(Fact Sheet 98-08, Dec 1998, by E. Rockwell and D. Tucker)

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. 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. 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 Dec 1998, 143 Baseline Water Quality Data Inventory and Analysis Reports were completed and sent to parks. Reports for all parks should be completed by late 1999.

Geologic Mapping

(Fact Sheet 99-06, Jan 1999, by J. Gregson)

Geologic Resources

Bedrock and surficial geologic maps and information provide the foundation for studies of groundwater, geomorphology, soils, and environmental hazards. Geologic maps describe the underlying physical habitat of many natural systems and are an integral component of the geophysical inventories stipulated by the National Park Service (NPS) in its Natural Resources Inventory and Monitoring Guideline (NPS-75) and the 1997 NPS Strategic Plan. The NPS Geologic Resources Inventory is a cooperative endeavor by the Geologic Resources Division,Inventory and Monitoring Program (Natural Resource Information Division - NRID), U.S. Geological Survey, and state geological surveys to implement a systematic, comprehensive inventory of the geologic resources in National Park System units. The inventory consists of four main phases:

(1) a bibliography of geologic literature and maps called GeoBib, (2) an evaluation of geologic maps of parks, resources, and issues, (3) the production of digital map products and information, and (4) a report with basic geologic information, hazards and issues, and existing data and studies.

Status of the Geologic Resource Inventories

The Geologic Resources Division and the I&M Program sponsored a workshop in baseline geologic data in Denver in fall 1997 to receive information from the National Park Service, the U.S. Geological Survey, state survey personnel, and cooperators about needed basic geologic data that the I&M Program could provided. At the meeting, Colorado, North Carolina, and Utah were chosen as pilot project states to maximize cooperation among the agencies.

The collection of existing geologic maps and literature in each National Park System unit for the GeoBib and the publication of the data on the Internet are near completion. Index maps of the location of associated geologic maps are being prepared for the parks in Colorado and Utah. Upon determination of map coverage for each park, map products can be evaluated and potential-mapping can be identified and initiated.

Pilot geologic-issues and map-scoping meetings by park teams were organized in 1998 to evaluate the resources in Colorado parks and will be organized for parks in Utah during 1999. Park Teams will evaluate existing maps for digital products and identify needed geologic mapping. New geologic mapping may be initiated case-by-case after careful evaluation of needs, costs, potential cooperators, and funding sources. The cooperators of the Geologic Resources Inventory are developing geology-GIS standards to ensure uniform data quantity and quality for digital geologic maps. Pilot digitization will provide additional information for the digital map standards.

Upon completion of an inventory in a park, the available geological literature and data from the National Park Service, U.S. Geological Survey, state, and academic institution will be documented in a summary. The content, format, and database of such reports are being developed and are outlined in a later section.

Relation with Existing Data Standards and Programs

The ideal goal of the first level of the Geologic Resource Inventory of bedrock and surficial geologic maps in each park at 1:24,000 scale is compatible with similar scales of base cartography, soils maps, and vegetation maps. However, acceptable geologic map scales must be determined with case-by-case evaluations of existing products, park needs, and mapping costs. Many agencies are digitizing maps, but scales vary, and digitized coverage of all National Park System units can probably not be completed without in-house or contracted work by the National Park Service.

Geologic Resource Bibliographies (GeoBib)

The bibliographies of parks are collected and the data are posted in a secure database on the Intranet of the National Park Service. The bibliographic searches of databases (Georef and Geoindex) for each park by the U.S. Geological Survey were converted to Procite data files. These files must still be converted for the Intranet system, and the citations must be edited for validity and duplicate entries. The completed GeoBib is expected to contain about 100,000 citations of geologic resource literature in an on-line database.

Bibliographies for 27 parks in the three pilot states have been edited, and data for an additional 15 western parks have been converted and loaded into the database for editing. After validation, lists of geologic map references will be prepared for each park and used to develop index maps of associated geologic maps. The lists and index maps will be converted to word processing documents for transfer to cooperators.

Geologic Resource Workshops

Because of their proximity to the Natural Resource Program Center and the offices of the U.S. Geological Survey, parks in Colorado were selected for the first workshops in the assessment of the quality and extent of geologic information in each park. Each workshop included a field trip by an authority on the park's geology and an on-site meeting to review the four inventory items. The participants discussed inventory needs, deliverable products, and tentatively assigned cooperator responsibilities.

The workshops facilitated a better understanding of the geology in the parks and revealed several applications for their management. Examples include the use of geologic data to construct fire histories, the identification of habitat for rare and endangered plant species, the identification of areas with cultural and possibly paleontological resources, and the location of potential hazards for park roads, facilities, and visitors. Digital geologic maps in conjunction with other digital data will enhance the development of precise models of hazards and resources.

Geologic Mapping and Digitizing

The Inventory and Monitoring Program shared the cost of new geologic mapping in Zion National Park with the state of Utah. Completion of the geologic maps of Curecanti National Recreation Area, Mesa Verde National Park, and Yucca House National Monument in 1999 is proposed. Digitizing of four USGS geologic maps of Craters of the Moon National Monument in a pilot project has been contracted, and proposals were generated for the digitization of maps of Black Canyon and Yucca House national monuments, Curecanti National Recreation Area, and Mesa Verde National Park. Digitization of geologic maps of other parks in Colorado in 1999 is planned.

Baseline Geologic Inventory Report

The inventory report will contain summaries of the exploration history, geology, unique features, paleontology, disturbed lands issues, geologic data, geologic hazards, and other issues to describe the basic geologic resources of each park. Several sections, such as stratigraphic columns and geologic cross section graphics, will incorporate available literature. Other sections will be summaries of ongoing programs such as the restoration of disturbed lands and paleontological inventories. A database system is being developed to provide on-line access for report development and dissemination.

The Geologic Resources Inventory is being developed in cooperation with the U.S. Geological Survey and states but may reveal many other opportunities for collaboration with other agencies or institutions. Good, uniform digital map standards that are adaptable to diverse geological conditions and firm guidance for map developers must still be developed. The diversity of geologic resources in the National Park System will provide a continuing challenge for management. The National Park Service identified GIS and digital cartographic products fundamental to expedite the acquisition of digital geologic information for National Park System units throughout the country.

Vegetation Mapping

(Fact Sheet 98-07, Dec 1998, by M. Story)

Every National Park System unit with significant natural resources will be provided with information on the composition and distribution of its vegetation. This information is based on descriptions from data collected by field sampling and interpretation of aerial photography. Aerial photography and remotely sensed imagery acquired for vegetation mapping will also be used to support geologic mapping, soil surveys, and species inventories.

To maintain consistency in detail and accuracy, standards and protocols were developed for the vegetation classification system, sampling methodologies, and accuracy assessments of final products. As a result, the National Park Service in cooperation with the vegetation subcommittee of the Federal Geographic Data Committee and other agencies developed a standard hierarchical vegetation classification. The standard is based on a system originally developed by UNESCO and further refined by The Nature Conservancy through its network of natural heritage programs. For consistency in detail and accuracy, the classification system, sampling methodologies, and procedures for the assessment of map accuracy were tested in representative National Park System units.

The primary product of the vegetation mapping is a digital map of the vegetation in a park that is compatible with the GIS of that park. Digitizing the vegetation data provides flexibility in map design and production and facilitates data integration and analysis. Other products include vegetation class descriptions, field keys, hard copy maps, detailed field data, analysis of data, and aerial photography. Field data will be maintained in the park in which they were collected to ensure their availability to managers.

Program Status

In 1994, standards and protocols for the classification system were developed under the contracted direction of the Biological Resources Division of the U. S. Geological Survey. Refinement of the field sampling methods and procedures for assessment of map accuracy has progressed. A completed inventory of existing data in 101 parks is providing the basis for identifying the need for aerial photographs and other base data. The I&M Program is locating and acquiring from other agencies aerial photographs that meet the requirements and standards of its vegetation mapping. When necessary, new imagery is obtained. The park units will be mapped in order of priority of need for vegetation information and the availability of Digital Orthophoto Quarter Quads, which serve as the cartographic base for the mapping.

Interagency agreements with the U. S. Bureau of Land Management and the U. S. Forest Service have been used to acquire photographs for the following park units: Bent's Old Fort National Historic Site; Colorado, Devils Tower, Florissant Fossil Beds, Great Sand Dunes, Natural Bridges, and Rainbow Bridge national monuments; Arches, Bryce Canyon, Canyonlands, Capitol Reef, Rocky Mountain, and Zion national parks; and Glen Canyon National Recreation Area. Reprints of existing photographs were obtained for the Mount Rushmore National Memorial; Devils Tower and Jewel Cave national monuments; and for Isle Royale, Great Smoky Mountains, and Theodore Roosevelt national parks. In 1995, photos were acquired under contract for Fort Laramie National Historic Site (specific areas of interest to the park) and for Agate Fossil Beds, Scotts Bluff, and Tuzigoot national monuments. The acquisition of photographs for the Congaree Swamp, Sunset Crater Volcano, Walnut Canyon, and Wupatki national monuments and for the Glacier and Voyagers national parks were contracted in 1996. New photography for Acadia, Badlands, Great Smoky Mountains, and Wind Cave national parks was contracted in 1997. Additional photography for Joshua Tree National Park was acquired in 1998. 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, U. S. Geological Survey, and National Aeronautic and Space Agency in Alaska is also planned. Additional imagery and maps will be acquired under contract.

Pilot Projects

To test the new classification system, field methodologies, and procedures for assessing map accuracy, pilot projects were conducted in several parks. A summary of the accomplishments 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 the Assateague Island National Seashore were delivered to the National Park Service by the contractor. The final accuracy assessment was completed in 1998.

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. In spring 1997, each polygon of the final map was visited to assess the accuracy of the final product. Final results of the assessment are available on the USGS/NPS Vegetation Mapping web site.

Scotts Bluff National Monument. New aerial photography (1:12,000) and field sampling were completed in the monument in 1995. Analysis of the vegetation in 100 plots indicated 18 vegetation types. Sampling accuracy was assessed in 150 sites. The classification, vegetation type descriptions, and field key were delivered. The park also was mapped by additional personnel a second time to obtain a benchmark for the mapping procedures. The results of the efforts at SCBL are available on the USGS/NPS Vegetation Mapping web site.

Great Smoky Mountains National Park. Existing aerial photography was 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. The acquisition of new photographs was completed in 1998.

Vegetation mapping is underway also in Fort Laramie National Historic Site; Mount Rushmore National Memorial; Agate Fossil Beds, Congaree Swamp, Devils Tower, and Jewel Cave national monuments; Acadia, Glacier, Isle Royal, Joshua Tree, Voyagers, Wind Cave, and Yosemite national parks; and Rock Creek Park. The standards and protocols developed for this program are also used for mapping vegetation on Point Reyes National Seashore and in Hawaii Volcanoes National Park.

Vegetation Mapping In Alaska

Mapping of 22 million hectares (54 million A) 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 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 being adapted for Alaska and field tested in one or more of the national parks in Alaska.

The USGS/NPS Vegetation Mapping Program was the subject of two seperate reviews in Fiscal Year 1998. One review was sponsored by the National Park Service and focused on the products and the procedures. The other review was a program review by the Biological Resources Division of the U.S. Geological Survey. The results of these reviews can be viewed on the USGS/NPS Vegetation Mapping web site.

Activities in 1999

Priorities for the upcoming field season include continued acquisition of aerial photos for priority parks, continued field use of procedures and methods, and delivery of products from park projects.

To date, the vegetation mapping program has been initiated in 20 parks in the lower 48 states. Mapping in 17 parks was fully funded. Complete vegetation was delivered to 5 parks (Devils Tower, Jewel Cave, Mount Rushmore, Scotts Bluff, and Tuzigoot national monuments) and will be delivered to 5 more parks in 1998 (Agate Fossil Beds National Monument, Assateague Island National Seashore, Fort Laramie National Historic Site, Isle Royale National Park, and Rock Creek Park). In 1999, mapping will be completed for Acadia National Park. Badlands National Park, Congaree Swamp National Monument, Theodore Roosevelt National Park, Voyageurs National Park, and Wind Cave National Park and will be started in several other parks, including Fire Island National Seashore; Olympic and Zion national parks; and Sunset Crater Volcano, Walnut Canyon, and Wupatki national monuments. Mapping will be initiated in others when funding becomes available.

Training Opportunity

The U.S. Geological 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 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, and the U.S. Geological Survey. The purpose of the workshop is to explain the classification system; discuss the data that are necessary to use the system; describe methods 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

SECTION COVER. PHOTOGRAPHS (*PHOTOGRAPHER*) CLOCKWISE FROM TOP RIGHT: RED-TAILED HAWK (*M. COFFEY*), GRAY ANGELFISH (*VIRGIN ISLANDS NATIONAL PARK*), HAWKSBILL (*BUCK ISLAND REEF NATIONAL MONUMENT*), WESTERN PRAIRIE FRINGED ORCHID (*L. THOMAS*), GREAT-SPANGLED FRITILLARY (*L. RIES*), CARIBOU (*P. KNUCKLES*).

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 are descriptions of long-term ecological monitoring and the status of the monitored geophysical and natural resources in two clusters and five National Park System. 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.

Cape Cod National Seashore, Massachusetts
Atlantic-Gulf Coast Biome

A. Bennett
Park I&M Coordinator

Contributors:
D. Joseph, Ozone
K. Heuer and K. Tonnessen, Wet Deposition
E. Hoopes, Piping Plover

Air Quality

Ozone

Ozone concentrations in the National Park Service Gaseous Air Pollutant Monitoring Network are highest in southern California and in the northeastern and east-central United States. The monitoring sites in the Pacific Northwest and Alaska routinely record the lowest levels of ozone. The highest daily maximum 1-h average ozone concentration on Cape Cod National Seashore in 1997 was 124 ppb. The second highest daily maximum 1-h value, 117 ppb, was the third highest recorded by the 40 ozone monitors in the network in 1997. The fourth highest 8-h average concentration, 100 ppb, in 1997 was the third highest in the network. The daily maximum 8-h ozone concentrations during 17 days in 1997 was greater than 84 ppb. The 1-h ozone averages were greater than or equal to 100 ppb on 47 days in that year.

The new U.S. Environmental Protection Agency (EPA) ambient air quality standard designed to protect human health is exceeded when the 3-year average of the fourth highest 8-h daily maximum ozone concentration exceeds 84 ppb. The 1995-97 average of the fourth highest 8-h concentration on Cape Cod National Seashore was 100 ppb (Fig. 1) which exceeds the EPA standard. The 3-year average of the fourth highest 8-h daily maximum concentration on Cape Cod National Seashore has varied between 90 and 110 ppb during 1989-97. This ozone chart qualitatively suggests a decreasing trend in the 3-year average between 1989 and 1997. A more quantitative analysis of the May-Sep average daily maximum ozone concentrations revealed a statistically significant improving air quality trend of 1.5 ppb/year during 1988-97.

Wet Deposition

Sulfate concentrations in precipitation ranged from 1.4 to 2.2 mg/L from 1981 to 1997 (Fig. 2). These concentrations are elevated and reflect the higher sulfur emissions in the eastern United States. However, sulfate concentrations at this coastal site may be due in part to naturally occurring sea-salt aerosols that contain sulfate. Concentrations of nitrate in precipitation on the seashore ranged from 0.7 to 1.3 mg/L. Nitrate concentrations were consistently lower than sulfate, but the values are considerably higher in eastern parks than in western parks because of higher nitrogen emissions. The theoretical pH value of unpolluted precipitation is 5.6. On Cape Cod National Seashore, the pH of precipitation was 4.4-4.6.

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Piping Plovers

Since 1986, the Piping Plover *Charadrius melodus* has been a federally listed endangered species. The plover is threatened by the cumulative effects of habitat loss, human disturbance, and predation. On the Atlantic Coast, the plover breeds on coastal beaches from Newfoundland to North Carolina. The beaches of Cape Cod National Seashore support as much as 10% of the nearly 1400 plovers on the Atlantic Coast. Protection of the plover on the seashore consists of temporal and spatial restrictions of off-road vehicles, seasonally restricted access by visitors of areas where the plovers nest, control of avian and mammalian predators with mesh-topped or string-topped welded wire structures around nests, and public education about the status and management of the plover. The effectiveness of the protective measures have been determined by monitoring the number of breeding pairs and reproductive success of the plover.

In 1998, the breeding population of the plover on the seashore consisted of 61 pairs (Table 4). The first clutches were initiated during early May and nesting peaked during the first week of June. As in 1997, hatching first peaked in the second week of June and again in the second week of July because severe overwash in June destroyed first clutches and the birds re-nested. The hatching success was 65%, the fledging success 66%, and the reproductive rate (chicks fledged/breeding pair) was 1.8. Overwash was the leading cause of nesting failure. Thirty-eight of the 51 enclosed clutches hatched. Overwash de-

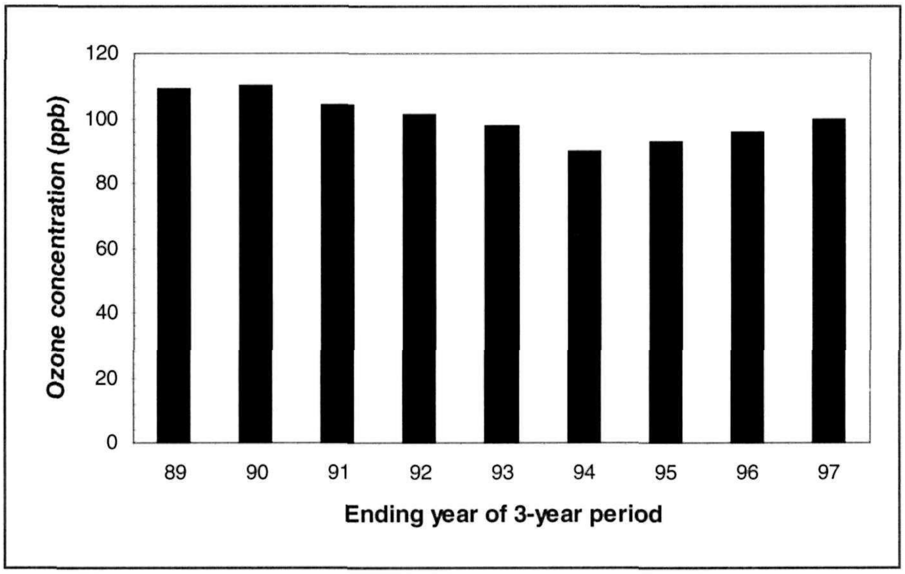

Figure 1. Three-year average of the fourth highest daily maximum 8-h ozone concentration (ppb), Cape Cod National Seashore, 1989-1997.

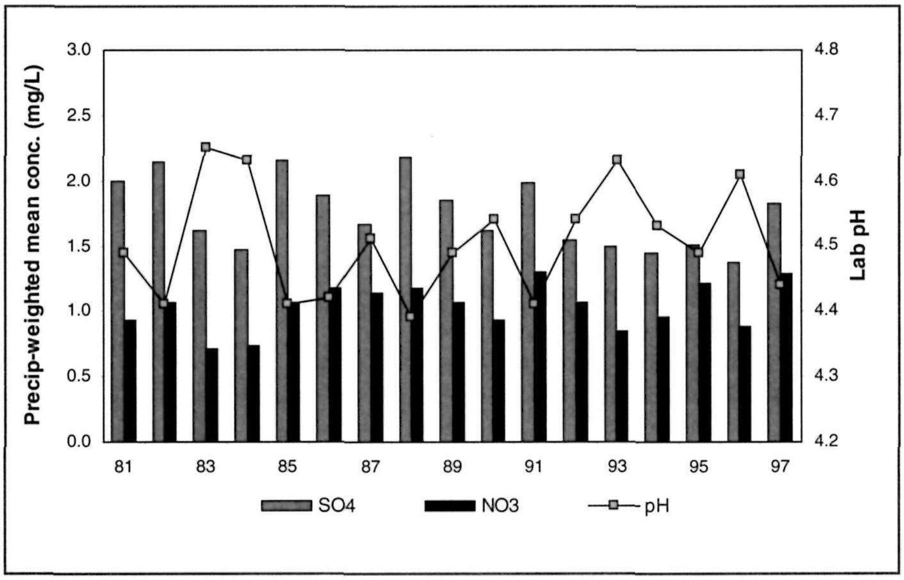

Figure 2. Annual average pH and precipitation-weighted mean sulfate and nitrate concentrations (National Atmospheric Deposition Program/National Trends Network), Cape Cod National Seashore 1981-1997.

ORV corridor on Race Point beach, Cape Cod National Seashore

stroyed 6 (46%) of the 13 clutches that did not hatch. Five of the 20 unprotected clutches hatched. The leading causes of hatching failure were abandonment of the nest by the parent and predation by crows *Corvus brachyrhynchos*. Fourty-two pairs nested on berms and 19 in the off-road vehicle corridor on the South Beach. For the third consecutive year, the North Beach remained open throughout the nesting season. All but approximately 2 km (1.3 mi) of the South Beach was closed for about 1 month. On 8 Aug, the entire off-road vehicle corridor was reopened to vehicles.

Monitoring of the Piping Plover will continue indefinitely or until the bird can be delisted.

Table 4. Number of breeding pairs and reproductive rate (RR) of the Piping Plover on Cape Cod National Seashore, 1985-1998.

Year	Pairs	RR
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	74	0.9
1997	67	1.5
1998	61	1.8

Channel Islands National Park, California

Pacific Coast Biome

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Scientific and Managerial Review of Long-term Ecological Monitoring Protocols

Channel Islands National Park has been in the forefront of long-term ecological monitoring to reduce uncertainty in management and guide the restoration of altered systems in parks. The park began monitoring marine resources in the early 1980s and terrestrial resources in the late 1980s.

The first phase of protocol design generally takes 2 or 3 years. Here, research is identified, ecosystem components are selected for monitoring, the level of statistical power to detect ecological change is determined, monitoring methods and locations are selected, preliminary collection and analysis of data are made, and a monitoring-protocol handbook is prepared. The second phase commences 5-10 years after program implementation. Here, the results of monitoring are reviewed to determine whether the original research and statistical power proved to be valid. Protocols are revised if necessary to improve the resource with information from monitoring.

Because techniques and technology are constantly changing, the formal review and analyses of data and monitoring protocol in the second phase ensure systematic improvements of methods and generation of useful information. A review of kelp forest monitoring in 1995 demonstrated the feasibility and importance of such reviews. This review consisted of the analysis of historic data of the resource, a workshop with discussions of monitoring results and options, a review of progress by the program steering committee, and a revision of monitoring protocols by park staff.

The park and the U.S. Geological Survey are initiating a review of the monitoring protocols for the vegetation and rocky intertidal communities, seabirds, and land birds. Data analyses will be conducted and include a trend analysis. A workshop will be held for scientific experts, statisticians, and management to discuss the results and recommend changes of the monitoring protocols. Changes will be incorporated into the program handbook, and the updated handbook will be printed. Another handbook with guidelines for periodic reviews and revisions of monitoring protocols will be developed. The guidelines should be applicable to reviews of monitoring programs in other parks.

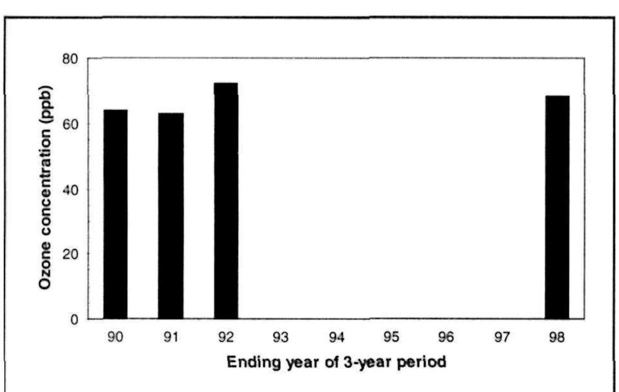

Figure 3. Three-year average of the fourth highest daily maximum 8-h ozone concentration (ppb), Channel Islands National Park, 1989-1998.

Air Quality

Ozone: The highest daily maximum 1-h average ozone concentration in Channel Islands National Park in 1997 was 81 ppb. The second highest daily maximum 1-h value, 80 ppb, was the 25th highest recorded by the 40 ozone monitors in the network in 1997. The fourth highest 8-h average concentration, 64 ppb, in 1997 was the 31st highest in the network.

The new U.S. Environmental Protection Agency (EPA) ambient air quality standard designed to protect human health is exceeded when the 3-year average of the fourth highest 8-h daily maximum ozone concentration exceeds 84 ppb. The 1996-98 average of the fourth highest 8-h concentration in Channel Islands National Park was 68 ppb, which meets the EPA standard. The 3-year average of the fourth highest 8-h daily maximum concentration has varied between 63 and 72 ppb during 1990-98 (Fig. 3).

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Kelp Forests

Long-term ecological monitoring of the kelp bed communities also known as *kelp forests* in Channel Islands National Park began in 1982. Kelp forests occur around the five islands of the park: Anacapa, San Miguel, Santa Barbara, Santa Cruz, and Santa Rosa. Sixty-eight indicator species or groups of taxa (Table 5) are monitored with a variety of protocols. Although not all sampling sites had been established and the protocol had not been finalized, changes of the kelp forest by the 1982-83 El Niño were detected. Because data from only 1 year of monitoring before the 1982-83 El Niño were available, determination of the effects of this natural perturbation was difficult. In spite of some differences between the 1982-83 El Niño and the 1997-98 El Niño, the effects of the two currents on the kelp communities were similar.

El Niños carry unusually warm nutrient-poor water to the marine communities around the Channel Islands. The effects are broad and often cause drastic decreases in some populations but drastic increases in others. Such changes affect the fauna and flora of the kelp forests and other marine communities around the Channel Islands.

The giant-spined sea star *Pisaster giganteus*, bat star *Asterina miniata*, and sunflower star *Pycnopodia helianthoides* are important kelp species. Their densities are estimated annually. Whereas the bat star is omnivorous and a scavenger, the giant-spined sea star and sunflower star are voracious predators and capable of decimating prey populations. For example, giant-spined sea stars in Channel Islands National Park have devastated a barnacle *Balanus* sp. population in a monitoring site in less than 1 year.

Whereas the giant-spined sea star and the bat star occur throughout the park, the sunflower star is a cold-water species and occurs mostly in the northern and western parts of the park at San Miguel and Santa Rosa islands. Warm water affects these and other species of sea stars by increasing the prevalence of an usually fatal wasting disease. The disease is caused by a bacterial infection and seems to be the main cause of sea star mortality during occurrences of the warm-water El Niño. Immediately following the 1982-83 and 1997-98 El Niños, the sizes of the sea star populations declined (Fig. 4). Within 3 years after the 1982-83 El Niño, they increased and are expected to increase again during 1999-2002 if oceanic conditions remain normal.

Results from monitoring the kelp communities since 1982 suggest that decades of baseline data are needed for a comprehensive understanding of kelp communities. As baseline information grows, the prediction of trends will lead to sustainable management and protection for future generations.

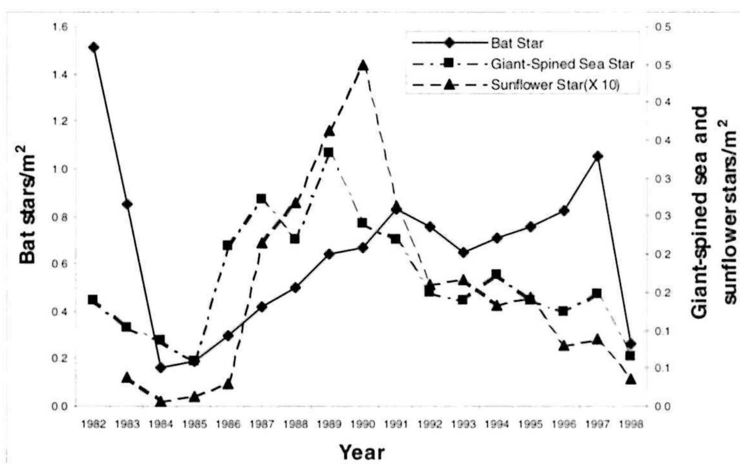

Figure 4. Combined mean density of sea stars in all kelp forests, Channel Islands National Park, 1982-1998.

Table 5. Regularly monitored species in kelp forests by taxonomic grouping, common name, scientific name, and monitoring technique. Channel Islands National Park, 1998.

Taxa/Common name	Scientific name	Monitoring technique
	Algae	
Miscellaneous green algae		R
Miscellaneous red algae		R
Articulated coralline algae		R
Encrusting coralline algae		R
Agar weed	*Gelidium spp.*	R
Sea tongue	*Gigartina spp.*	R
Miscellaneous brown algae		R
Acid weed	*Desmarestia spp.*	R
Oar weed	*Laminaria farlowii*	R,Q
Bladder chain kelp	*Cystoseira spp.*	R
Giant kelp	*Macrocystis pyrifera*	R,Q,M
California sea palm	*Pterygophora californica*	R,Q
Southern sea palm	*Eisenia arborea*	R,Q
Miscellaneous plants		R
	Invertebrates	
Miscellaneous sponges		R
Orange puffball sponge	*Tethya aurantia*	B,S
Southern staghorn bryozoan	*Diaperoecia californica*	R
Miscellaneous bryozoans		R
California hydrocoral	*Stylaster (Allopora) californica*	B,S
White-spotted rose anemone	*Tealia lofotensis*	B
Red gorgonian	*Lophogorgia chilensis*	B,S
Brown gorgonia	*Muricea fruticosa*	B,S
California golden gorgonian		
Strawberry anemone	*M.californica*	B,S
Orange cup coral	*Corynactis californica*	R
Cup coral	*Balanophyllia elegans*	R
	Astangia lajollaensis	R

Table 5 continued

Taxa/Common name	Scientific name	Monitoring technique
	Invertebrates cont'd	
Hydroids	*Diopatra ornata*	R
Ornate tube worm	*Phragmatopoma californica*	R
Colonial sand-tube worm	*Serpulobis squamigerus*	R
Scaled-tube worm		R
	Cypraea spadicea	
Chestnut cowrie	*Lithopoma (Astraea) undosum*	Q
Wvy turban snail	*L. (Astraea) givverosum*	Q,S
Red turban snail	*Asterina (Patiria) miniata*	Q,S
Bat star		Q,S
	Pisaster giganteus	
Giant-spined sea star	*Pycnopodia helianthoides*	Q,S,M
Sunflower star	*Lytechinus anamesus*	B,S
White sea urchin	*Strongylocentrotus franciscanus*	B,S
Red sea urchin		Q,S
	S. purpuratus	
Purple sea urchin	*Parastichopus parvimensis*	Q,S
Warty sea cucumber	*Pachythyone rubra*	Q
Aggregated red sea cucumber	*Haliotis rufescens*	R
Red abalone		B,S
Pink abalone	*H. corugata*	B,S
Green abalone	*H. fulgens*	B,S
Kellet's whelk	*Kelletia kelletii*	B,S
Giant keyhole limpet	*Megathura crenulata*	B,S
California brown sea hare	*Aplysia californica*	B
Rock sclop	*Crassedoma (Hinnites)*	B,S
California spiny lobster	*giganteum*	
	Panulirus interruptus	B
Tunicates		R
Stalked tunicate	*Styela montereyensis*	Q
Miscellaneous invertebrates		R

Table 5 continued

Taxa/Common name	Scientific name	Monitoring technique
	Fishes	
Blueberry goby	*Lythrypnus dalli*	Q
Blackeye goby	*Coryphopterus nicholsii*	Q
Island kelpfish	*Alloclinus holderi*	Q
Blacksmith	*Chromis punctipinnis*	V
Senorita	*Oxyjulis californica*	V
Blue rockfish	*Sebastes mystinus*	V
Olive rockfish	*S. serranoides*	V
Kelp rockfish	*S. atrovirens*	V
Kelp bass	*Paralabrax clathratus*	V
California sheephead	*Semicossyphus pulcher*	V
Black surfperch	*Embiotoca jacksoni*	V
Striped surfperch	*E. lateralis*	V
Pile perch	*Damalichthys vacca*	V
Garibaldi	*Hypsypops rubicundus*	V
Opaleye	*Girella nigricans*	V
Rockwrasse	*Halichoeres semicinctus*	V
	Substrate	
Bare substrate		R
Substrates: rock		R
cobble		R
sand		R

B=Band transect | M=5m^2-quadrat
Q=Quadrat | S=Size frequency measurement
R=Random point contact | V=Visual transect

Changes in scientific nomenclature

Patricia miniata = *Asterina miniata*
Astraea undosum = *Lithopoma undosum*
A. givverosa = *L. gibberosum*
Hinnites giganteum = *Crassedoma giganteum*
Allopora californica = *Stylaster californica*

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Rocky Intertidal Zones

Biannual monitoring of the rocky intertidal zone in Channel Islands National Park was expanded in 1998 to include six more sampling sites. Addition of the sites expanded sampling to the rocky intertidal zones of Santa Cruz Island. The sites were established in 1994 for a study funded by the Santa Barbara County and California State Coastal Commission with monies to mitigate damages from oil development and shipping. Park personnel assisted with the establishment of the sites, and monitoring had been conducted in accordance with park protocol. In 1998, the park assumed monitoring in these sites. Data from monitoring during 1994-98 were transferred to park records and became part of the long-term ecological database.

El Niño 1997-98 changed the cover of California mussels and rockweeds *Hesperophycus harveyanus* and *Pelvetia fastigiata* in the fixed photoplots. Most of the damage was caused by waves. The turfweed *Endocladia muricata* that was devastated by the 1982-83 El Niño was hardly affected by the 1997-98 El Niños. Sea star populations in the rocky intertidal zone remained stable despite the warm water of the El Niño current during 1997-98 and the presence of wasting disease in the area. Black abalone *Haliotis cracherodii* continued to decline. Former densities of 100/m^2 were reduced to less than 1/m^2 even on San Miguel Island where densities had remained higher than elsewhere in the park. The cause of the black abalone decline, withering syndrome, is still present. Restoration of this species is in doubt until strains resistant to the disease can be found and cultured. Owl limpets *Lottia gigantea* on Santa Rosa Island recently dropped to alarming levels (Fig. 5). The density in one site in 1998 was less than 10% of the density in the same site in 1989. The cause of the decline is not known at this time.

The park has also participated in the *Multi-Agency Rocky Intertidal Network* under the leadership of the Minerals Management Service to provide support, maximize coordination, and improve communications among nine agencies that conduct monitoring of rocky intertidal zones in southern California. The network is expected to increase access to the data by all users, integrate monitoring and analyses, and address questions beyond the scope of single programs.

Monitoring of the rocky intertidal zone will be continued in 1999.

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Seabirds

The welfare of seabirds in Channel Islands National Park is threatened by native and introduced predators, oil and chemical pollution, incidental take by commercial fisheries, alterations of marine food webs, and climate change. The park initiated monitoring of seabirds in 1985 to gain information for the protection, restoration, and conservation of the birds.

Time-series data have been collected on aspects of the distribution, abundance, and demography. During the breeding season in 1998, the population size,

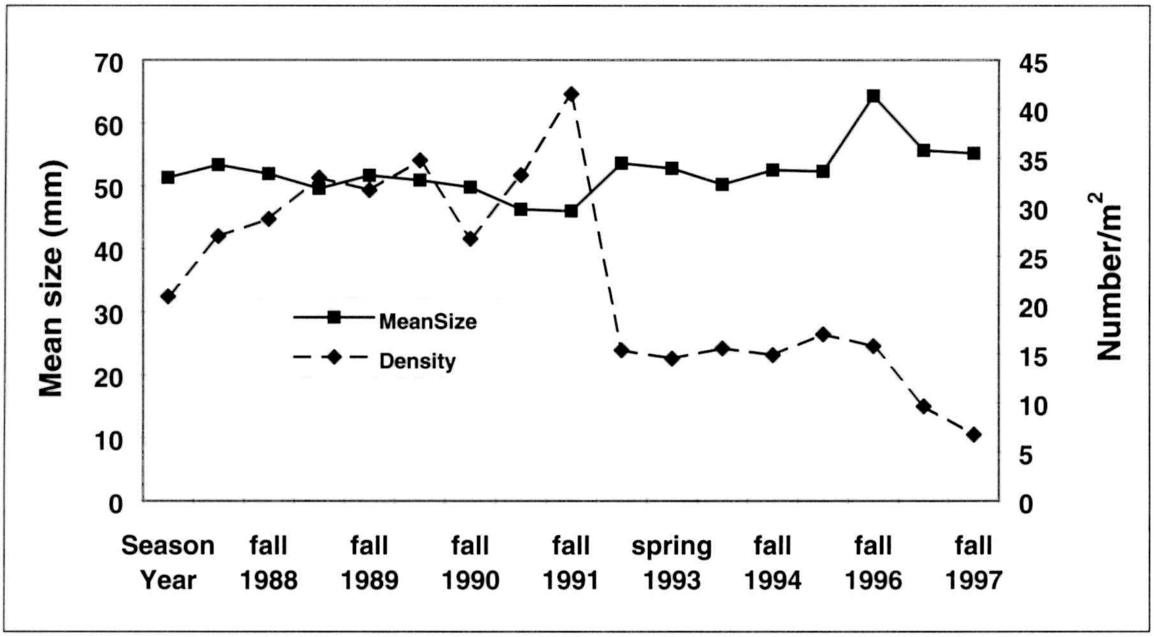


Figure 5. Mean size and density of owl limpets at Santa Barbara Island, Channel Islands National Park, 1989-1997.

phenology, and productivity of the Double-crested Cormorant *Phalacrocorax auritus*, Pelagic Cormorant *P. pelagicus*, Brandt's Cormorant *P. penicillatus*, Pigeon Guillemot *Cepphus columba*, Western Gull *Larus occidentalis*, and Xantus' Murrelet *Synthliboramphus hypoleucus* on Santa Barbara Island were monitored.

The number of nesting pairs of all cormorant species decreased substantially. The Double-crested Cormorant population decreased from an estimated 270 pairs in 1996 and 233 pairs in 1997 to 96 pairs in 1998. The decrease seems to be attributable to the 1997-98 El Niño that depressed food supply. Productivity however improved to an estimated 0.60 chicks/pair (Fig. 6).

The Brandt's Cormorant population size fluctuated during 1993-97 in a range of 302-508. The variability may have been the result of changes in breeding effort and breeding success by the birds or inadequate sampling by monitors. In 1998, 55 pairs of Brandt's Cormorants bred, and the productivity was 0.63 chicks/pair. The productivity of the Brandt's Cormorant has fluctuated. The decline in the number of nesting pairs in 1998 seems to be attributable to the 1997-98 El Niño that depressed the food supply. Several hundred cormorants roosted in the Webster Point colony in March when the birds usually initiate nesting. However, the birds did not nest, possibly in response to the depressed food supply.

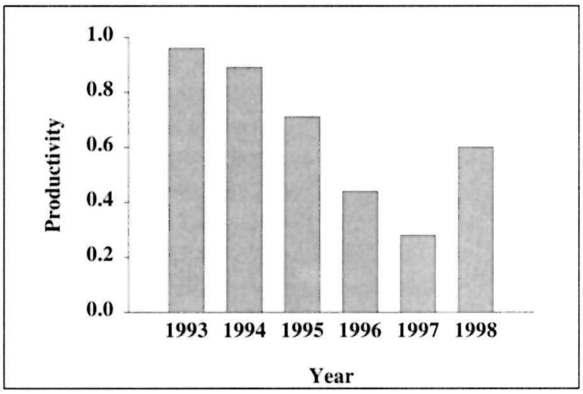
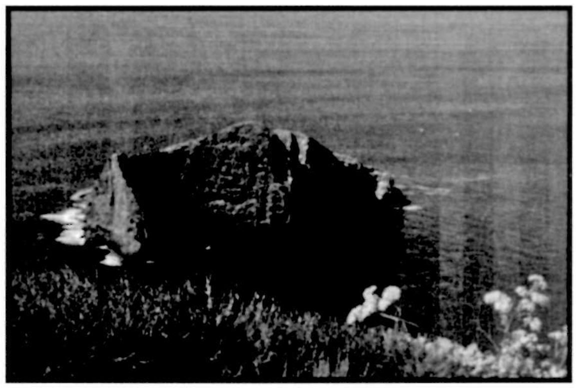
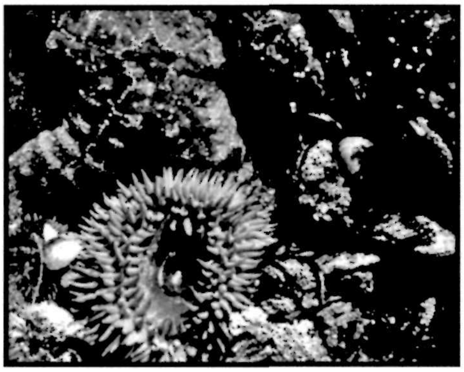
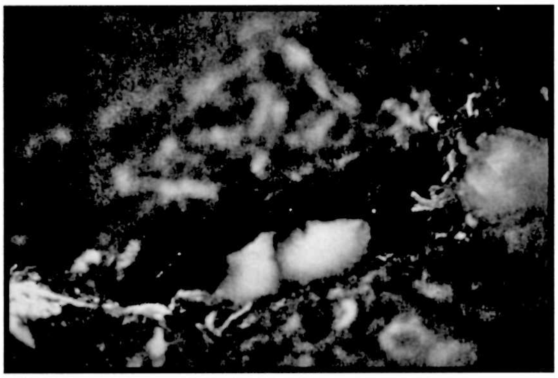


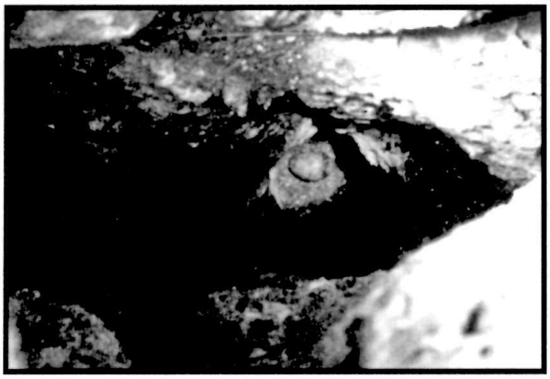
Figure 6. Trends in the productivity (number of chicks per pair) of Double-crested Cormorants, Santa Barbara Island, Channel Islands National Park, 1993-1998.





Staff in Channel Islands National Park monitor the diverse flora and fauna of intertidal habitats to determine changes in abundance and diversity.





Xantus' Murrelets in Channel Islands National Park. Unattended eggs are vulnerable to predation by mice. The first laid egg is particularly vulnerable because the parents leave it frequently unattended until the second egg is laid.

The productivity in Western Gulls in Channel Islands National Park was 0.86 chicks/pair. Hatching success remained constant during 1995-98, but fledging success and productivity fluctuated.

Peregrine Falcons were extirpated from the Channel Islands by the 1950s. After reductions of DDT and PCBs in the environment and reintroductions of nesting pairs, the population began to recover. Now, at least one pair nests on each of the islands.

Seventeen pairs of Pelagic Cormorants nested on Santa Barbara in 1997, but none nested there in 1998. A maximum of 38 Pigeon Guillemots was near the island this year, but the reproductive success of the birds could not be determined.

The estimated number of breeding Western Gulls in 1998 was 4203 pairs. The population size of the Western Gull has varied considerably but was similar in 1994, 1996, and 1998. Some fluctuations in abundance may have been due to observer differences. However, according to the island-wide population counts, the breeding population increased since the early 1990s. This increase was not reflected in the monitoring sites, which indicated that the population was colonizing new areas or increasing in areas other than in the study plots.

Table 6. Growth rates (g/day) of Western Gull chicks on Santa Barbara Island, Channel Islands National Park, 1996 - 1998.

Year	Fledged	Not Fledged	All Chicks
	Mean – s.d. (N)	Mean – s.d. (N)	Mean – s.d. (N)
1996	26.25 – 5.65 (143)	21.65 – 7.03 (17)	25.76 – 5.96 (160)
1997	23.31 – 4.94 (62)	18.10 – 5.88 (9)	22.65 – 5.32 (71)
1998	24.25 – 5.77 (115)	20.45 – 6.43 (40)	23.27 – 6.15 (155)

The productivity of the Western Gull in 1998 was 0.86 chicks/pair. Hatching success has remained constant from 1995 to 1998, but fledging success and productivity fluctuated from 1993 to 1998. In 1998, fledging success increased and led to an overall slight increase in productivity. Fledging success and productivity were higher in 1998 than in any other year since 1994. The growth rate of chicks was higher in 1998 than in 1997 but lower than in 1996 (Table 6).

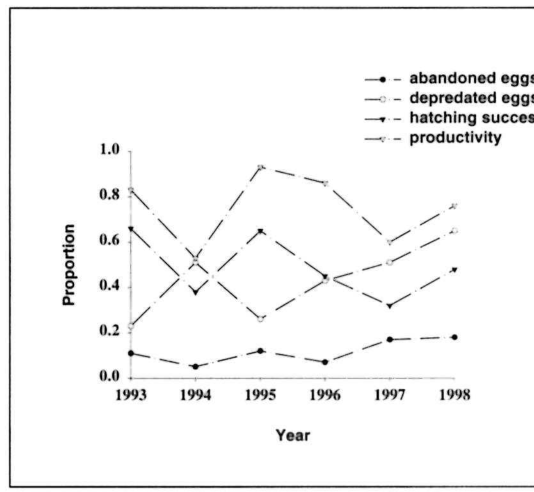


Figure 7. Trends in breeding parameters of the Xantus Murrelet, Channel Islands National Park, 1993-1998.

Xantus' Murrelets produced an average of 0.76 chicks/pair (Fig. 7). Since 1996, site occupancy by murrelets has decreased in the Nature Trail study area but has increased slightly in the Cat Canyon sites. Overall, occupancy has decreased. Habitat changes may be affecting the occupancy rate in the Nature Trail sites.

Hatching success of the murrelets and the estimated predation on murrelet eggs by deermice *Peromyscus maniculatus* ssp. fluctuated in an inverse relation from 1993 to 1997. Productivity in the murrelets fluctuated between 1993 and 1998 but has remained relatively constant. In 1998, productivity and hatching success in the murrelets increased even though the density of the mice increased. Seemingly, the explosion of the mouse population in 1998 did not occur until most murrelets were incubating. The presence of the incubating birds in the nest prevented greater predation on the eggs by the mice. The rate of nest abandonment by the murrelets has increased slightly since 1993. For unknown reasons, it is especially high in the Nature Trail sites.

The number of discovered dead Xantus' Murrelets increased during 1995-98. Eight murrelet carcasses were discovered in 1996, 16 in 1997, and 35 in 1998. The number of discovered dead birds is routinely recorded during field work and represents the minimum number of dead birds in a season. The increase in sighted carcasses in 1998 does not indicate an increase in predation but merely an increase in the discovery of carcasses. For example, in 1998, many carcasses were recovered from a previously unknown owl

Xantus' Murrelets lay 2 eggs. The second egg is laid 4-10 days after the first egg. The birds leave the first egg and sometimes both eggs unattended before they begin incubating. Unattended eggs are vulnerable to predation by mice, and the first egg is extremely vulnerable because it is frequently left alone until the second egg is laid.

Santa Barbara Island has one of the highest recorded densities of deermice anywhere in the world, As elsewhere, however, the density of mice on the island fluctuates from year to year. When the mouse density is high, predation on murrelet eggs seems to increase and hatching success to decrease.

roost. Predation by the Peregrine Falcon *Falco peregrinus* and Barn Owl *Tyto alba* may depress the population size of the Xantus' Murrelet. Both predators should be monitored to determine the effect of their predation on murrelets on Santa Barbara Island.

Monitoring of seabirds will be continued in 1999.

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Island Fox

The island fox *Urocyon littoralis littoralis* is a small carnivore of about the size of a housecat. Its closest relative is the common gray fox *U. cinereoargenteus.* The island fox occurs only on 6 of the 8 Channel Islands of California, namely, San Clemente, Santa Catalina, and San Nicolas in the south and Santa Cruz, Santa Rosa, and San Miguel in the north. The three northern islands on which it occurs are within the boundaries of Channel Islands National Park. The fox population on San Miguel has been declining since 1994 and is approaching a critically low level

(Fig. 8). The fox populations on the other northern Channel Islands (Santa Cruz and Santa Rosa) are also declining. The state of California designated the island fox a threatened species. The park is trying to determine the cause of the decline.

When it implemented long-term ecological monitoring of terrestrial ecosystems in 1993, the park began monitoring the island fox. The foxes are monitored every year by capture-mark-recapture methods. The animals are live-trapped in box traps, marked, and released. Traps are set out in large grids and trapped for six consecutive nights during summer after the pups have left the dens. Three grids are on San Miguel and two are on Santa Cruz. The ratio of marked to unmarked foxes is used to estimate the population size.

Foxes are marked with passive integrated transponder (PIT) tags that are no larger than a grain of rice and are inserted under the skin between the shoulder blades. When a handheld reader is passed over the skin, a signal sent by the reader is received and sent back by the tag and a unique number appears on the reader's screen (not unlike a barcode reader in a supermarket). Each animal is thus uniquely identified with a tag that lasts for the lifetime of the animal (a maximum of about 8-10 years).

In 1997, an estimated 70 adult foxes occurred on San Miguel. By 1998, the population had declined to an estimated 30-40 adults. San Miguel is the smallest island on which the foxes occur (3777 ha, 9325 A), and the fox population there consisted of about 450 adults or 0.1/ha (0.05/A) when foxes were abundant. The current low population level renders the population vulnerable to chance events such as weather and perhaps to genetic problems. The genetic variability is probably lower in the remaining foxes than in a larger, genetically more diverse population. Even if the population rebounds, its genetic diversity may be low, rendering the individuals less adaptable to future environmental changes. In essence, the remaining foxes are highly vulnerable to extinction, and recovery of the population size from so few adults will be difficult.

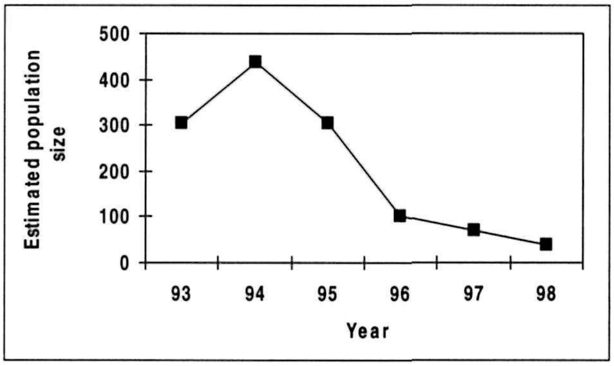
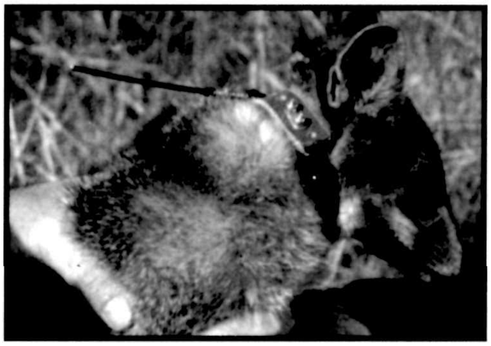


Figure 8. Estimated population size of the island fox on San Miguel Island, Channel Islands National Park, 1993-1998.



RADIO-COLLARED ISLAND FOX IN CHANNEL ISLANDS NATIONAL PARK

The park recently received a $50,000 grant from Canon U.S.A. Inc. to study the decline of the island foxes and to determine the ecological factors that may drive island fox population dynamics. The study is part of the *Expedition Into The Parks* program, which is funded by Canon U.S.A. Inc. through the National Park Foundation. In cooperation with a non-profit research organization, the Institute for Wildlife Studies, the park is using the donated funds to complete a survey of all island fox populations for canine diseases and parasites. Blood and fecal (scat) samples of foxes are examined for disease indicators and parasites. Fox blood is tested for evidence of previous exposure to certain diseases as indicated by the presence of antibodies. Results of blood tests from 1994 to 1997 provided no evidence that distemper, parvovirus, or leptospirosis is associated with the decline. Most foxes tested positive for canine adenovirus, which can cause infectious canine hepatitis. Whether infectious canine hepatitis is causing the decline of the population size is not known.

Although test results were inconclusive, canine parasites may in fact have played a role in the decline. Preliminary results indicate heartworm, which is a common canine parasite that originated in the southeastern United States and spread west in recent decades. Heartworm larvae are passed to canids through the bites of mosquitoes. Typically, adult heartworms lodge in the heart of an animal and cause progressive obstruction, shortening the life expectancy of the animal.

Heartworm was absent from the fox populations on two of the southern islands, San Clemente and Santa Catalina, but present on the four other islands. Prevalence was highest on San Miguel and Santa Rosa, where all adults have it. Blood samples from 1988, which are the earliest available, revealed that the prevalence of heartworm then was nearly as high in 1998 (Fig. 9).

Heartworm seems to have contributed to the decline of the fox abundance. On the four islands where the island foxes are afflicted with heartworm, the population segment of older-age foxes was significantly smaller in 1998 than in 1988. In contrast, on the two islands where the foxes are free of heartworm, the proportion of older-aged individuals has not declined.

Predation may be another factor in the decline. Golden Eagles *Aquila chrysaetos* are predators of island foxes. In a 4-month period, they killed 4 of 8 radio-collared foxes on San Miguel Island. Another two foxes died from other causes. To determine causes of mortality in foxes, the park recently initiated a study with radiotelemetry on San Miguel. Seven pups and one adult have been radio collared since November 1998. Within several weeks of being collared, one of the pups had been killed and eaten by a Golden Eagle, suggesting that predation by Golden Eagles may be a significant cause of mortality in pups on San Miguel. Pup survival on San Miguel during the past two winters has been close to zero. The study will either facilitate estimation of pup survival and dispersal or identify causes of mortality.

Until the causes for the decline are identified and mitigated, the species warrants federal listing as endangered under the Endangered Species Act of 1973 (16 U.S.C. 1531 et seq. as amended). The abundance of the island fox is so low that recovery may be difficult and take a long time.

GIS Assists with Monitoring of the Island Fox

Biologists in Channel Islands National Park are using various technologies and software to determine the causes of the declining abundance of the island fox *Urocyon littoralis* on the islands. On San Miguel Island, they are investigating causes of mortality and quantifying survival and dispersal with radiotelemetry and GPS (Global Positioning System). Radio-collared foxes are monitored weekly. The GPS files are downloaded, differentially corrected, and entered in MS Access. The Access table of point locations and IDs are then exported as a .dbf file and used to generate a point coverage in ArcInfo.

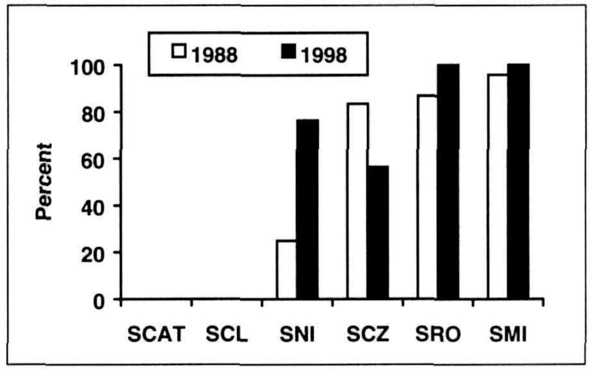


Figure 9. Seroprevalence for heartworm in the island fox, Channel Islands National Park, 1988 and 1998. SCAT = Santa Catalina, SCI = San Clemente, SNI = Saint Nicholas, SCZ = Santa Cruz, SRO = Santa Rosa, SMI = San Miguel.

The ability of ArcView to connect GIS data layers with non-spatial databases for visualization and analysis is now used for monitoring the island fox. First, by pulling up the coverage of the GPS points, researchers can quickly see where the animals are on the island. By temporarily joining the ArcInfo point coverages with the GPS data in Access by a unique index number, the GPS information can be queried by individual or date. This provides a view of the travels and dispersal routes of specific animals. The results have presented insight into fox behavior. For example, one female who has been trapped every year since monitoring began in 1993 recently traveled across almost one-third of the island (3-5 km, ~2-3 mi).

As fox densities decrease island-wide, individuals, especially pups, seem to disperse farther and range wider in search of mates and consequently increase the size of their home ranges. To determine whether home range size increases as density decreases, the ArcView extension developed by the U.S. Geological Survey called *Movement* is being used. This set of analysis functions of animal movement provides various information. In Channel Islands National Park, researchers are using the function that calculates a MCP (Minimum Convex Polygon) home range for any set of points from a set of GPS point locations by a fox's ID number. The home range can then be calculated in ArcView. The same points can be queried by any subset of interest such as season or weather event or a home range polygon can be superimposed over another data layer such as a vegetation map. Completion of analysis in 1999 is expected to provide useful information for the conservation of the island fox and possibly for the reversal of its population decline.

Pinnipeds on San Miguel Island

The pinnipeds on San Miguel Island have been studied for 30 years. The primary focus has been on natality, survival, recruitment, and population-size trends of California sea lions *Zalophus californianus* and northern fur seals *Callorhinus ursinus* .

Daily Census of California Sea Lions and Northern Fur Seals

Daily counts of California sea lions and northern fur seals were made in the East Adams Cove study area from 21 May to 2 Aug 1998. Large adult males, small adult males, adult females, and pups of each species were counted in 1-3-day intervals. The onset of parturition and the duration of the pupping season in both species were protracted in 1998. The first healthy sea lion pups were not sighted before 29 May, about 1 week later than usual, and the mean pupping date of 16 June was about 5 days later than in other years. Newborn pups were sighted as late as 4 Aug.

Sea lion in Channel Islands National Park

The natality of California sea lions and northern fur seals significantly declined in 1998. In sea lions it was 43% of the natality in 1997 and in northern fur seals, 81%. The mortality of pups of both species was the highest ever recorded. At the end of August, it was 39% in sea lions and 52% in northern fur seals. The lower natality and the higher pup mortality seem to have been attributable to a lesser abundance of prey. In response to El Niño currents in the coastal waters of California, upwelling of cool, nutrient-rich waters into surface layers decreases and the mixed layer of the water column deepens. Prey of marine mammals respond to such conditions by moving northward or by moving to greater than usual depths and thereby become less available to foraging sea lions and seals. The difficulty of securing adequate food impairs the maintenance of healthy pregnancies and normal milk production. The growth of pups is slow, and the mortality of pups from starvation and disease rises.

Sighting of Marked Animals

During 21 May-2 Aug 1998, sightings of branded sea lions and tagged northern fur seals were recorded during a minimum of 8 h each day at Point Bennett and along the southern side of Point Bennett to Tyler Bight. Sightings were made with binoculars, spotting scopes, or a Questar scope.

The number of 2-year-old California sea lions of each sex was low, indicating that survival of this age group either had been low during the past winter or that this age group had chosen other haul-out sites along the California coast. Adult females with pups were 4-11 years old, but the percentage of females with pups in all age groups was lower than in past years. The number of sighted females with pups declined from 177 in 1997 to 149, i.e., a 16% decrease in observed natality. Five branded females were nursing yearlings. Two 10-year-old males established territories. One male returned to the territory that he established in 1997.

Sightings of branded California sea lions are providing the first empirical data on territorial tenure, age, and behavior of territorial males. Fifty-eight adult males branded in Puget Sound during the winters of 1994-98 were sighted at San Miguel Island during the breeding season. Nine of them established territories. Ten adult males branded on the Columbia River during winter 1997-98 were sighted. One of these males established a territory.

Natality and Mortality

During 29-31 Jul 1998, a survey of live pups of California sea lions was made at Point Bennett and on the northern and southern shores of San Miguel Island. A record of dead pups was kept throughout the season in the Point Bennett rookery and at the time of the survey of live pups at Castle Rock. The mean number of live pups on San Miguel Island was 9278 and the number of dead pups was 2952. The estimated natality was 12,230 pups, which was 57% of the natality in 1997. On 3 Aug at Castle Rock, the mean number of live pups was 275 and the total number of dead pups was 10. The estimated natality was 285 pups, which was 53% of the natality in the previous year.

An observed mortality of California sea lion pups was calculated from a sample area in the Point Bennett rookery. In this area, the natality was 8453. The observed pup mortality at the end of August was 3316 or 39%, which was 18.4% greater than in 1996.

The survey of live northern fur seal pups was made on 3 Aug at Castle Rock and on 6 Aug in Adams Cove. The number of live pups was 309 and the number of dead pups was 116 . The estimated natality was 425 in Adams Cove, which was 19% of the natality in 1997. The observed pup mortality was 52% at the end of August. At Castle Rock, the mean number of live pups was 194 and the estimated natality was 203, which was 20% of the natality in 1997.

Although the effects of the 1997-98 El Niño lessened in 1998, residual pools of warm water remained along the California coast and depressed natality and pup survival. The low natality and high pup mortality in both species during 1997-98 will lower recruitment in these cohorts in the coming years.

Foraging Ecology of California Sea Lions

In May, 10 pregnant California sea lions were fitted with dive recorders to study the effects of El Niño on the foraging behavior of reproductive females. Four females lost their newborn pups by the first or second foraging trip. Three of the 10 females did not return to San Miguel Island and 2 were sighted several more times on the island but without pups. Five of the 10 dive recorders were recovered and data will be analyzed. Reports of large numbers of all age classes of California sea lions at Año Nuevo Island and the Farallon Islands suggested that in response to El Niño prey was distributed farther north at the outer edges of the foraging ranges of females with pups.

Denali National Park and Preserve, Alaska
Artic-Subarctic Biome

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During Fiscal Year 1998, the Biological Resources Division of the U.S.Geological Survey completed peer reviews of most protocols, obtained data sets from cooperating investigators, continued the development of protocols for monitoring soils and macro-invertebrates, initiated cost-benefit assessments of protocols and program and sampling designs, and began an evaluation of ecological modeling and its application to monitoring. Park staff continued monitoring natural resources and organizing data sets. The Biological Resources Division and the park developed a brief strategic plan for monitoring and coordinated the annual meeting of the parks that conduct prototype long-term ecological monitoring.

Air Quality

Fine Particles and Visibility

Denali National Park and Preserve is part of the IMPROVE visibility monitoring network. Particulate matter and the optical properties of the atmosphere that are important for understanding the effect of air pollution on visual air quality are measured. The Mar 1997–Feb 1998 annual average fine mass was 1.8 μg/m^3, which was among the lowest measured on all IMPROVE sites. More than three-fourths of that mass were organics (54%) and sulfates (28%). The calculated extinction budget during this period indicated that 37% of the aerosol light extinction was caused by sulfates, 30% by organics, 19% by soil and coarse particles, 9% by soot, and 4% by nitrates. The annual average standard visual range resulting from this mix was 172 km (8 dv).

Fine particle and visibility in the park in 1997 had seasonal patterns. Summer fine mass was 3.5 μg/m^3 or about twice the annual average; about 75% of this mass was organics. The lowest seasonal visibility, 134 km (11 dv), occurred in summer. Organics (52%) and sulfates (23%) were the largest contributors to summer aerosol light extinction. Visibility was highest (225 km, 6 dv) and seasonal fine mass the lowest (0.9 μg/m^3) in winter (Dec 1997-Feb1998). Forty-two percent of wintertime aerosol extinction was produced by sulfates, 19% by coarse particles, 17% by organics, and about 11% each by nitrates and soot. During 1988-96, the days with the best, average, and worst visibility each improved about 0.1-0.2 dv/year (Fig. 10).

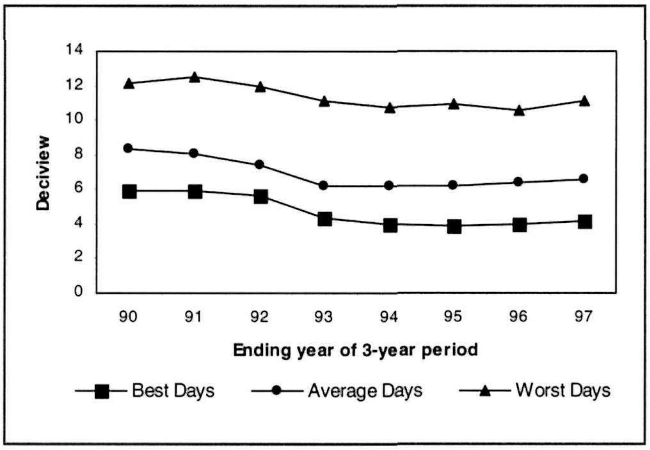

Figure 10. Three-year average deciview for best, average, and worst visibility days in Denali National Park and Preserve, 1990-1997.

Ozone

Ozone concentrations in Denali National Park and Preserve are among the lowest in the National Park Service Gaseous Air Pollutant Monitoring Network. The highest daily maximum 1-h average ozone concentration in 1997 was 57 ppb. The second highest daily maximum 1-h value, 55 ppb, was the 38th highest recorded by the 40 ozone monitors in the network in 1997. The fourth highest 8-h average concentration in 1997, 52 ppb, was the 37th highest in the network.

The new U.S. Environmental Protection Agency ambient air quality standard designed to protect human health is exceeded when the 3-year average of the fourth highest 8-h daily maximum ozone concentration exceeds 84 ppb. The 1995-97 average of the fourth highest 8-h concentration in Denali National Park and Preserve was 52 ppb, well below the EPA standard. The 3-year average of the fourth highest

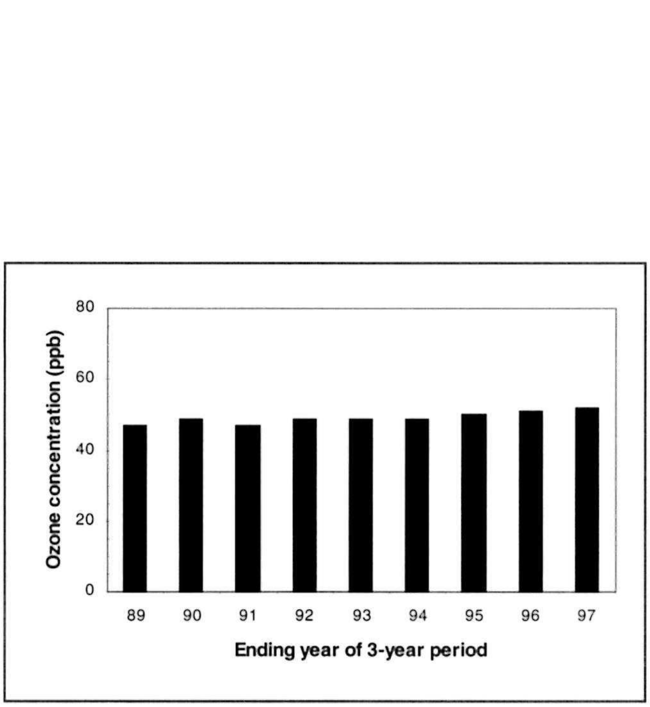

Figure 11. Rolling 3-year average visibility (dv) for the best, average, and worst visibility days in Denali National Park and Preserve. During 1988-96, the days with the best, average, and worst visibility each improved about 0.1-0.2 dv/year.

8-h daily maximum concentration has varied between 47 and 52 ppb between 1989 and 1997 (Fig. 11). This ozone chart qualitatively suggests a small increase in the 3-year average between 1989 and 1997. However, a more quantitative analysis of the average daily maximum ozone concentrations in May-September did not reveal statistically significant improving or degrading air quality trends during 1988-97.

Wet Deposition

The lowest concentrations of sulfate and nitrate in precipitation at the four prototype parks were recorded at Denali National Park (Fig. 12). Sulfate reached a maximum concentration of 0.52 mg/L in 1981, and nitrate reached a maximum concentration of 0.26 mg/L in 1991. However, nitrate concentrations increased significantly from 1985 to 1993 ($p < 0.05$). The pH of precipitation was considerably higher (5.0-5.6) in Denali National Park and Preserve than in the other parks that conduct prototype ecological monitoring. The low concentrations of sulfate and nitrate in combination with a higher precipitation pH characterizes Denali National Park as a background site.

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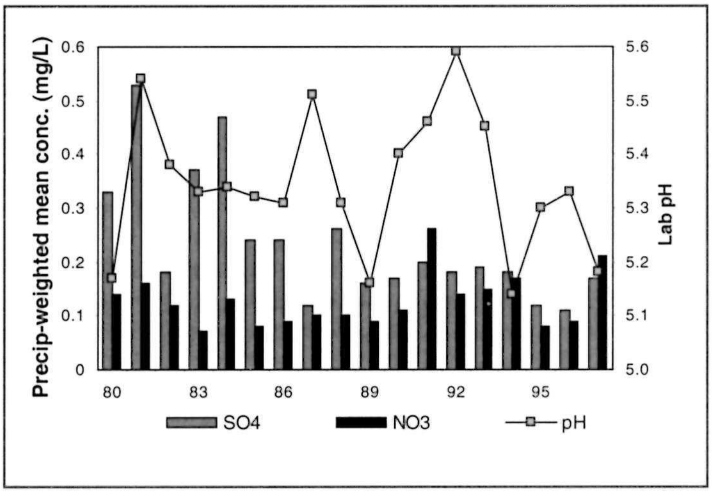

Figure 12. Annual average pH and precipitation-weighted mean sulfate and nitrate concentrations (National Atmospheric Deposition Program/National Trends Network), Denali National Park and Preserve, 1981-1997.

Weather

Weather data are collected in Denali National Park and Preserve to determine the effect of weather on natural resources such as air and water quality, soils, vegetation, breeding birds, and small mammals. In 1998, weather data were collected with the 11 automated stations that were operated in 1997 (one station was relocated) and with two additional stations that were installed on Mt. McKinley.

The core of the monitoring equipment consists of six automated stations in the Rock Creek drainage, a headwater stream in the northeastern corner of the park that was selected in 1992 as the study site for the design phase of long-term ecological monitoring. These six stations, which span almost the entire range of elevation in the Rock Creek watershed, have been operating since 1993. Data were collected at each station throughout 1998 except during sporadic periods of downtime from damage or malfunction.

The extended network of weather stations in the park consists of four RAWS (Remote Automated Weather Stations) that are maintained in cooperation with the National Interagency Fire Center, the Bureau of Land Management, and the Alaska Support Office of the National Park Service. These stations gather data that are used for the prediction of weather that may be favorable for natural fire, weather forecasting, and long-term monitoring of resources.

In 1998, two stations on Mt. McKinley were added to the weather network in the park. One station was permanently installed at 4331 m (14 200 feet) in a location known as the *Edge of the World* along the popular West Buttress climbing route. It was funded jointly by the I&M Program and the park's mountaineering safety program. The station was installed for the dual purpose of aiding mountaineering rangers during the climbing season and of providing information on climatic conditions at high altitudes. The second station is installed during the climbing season at the base camp on the Kahiltna Glacier at an elevation of 2196 m (7200 feet). The two stations collect weather data simultaneously for a portion of each summer, and the station at the Edge of the World is intended to operate throughout the year.

In general, 1998 was a normal weather year. Most measured parameters were within their average range each month. However, rainfall of 11.5 cm (4.5 in.) in July exceeded the average rainfall in that month by 4.2 cm (1.7 in.) and was the most rainfall in that month in 12 years. In April, precipitation was 27.9 cm (11 in.) or an equivalent of 2.1 cm (0.8 in.) precipitation. This exceeded the average precipitation in this month by 1.0 cm (0.4 in.).

Monthly snow surveys were continued in 1998 in cooperation with the U.S. Natural Resources Conservation Service. The surveys were conducted at five ground survey snow courses on the north side of the Alaska Range and at five aerial snow depth observation markers on the south side. Snow depth and density were measured at the snow courses. Two courses are located near park headquarters at different elevations and three are distributed throughout the northwest portion of the park. Snow depths were observed at each of the five aerial markers that are distributed along the southern flanks of the Alaska Range in the southeast portion of the park. Snow depths and densities were near average throughout the year. The greatest total accumulation of snow was in Dec 1997 (snow surveys are conducted each winter at the beginning of the month between December and May). The most unusual occurrence was a springtime snow that deposited 14 cm (5.6 in.) of snow at park headquarters on 30 Apr. This occurred after several weeks of unseasonably warm weather during which daytime temperatures were in the 10-15° C range. The same storm deposited several meters of snow at higher elevations near Mt. McKinley and throughout the Alaska Range.

Stream Channels

Stream channels in Denali National Park and Preserve have been monitored since 1991 to collect long-term information for detecting or predicting resource changes. The information has improved an understanding of taiga and tundra ecosystems in interior Alaska, has been helpful in the representation of an intact, naturally functioning subarctic site in broad-based monitoring networks, and has been used in management for the preservation of resources.

Water quality and stream morphology have been monitored in two stream channel reference sites in the Rock Creek watershed near park headquarters since 1992. The lower site is immediately upstream of the stream gaging station at the lower end of the study area, and the second station is midway upstream. Water quality often is monitored to determine ecosystem trends in wilderness areas. Surface water composition provides links to local geology, morphology, nutrient status, and biological productivity. During summer 1998, major ions, selected nutrients, alkalinity, pH, and total organic carbon were sampled biweekly, and samples were sent to a U.S. Forest Service analytical laboratory for analyses. To date, results indicate a geochemical dominance of the stream water chemistry. For example, the 1998 mean concentrations were 2909.0 ueq/L Ca^{++}, 11 678.9 ueq/L Mg^{++}, and 8493.3 ueq/L SO_4^-. Stream water nutrient levels are normally low; the PO_4^- was below the detection limits of 1.27 ueq/L . However, nitrate levels of 61.2 ueq/L NO_3^- were at much higher concentrations in 1998 than in previous years;

Stream morphology too is monitored annually in these two sites. The significance of geomorphic and hydrologic landscape characteristics is often ignored or minimized in long-term ecological studies. However, some earth scientists believe that changes in basin characteristics may provide preliminary and direct indications of alteration in climate or land use, especially in areas that respond quickly to such alterations. Therefore, stream channel reference sites are an integral part of long-term monitoring in the park.

In a stream gaging station immediately downstream of the lower sampling station in the lower Rock Creek watershed, long-term stream discharge records are collected from continuous stage measurements. The records are used to calculate the watershed mass-balance. Depending on the stability of the cross-section and the desired accuracy of the stage information, the stilling well is either placed in the stream such as in Rock Creek, dug into a nearby bank, or used in conjunction with a weir or flume. Rock Creek has an unstable streambed, which may require careful and constant calibration of the discharge rating curve, especially after flood events. For example, a flash flood in the watershed on 30 Jun 1998 seemingly transported sediment into the gage reach and thereby changed the channel shape and skewed the relation between the depth of water and the predicted discharge. The hydrograph from the uncorrected stage data showed an obvious change in base flow. By 27 Jul, the sediment had been transported downstream, and the rating curve was once again valid for the original channel shape. After checking the rating curve for outliers and applying other corrective techniques, the hydrograph was redrawn. A weir or flume in the Rock Creek gaging station would improve the accuracy of stream gaging information from this site.

Ecological Hydrology

Stage data in the Rock Creek watershed have been collected for 7 years. Preliminary analysis of stages, precipitation, and evapotranspiration have already provided some insights into the ecological hydrology of Rock Creek. Such analyses provide important linkages to other aspects of the entire ecological system and are required for investigating the relations between vegetation, soils, climate, and streamflow.

Discharge in Rock Creek normally peaks between early May and mid June when snowpack melts during a leafless period in spring before trees and shrubs begin to transpire. Frozen soils and near-maximum incoming solar radiation induce the quick and flashy nature of the spring runoff. Large precipitation events during the cool wet months of July and August can also induce large flashy streamflow peaks. In 1998, the peak discharge occurred on 9 August. The estimated total run-off from the Rock Creek watershed in 1998 was 38.07 cm (14.99 in.).

Throughout the relatively cool summer, precipitation is the dominant hydrologic influence. Between 1 May and 30 Sep1998, precipitation totaled 29.85 cm (11.75 in.) and pan evaporation totaled only 9.25 cm (3.64 in; Fig.13). Precipitation amounts generally exceeded pan evaporation in all years studied, and this trend is different from other small arctic watersheds where evapotranspiration potentially exceeds summer rainfall, especially during June and early July. The sum of precipitation and evapotranspiration (as pan evaporation) accounted for virtually all runoff, signifying the

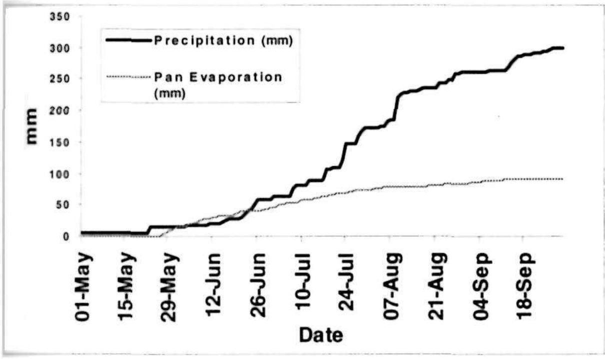

Figure 13. Cumulative pan evaporation and precipitation in the Rock Creek watershed, Denali National Park and Preserve, 1998.

lack of importance of soil recharge in the hydrologic ecology of Rock Creek.

The type of water storage in Rock Creek (snowpack versus groundwater or canopy) and the timing of storage release, have important implications for streamflow, availability of water to vegetation, and other key feedback to watershed ecology. For example, dominant storages such as snowpack are considered to have rapid turnover rates, which reflect a landscape with little memory from year to year. Conversely, a ground-water dominated system may transmit the effects of surplus or deficit for several years. This is an example of improvement of this type of analysis from an understanding of relations between hydrologic, climatologic, and ecologic processes.

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Glaciers

In 1998, monitoring of all the glaciers that were monitored in 1997 was continued. The seasonal mass balance (the net change in mass, i.e., the gain or loss of snow or ice over time) of each glacier was measured. In spring, the *winter balance* (the amount of accumulation on each glacier during the previous winter) was measured. In late summer, the *summar balance* (the remaining accumulation after melting) was measured. The results of the two measurements reveal the net mass balance of a given glacier in one year. In 1998, mass balance data were collected in index sites on the Traleika and Kahiltna glaciers, where surveys have been conducted seasonally since 1991, and on the East Fork Toklat Glacier, a small glacier in the northeast corner of the park, where a benchmark site was established in 1997.

In addition to mass balance, data on glacier flow and surface elevation were collected during each survey. Results in 1997 revealed significant and unexpected thickening of the Traleika Glacier by 25 m (82 ft) and nearly doubling of its rate of ice motion despite a consistently negative mass balance. The Traleika Glacier is a tributary of the Muldrow Glacier, which surges once approximately every 50 years (surges are periodic rapid advances of glaciers that occur when the ice breaks away from its bed and slides on subglacial water). Prior to 1998, pre-surge monitoring of the Muldrow Glacier had not involved its tributary glaciers. However, thickening and acceleration of ice in the area of surge onset have been seen to precede advances in other surge-type glaciers and such changes of the Traleika Glacier in 1997 prompted park staff to shift the emphasis of study to this tributary glacier in 1998. The next surge of the Muldrow Glacier may actually begin in the Traleika Glacier. The determination to redirect surge related studies to the Traleika in time to observe the pre-surge buildup would not have been possible without the long-term monitoring of mass balance since 1991. The study of the pre-surge buildup will help glaciologists gain a better understanding of glacier dynamics.

The speed of ice motion in the Two-Mi Moraine target site established by Bradford Washburn in 1976 on the Muldrow Glacier was 40% greater in 1997 than in 1996. The acceleration may have been a precursor to a surge. The trend, however, did not continue in 1998 when the speed of ice motion decreased. The absence of a meaningful trend in the behavior of the Muldrow Glacier confirms the importance of increased monitoring of the Traleika Glacier for signs of an impending surge.

In 1998, data were collected for the first time on the East Fork Toklat Glacier. The purpose of benchmark monitoring is the collection of seasonal mass balance, surface elevation, and ice flow data in much greater detail than can be done on the larger glaciers where the index sites are maintained. Measurements on benchmark glaciers provide important ground truth data for future observations of other glaciers by remote sensing. Remote sensing will facilitate the monitoring of many more glaciers in the park without costly and time-consuming field methods.

The changes on the East Fork Toklat Glacier in 1998 were more significant than expected. At lower elevations near the glacier's terminus melting caused the ice surface to drop approximately 4.5 m (~15 ft). Consequently, index stakes (reference points for repeated measurements) that had been installed to a depth of 6 m (~20 ft) in the ice had to be reset to at least 9 m (~30 ft) in September. Otherwise, melting in 1999 would completely remove many index stakes on the lower half of the glacier. Although the amount of melting near the glacier's terminus was greater than anticipated, the large amount of snow accumulation at the head of the glacier was equally unexpected. In late April, a large amount of snow fell at higher elevations on the East Fork Toklat Glacier and melting was not sufficient to expose many index stakes during summer. Index stakes that did emerge from the snowpack had to be lengthened by 3-6 m (10-20 ft) to ensure their relocation in 1999. Whether snowfall and summer melting in 1998 was anomalous has not been determined. Only measurements during subsequent years will reveal the long-term trend in the mass balance and the resulting changes in ice thickness and flow and their relation to climate variables.

Effects of Climate Change on Vegetation in the Rock Creek Drainage

Vegetation in the Rock Creek Drainage of Denali National Park and Preserve is monitored to determine the effects of climate change on the the position of the forest-tundra ecotone and to discern concomitant changes in the community structure of three major vegetation types in the northern part of the park: spruce *Picea* spp. forest, treeline spruce-birch *Picea-Betula* scrub woodland, and alpine tundra. Vegetation is sampled in permanent monitoring sites along an elevation gradient; one site each is in each vegetation type. In each site, the initial structure and composition of the tree, shrub, and herbaceous strata were documented to provide baseline data for future comparisons. The principal objectives of the project have been the measurement of differences of growth and reproduction in white spruce *Picea glauca* in different landscapes over time and the relation of trends in these parameters to changes in the position of treeline on the landscape. In 1998, park staff in cooperation with personnel of the U.S. Geological Survey began to revise the scope and character of the vegetation monitoring to address a broad array of management needs.

Cone Production

In 1998, spruce cone production was unusually high at a mean of 390 cones/tree or four times as many cones as in 1992 when cone production was thought to be unusually high. At treeline, the mean number of cones per tree was 162 or three times as many cones per tree than in 1993 when production there was unusually high.

Yearly increases in the diameter of spruce trees in vegetation plots in the forest and at treeline are recorded by dendrometers. The rate of spruce growth increased in both communities during 1994-98 but declined in 1998. The decline illustrated a shift in the allocation of resources from growth to reproduction by spruce in the study area during the growing season. The demand for resources by the large crop of growing and maturing cones probably reduced the energy allocation to vegetative growth by these trees. Unusually large cone crops such as in 1998 are only episodical even in the lowlands and are usually separated by as many as 12 years during which cone production is negligible. Unusually high cone production is even less frequent in mountainous areas such as in the park, where summers are short and cool. Although warm, dry summer weather is a presumed prerequisite for a substantial cone production, the conditions that give rise to this phenomenon are not well known. Long-term data from the park and information from other stations such as Bonanza Creek near Fairbanks will help identify the conditions that favor large spruce cone crops.

The 1998 cone crop presented a first opportunity to examine the meteorological conditions that may stimulate increased reproduction by white spruce in the Alaska Range. White spruce initiate cones during the summer prior to the year in which the cones mature. Therefore the conditions that are most relevant to the formation of cones in 1998 occurred during summer 1997. A plot of cumulative thawing-degree days in June and July (departures of average daily temperature above 0° C) during1991-97 revealed that beginning on 28 Jun and lasting for the remainder of the season conditions were warmer in 1997 than during any of the previous 6 years. Total precipitation on the other hand, did not indicate that summer 1997 was particularly dry, as would be expected based on the hypothesis that warm *and* dry conditions are required for the stimulation of a large cone crop. In fact, the total precipitation in Apr-Jul 1997 was the second highest noted during this period. Further analyses of temperature, precipitation, and other climatic parameters will be done to fully explore their relation to cone production.

The formation of a large cone crop does not guarantee abundant seeds in the following year. The second critical step in the production of a large spruce seed crop is the fertilization and maturation of the seeds inside the cones. This takes place during the second summer of cone growth and also depends on climatic factors. A very large cone crop may in fact produce only a paltry number of viable seeds if conditions during the second summer are not favorable. In late summer, cones were harvested from trees in eight widely scattered sites at treeline to estimate the relative productivity (in terms of viable seed) of the cones in the 1998 crop. By examining the cones for the quantity and quality of their seeds, a measure of the amount and variability in seed productivity and viability within and among eight different sites during a banner cone crop can be determined.

Stand Structure of Permanent Vegetation Plots

The episodic character of spruce reproduction affects the patterns of stand establishment of spruce in the landscape. Recruitment of spruce seedlings is relatively infrequent and in pulses of relatively even-aged cohorts rather than in steady, even accumulation of new seedlings. The episodic nature of spruce recruitment is magnified by the species' preference for a mineral soil seedbed for successful establishment. The suitability of a potential seedbed is enhanced by certain types of disturbance such as fire that exposes a mineral soil surface. Hence, spruce strongly benefit when a productive seed year coincides with a fire or other disturbance. Suitable microclimatic conditions during the sensitive seedling stage is the third requirement for successful establishment of a stand of spruce.

A comparison of the size class distribution of white spruce in the permanent vegetation plots in the forest and at treeline revealed several differences in the population structure of spruce between these two sites. Most notably, seedling establishment was significant in the forest prior to 1992 when these measurements were taken but low or absent at treeline. This is evidenced by the large number of trees in the less-than-0-cm-diameter (at 1.3 m, 4.3 ft, above the ground) size class in the forest and the small number of trees in these size classes at treeline. Most trees at treeline are of similar size. Thus, these stands may be formed by one relatively even-aged cohort dating to a specific pulse of establishment (perhaps derived from an unusually high seed crop in the past). If as expected the cone crop of 1998 produces a large number of viable seeds at treeline and in the forest, it may create a strong pulse of spruce establishment in the landscape.

Monitoring of the vegetation in the Rock Creek drainage will be continued in 1999.

Reproductive Success of Golden Eagles

Golden Eagles *Aquila chrysaetos* are the largest avian predators that nest in northeastern Denali National Park and Preserve. An understanding of the ecology of this species in North America is largely based on data from resident populations in temperate climates. However, Golden Eagles in northern North America are migratory and spend as many as 5 months migrating to, wintering in, and returning from temperate climates thousands of kilometers from their northern nesting areas. This life history strategy is common to birds that breed in northern latitudes and makes high energy demands on the birds for migration immediately before the breeding season. Furthermore, Golden Eagles arrive in their northern breeding areas in late winter when the abundance and diversity of their prey are at the lowest annual level. Therefore, productivity could be markedly lower in northern populations of Golden Eagles than in conspecifics in temperate climates.

Prior to 1988, Murie completed the only ecological study of Golden Eagles in Denali National Park and Preserve. Murie's results provided new information about Golden Eagles in northern latitudes. However, he focused on food habits and his study was limited by small sample sizes (n = 5 nests/year) and a relatively short study period (3 years). Overall, few studies of Golden Eagles in Alaska have been conducted and information about the ecology of the species is scarce.

In 1988, Denali National Park and Preserve began a comprehensive study of the ecology of its Golden Eagles. A major objective has been the documentation of the reproductive characteristics of the species. Reproductive success of Golden Eagles in temperature climates is strongly tied to food supplies that are available immediately before egg laying. Therefore, a secondary objective has been the examination of responses by Golden Eagles in the park to natural changes in the abundance of their late winter and early spring food source, snowshoe hares *Lepus americanus* and Willow Ptarmigans *Lagopus lagopus*.

From 1988 to 1998, eagles in the study area were surveyed from helicopters twice annually, once immediately after egg laying and once immediately before the fledging of young. Territorial and reproducing pairs of Golden Eagles were identified, fledglings were counted, and nesting success was documented. Nesting success was defined as the number of laying pairs producing at least one fledgling. Data collection methods had been designed in close cooperation with personnel from the U.S. Geological Survey.

In Alaska, the amplitudes of population cycles of snowshoe hares and ptarmigans are large. Indices of broad changes in the abundance of snowshoe hares and Willow Ptarmigans were obtained from observations during routine field activities. The observations were assumed to be comparable to an estimated abundance determined from spotlighting along transects as shown in a study with black-tailed jackrabbits *Lepus californicus* in Idaho.

Since 1988, the annual reproductive success of Golden Eagles in the park has been monitored in 56-72 nesting areas (Table 7). In 1998, eagles in 70 preselected nesting areas were monitored. The occupancy rates in 1998 (88%) and in all other years were similar, suggesting that the breeding population in the park is stable. In 1998, 49% of the territorial pairs or 22% fewer pairs than in 1997 laid eggs. The success rate or the number of reproducing pairs that raised at least one fledgling was 62%. This rate was lower than the rates in the preceding 2 years. In 1998, 31 young or slightly fewer than half of the number of young in 1997 were fledged in the study area. The mean brood size was 1.48. The natality was 0.44 fledglings/territorial pair.

In 1998, the number of snowshoe hares (7.2/day) and Willow Ptarmigans (23/day) in the study area was the highest since 1989 (Fig. 14 on page 62). Annual indices of the abundance of snowshoe hares and Willow Ptarmigans highly correlated (r^2 = 0.96, n = 11

Table 7. Reproductive characteristics of Golden Eagles, Denali National Park and Preserve, Alaska, 1988-1998.

Year	Surveyed nesting areas	Occupied nesting areas	Pairs with eggs	Pairs with fledglings	Total number of fledglings	Occupancy rate (%)[a]	Laying rate (%)[b]	Success rate (%)[c]	Fledglings per occupied territory	Mean brood size
1988	56	47	37	28	38	84	79	76	0.81	1.36
1989	66	50	45	35	58	76	90	78	1.16	1.66
1990	66	46	38	28	47	70	83	74	1.02	1.68
1991	66	51	35	29	43	78	69	83	0.84	1.48
1992	70	57	36	19	26	81	63	53	0.46	1.37
1993	68	55	25	17	23	81	45	68	0.42	1.35
1994	68	58	19	8	9	85	33	42	0.16	1.13
1995	68	59	27	19	25	87	46	70	0.42	1.32
1996	72	62	26	23	30	86	42	88	0.48	1.30
1997	72	63	45	33	54	88	71	73	0.86	1.64
1998	70	62	34	21	31	88	49	62	0.44	1.48

[a] = percentage of nesting areas occupied by a territorial pair
[b] = percentage of territorial pairs that lay eggs
[c] = percentage of pairs with eggs that successfully raised on fledgling

years, $P < 0.001$; Fig. 15 on page 62). Therefore, the mean number of snowshoe hares observed per field day was used as the index of prey abundance for examining the reproduction of Golden Eagles in response to changes in abundance of food supply. Overall, the occupancy and success rates of the eagles were not affected by the changes in prey abundance. However, laying rates, success rates, and mean brood size changed in response to the abundance of hares in all years except in 1998. The laying rate (the percentage of territorial pairs with eggs) was the most important factor influencing the natality of the Golden Eagles in the park. Between 1988 and 1997, laying rates varied widely and most closely related to the abundance of hares and ptarmigans (Fig.15). However, the percentage of reproducing Golden Eagles in 1998 was lower than expected despite a high abundance of hares and ptarmigans. Harsh weather during late April when the eagles are incubating and in June and July when the eagles are rearing broods influenced the reproductive success in 1998. Almost 1 m (3 ft) of snow accumulated throughout the study area during 6 consecutive days in late April. Eagles that laid eggs in mid-April may have abandoned nesting in response to the harsh weather prior to the first surveys in early May. Furthermore, summer 1998 was unusually wet and cool. Above average rainfall may have interfered with the ability of breeding Golden Eagles to obtain food, and lower than average temperatures may have increased the energy demands of nestlings. These two factors may have contributed to overall lower population productivity in 1998 despite high numbers of prey. Data from the park suggest that Golden Eagles produce smaller broods and fewer fledglings in northern latitudes than in temperate climates and that reproductive success of the eagles in the park is influenced by fluctuations in the abundance of prey in late winter or early spring.

Data suggested that Golden Eagles that nest in northern latitudes produce smaller broods and fewer fledglings than eagles in temperate climates and that reproductive success of eagles in the park is influenced by fluctuations in the abundance of prey in late winter or early spring. In the park, eggs hatch nearly 1 month earlier than reported by Murie and provide a better estimate of the size of the breeding population of eagles in the park.

Monitoring of Golden Eagles will be continued in 1999. The development of a weather severity index to ex-

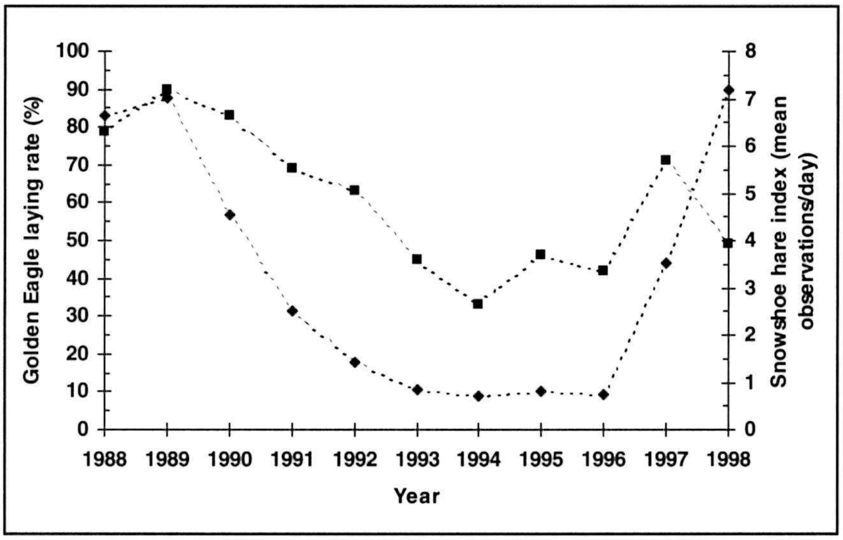

Figure 14. Laying rate of Golden Eagles and index of snowshoe hare abundance, Denali National Park and Preserve, 1988-1998.

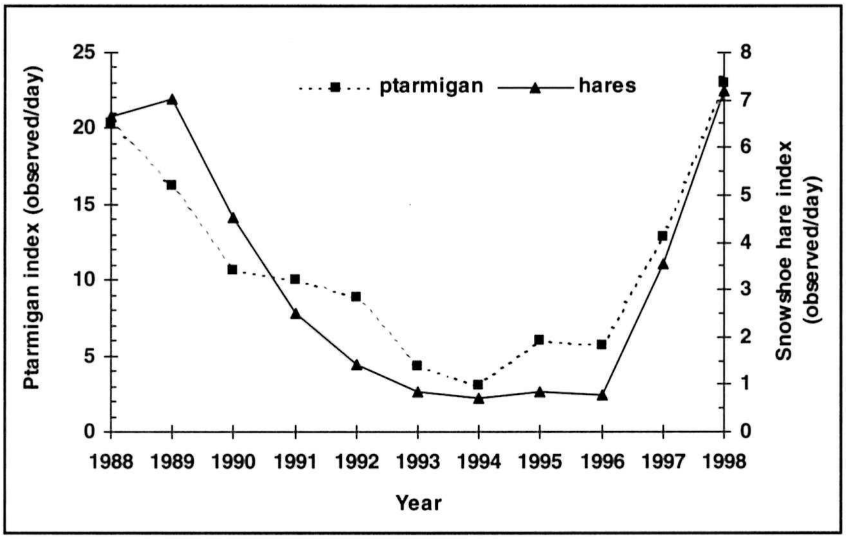

Figure 15. Indices of ptarmigans and snowshoe hare abundance, Denali National Park and Preserve, 1988-1998.

amine the relation between late winter and early spring weather and eagle reproduction is planned. In cooperation with personnel from the U.S. Geological Survey, a protocol for the long-term monitoring of Golden Eagles in the park will be completed. Cooperative research by the park, the U.S. Geological Survey, and the Oregon State University into environmental factors that influence reproductive success and survival of Golden Eagles will also be continued.

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Land Birds

The abundance of land birds has declined throughout North America during the past few decades. In response, governmental and non-governmental organizations formed partnerships to monitor bird habitat associations, life histories, and population dynamics. The international, ecological, and economic importance of land birds encouraged scientists, land managers, and policy makers to collect the basic information for making responsible land-management decisions.

In 1982, the National Park Service formed a partnership with the Alaska Bird Observatory to determine population size trends of land birds in Denali National Park and Preserve. The relative abundance of land birds among years in the park is determined by standard point-count methods for visual and auditory identification. Power calculations indicate that when birds are counted on 100 on-road and 108 off-road points in spruce *Picea* spp. forest, species that occur at more than 14% of the point-count stations can be monitored with a 90% probability of detecting a 50% decline during 25 years.

In 1998, species richness was greatest (37 species) near the western part of the park where habitat is diverse and includes many ponds, tundra, shrubs, and forests. Only 26 species were detected near the eastern portion of the park where habitat consists primarily of tundra and forest. The frequency of occurrence (proportion of point-count stations where birds were detected) of most species remained relatively constant among years. In spruce forests, the coefficients of variation (relative amount of variation) were relatively low and ranged from 0.04 (Dark-eyed Juncos *Junco hyemalis*) to 0.44 (Redpoll spp. *Carduelis* spp.) in 9 of the 10 most frequently observed species in 1998. In contrast, the coefficient of variation was high in Fox Sparrows *Passerella iliaca* (0.96).

Off-road surveys had been conducted exclusively in forest stands dominated by spruce *Picea* from 1993 to 1997. During 1998, 2 off-road routes were added in alpine tundra and riparian habitats. Off-road surveys in riparian habitats revealed Blackpoll Warblers *D. striata* at 67% of the stations surveyed. This species was not detected on surveys elsewhere in the park. Blackpoll warblers have concerned scientists because population declines have been documented elsewhere and because this species selects a narrow range of habitats.

Monitoring of land birds in the park will be continued in 1999. Surveys on off-road routes in shrub, alpine tundra, and mixed riparian habitats may be added.

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Breeding Birds

Breeding birds of all species in Denali National Park are surveyed to detect changes in populations sizes. Surveys follow the protocol of the national North American Breeding Bird Survey to obtain an index of relative abundance rather than a complete count of breeding bird populations.

Annual surveys of breeding birds in the park have been conducted since 1982. Surveys at the Toklat and the Savage routes along the Denali Park road are recognized by the national North American Breeding Bird Survey. In 1998, 330 birds of 31 species were sighted at the Toklat route (Table 8), and 311 individuals of 22 species were sighted at the Savage route (Table 9). A preliminary review of the data collected in 1998 suggested that the numbers of individuals and species were consistent with those observed in previous years.

Table 8. Breeding bird species on the Savage route, Denali National Park and Preserve, Alaska, 17 June 1998.

Species	Number of Individuals
Harlequin Duck	1
Green-winged Teal	1
Willow Ptarmigan	11
Mew Gull	7
Gray Jay	7
Black-billed Magpie	6
Boreal Chickadee	1
Arctic Warbler	11
Swainson's Thrush	5
Hermit Thrush	3
American Robin	12
Varied Thrush	3
Olive-sided flycatcher	1
Myrtle Warbler	2
Orange-crowned Warbler	22
Wilson's Warbler	39
American Tree Sparrow	53
Savannah Sparrow	35
White-crowned Sparrow	74
Golden-crowned Sparrow	1
Slate-colored Junco	3
Common Redpoll	13

Productivity and Survivorship of Migratory Land Birds

Migratory land birds may be sensitive indicators of regional and global environmental changes. Recent trends in population size suggest that the abundance of many species of land birds is severely declining. Population-size trends alone, however, provide no information about the primary demographic parameters—productivity and survival—of the land bird species and thus provide no means for determining the stages in the life cycle of a species where problems occur or to what extent the observed trends are being driven by natality or mortality. Data on productivity and survival of migratory land birds in Denali National Park and Preserve are collected to identify key ecological processes that drive the trends and to use such information for the reversal of declines.

Table 9. Breeding bird species on the Toklat route, Denali National Park and Preserve, Alaska, 18 June 1998.

Species	Number of Individuals
Green-winged Teal	10
American Widgeon	9
Lesser Scaup	4
Greater Scaup	6
Oldsquaw	4
Northern Harrier	1
Long-tailed Jaeger	1
Willow Ptarmigan	3
Rock Ptarmigan	3
Common Snipe	2
Lesser Yellowlegs	1
Greater Yellowlegs	1
Mew Gull	2
Alder Flycatcher	9
Say's Phoebe	2
Cliff Swallow	16
Northern Wheatear	1
Arctic Warbler	1
Swainson's Thrush	1
American Robin	1
Lapland Longspur	2
Orange-crowned	14
Warbler	45
Wilson's Warbler	42
American tree	48
Sparrow	
Savannah Sparrow	
Fox Sparrow	3
Song Sparrow	4
Golden-crowned	6
Sparrow	55
White-crowned	1
Sparrow	32
Slate-colored Junco	
Common Redpoll	

Since 1989, The Institute for Bird Populations has coordinated the cooperative *Monitoring 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 to provide indices of population size and post-fledging productivity and to estimate adult survival and recruitment into the adult population of targeted 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 and management for a reversal of the declines, and to evaluate the effectiveness of management.

The Institute for Bird Populations operated six constant-effort mist-netting and banding stations in the park in 1998. Four were in the same locations as during 1992-97. Two were in the locations where they were established in 1997.

During 1998, 1138 birds of 31 species were banded and 417 previously banded birds were captured. As in previous years, the capture rates of adult birds were higher in the less heavily forested stations dominated by willow *Salix* spp. or birch-alder *Betula* spp.-*Alnus* spp. scrub and lower in the more heavily forested stations dominated by spruce *Picea* spp. or alder forest. Mean productivity was 0.527 (0.46-0.56) in forested stations and 0.523 (0.41-0.60) in scrub stations. Productivity is the quotient of the number of captured young and the sum of the number of captured young and captured adults

Overall, the abundance of adults tended to increase during 1997-98. The number of captured adults of all species (pooled) increased by 12.4%. The abundance of adults increased in the Orange-crowned Warbler *Vermivora celata*, decreased in the Arctic Warbler *Phylloscopus borealis*, and decreased in the Savannah Sparrow *Passerculus sandwichensis*.

In contrast to indices of population size, indices of productivity (proportion of young captured) remained unchanged, increasing by only 0.018 from 0.462 in 1997 to 0.480 in 1998. Productivity since 1991 has remained relatively constant despite pronounced differences in the timing of initiation of breeding. Productivity seemed to be depressed only in 1994, possibly as a result of heavy rains during the latter half of June.

The annual adult survival rates of eight targeted species were estimated from modified Cormack-Jolly-Seber mark-recapture analyses that include a transient model. The survival of the Arctic Warbler was estimated with a time-dependent model, and the survival of the White-crowned Sparrow *Zonotrichia leucophrys* was estimated with time-dependence in proportion of residents. The survival of all other species was estimated with time-constant models.

Seven-year trends in the abundance of adults of 9 targeted species were calculated with constant-effort between-year changes. The abundance of adult Swainson's Thrushes *Catharus ustulatus* and Common Redpoll *Carduelis flammea* continued to decline, although the population size and productivity increased in each of these species in 1998. In contrast, the abundance of adult Yellow-rumped warbler *Dendroica coronata* and Orange-crowned warbler continued to increase. Population-size trends in the remaining species seemed stable.

Population-size trends tended to be more positive in the park than in seven national forests in the Pacific Northwest, where the abundance of many species is declining. In the park, productivity also tended to be higher but survival tended to be lower than in national forests in the Pacific Northwest. These results agreed with theoretical predictions that at higher latitudes productivity is higher and balanced by lower survivorship. However, differences in productivity were more pronounced than differences in survivorship between birds in the park and birds in forests of the Pacific Northwest, suggesting that low productivity of birds in Pacific Northwest forests drives the decreasing population-size trends there.

MAPS will be continued in 1999 without significant changes of the protocol or station locations.

Small Mammals

Small mammals in Denali National Park and Preserve are monitored to determine the temporal abundance and dynamics of small mammal populations in the Rock Creek watershed and to determine whether the environment of the Rock Creek watershed is representative of environments in adjacent watersheds.

Small mammals were sampled in the Rock Creek watershed, in two watersheds west of Rock Creek, and in the Hines Creek watershed south of the park road. Small mammals were trapped in 4 plots (2 riparian grids and 2 ridge grids) in each watershed and in 4 plots in a spruce forest.

A total of 1719 small mammals or approximately 1 mammal in every 28 traps was captured. The abundance of red-backed voles *Clethrionomys* spp. and meadow voles *Microtus* spp. in 1998 was the lowest in 7 years. In 1997, the abundance of red-backed voles had severely declined, but the abundance of meadow voles was at a reasonably high level and higher than the abundance of red-backed voles for the first time. In 1998, however, the abundance of both genera was low. The abundance of red-backed voles in the Rock Creek watershed was the same as in 1997, and the abundance of meadow mice fell to 1994 levels.

A model of small mammal population dynamics based on spring weather conditions predicts that populations of red-backed voles tend to be large if spring is warm and dry and small if spring is cool and damp. Spring 1998 was cool and damp, and the abundance of red-backed voles was low. It was even lower than predicted by the model.

In 1998, the small mammal populations were at the trough of their population cycles not only in the Rock Creek watershed but in the other watersheds where the animals were sampled. Whether the populations in these watersheds simultaneously reach the zenith of their population cycles is not yet known.

Sampling of small mammals will be continued in 1999. Sampling in watersheds at a greater distance from the Rock Creek watershed may be added.

Wolves and Caribou

In Alaska, gray wolves *Canis lupus* are abundant, and a contentious and closely scrutinized debate over intensive management of wolves continues. Wildlife managers must attempt to address the interests of diverse constituencies while managing predators and their ungulate prey in highly dynamic environments. Management is confounded by controversial information about the role of wolves in limiting and regulating prey abundance below levels that could be supported by their forage, the importance of winter snowfall in wolf-prey relations, and the responses by wolves to changes in prey abundance or vulnerability.

In Denali National Park and Preserve, gray wolves and their ungulate prey are important components of the ecosystem. The animals are non-consumptive resources, and the management of wolves is commonly a source of controversy in and around the park. Nevertheless, the 18 800 km^2 (7257 mi^2) park offers a unique opportunity for the study of the wolf-ungulate relations and population dynamics because predators and prey are largely unaffected by human harvest and may therefore be the closest approximation of a naturally functioning wolf-multi-prey system in the world.

Since 1986, researchers of the U.S. Geological Survey (formerly of the U.S. Fish and Wildlife Service) and National Park Service staff have intensively studied wolves and caribou *Rangifer tarandus* in the park. Since 1998, the study has received financial support from the service-wide Inventory and Monitoring Program. The objectives of monitoring are the annual assessment of the status and trends of the wolf and caribou populations and the evaluation of the dynamics and interactions of the species in the park's protected subarctic ecosystem.

Wolves and caribou in the park are monitored with standard radiotelemetry techniques to determine population size, physical condition, distribution, productivity, survival, and dispersal. The number of adult female caribou on the calving grounds and the age and sex composition of the herd are determined from helicopters.

Since 1986, wolf and caribou populations have fluctuated widely in response to variation in winter snowfall (Tables 10-11 on pages 68-69; Figs 16-17 on pages 69-70). In 1988-94, winter snowfalls were high, and the number of wolves increased rapidly and remained high through winter1992-93. Reproduction was high and dispersal of young wolves substantially decreased. The herd reached a size of 3200 caribou in fall 1989 but declined to about 2000 by fall 1993. Recruitment of calves was poor, averaging only 12:100 in September 1990-93 compared to 35:100 during 1984-89. The annual mortality of adult females increased from about 4% to 20%. The mortality of adult males also increased, and the adult sex ratio plummeted from 56:100 in 1987 to 40:100 by 1993.

The amount of snowfall returned to average levels during winter 1994-95 and has remained at an average level. In 1998, the caribou population leveled off at about 2000-2100. Survival of adult females returned to 1986-88 levels (Table 11), but recruitment during 1994-98 was low at an average of only 16:100. The adult sex ratio declined further to about 30:100. By March 1998, the number of wolves had declined to about 82 individuals. Recruitment declined, dispersal by young wolves increased, and adult mortality increased. Research and monitoring of wolves and caribou will be continued in 1999.

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Table 10. Numbers of radio-collared packs, estimated density, and estimated total population size of wolves, Denali National Park and Preserve, Alaska, 1986-1998.

	Late winter (~15 Mar)					Fall (~ 1 Oct)				
Year	Packs	Wolves	Area (km^2)	Density per 1000 km^2	Estimated population size	Packs	Wolves	Area (km^2)	Density per 1000 km^2	Estimated population size
1986	4	26	7380	3.5	60	4	22	8180	2.7	47
1987	8	37	112125	3.1	54	9	70	13150	5.3	92
1988	14	69	15355	4.5	78	14	121	14670	8.2	142
1989	13	98	16810	5.8	100	11	127	15240	8.3	143
1990	10	106	13930	7.6	131	11	136	13930	9.8	169
1991	13	111	14275	7.8	135	13	137	14275	9.6	166
1992	15	103	13620	7.6	131	15	120	13620	8.8	152
1993	12	68	9900	6.9	119	12	93	9900	9.4	162
1994	10	61	11145	5.5	95	12	72	11145	6.5	112
1995	12	59	12120	4.9	85	11	80	12045	6.6	114
1996	11	69	12640	5.5	95	11	104	12776	8.1	140
1997	11	78	13080	6.0	103	12	75	12808	5.9	101
1998	12	61	12808	4.8	82	12	68	12808	5.3	92

[a] Estimated population size is an extrapolation of the density in the study area to the 17,270 km2 of wolf habitat in the park The area of wolf habitat was determined by substracting areas above 1830 m (6000 ft) in elevation and large glaciers below that elevation from the area of the entire park.

[b] The estimated density in 1998 is tentative. It was calculated with Fall 1997 area. Area used for density calculations each year is based on radiolocations from 1 May in the previous year through 30 April in the following year (e.g , in 1997, locations used during May 1996 - April 1998) to ensure sufficient locations. Therefore, the area cannot be estimated until after 30 April 1999.

Table 11. Composition of the Denali caribou herd in late September and estimated herd size in fall, Denali National Park and Preserve, Alaska, 1984-1998.

Year	Cows > 1 YO[a]	Calves	Bulls	Calves:cows	Bull:cows	Herd size
1984	375	154	184	0.41	0.49	2200
1985	654	183	368	0.28	0.56	
1986	547	210	303	0.38	0.56	2470
1987	631	234	356	0.37	0.56	2540
1988	678	221	451	0.33	0.67	2950
1989	830	246	428	0.30	0.52	3210
1990	777	130	387	0.17	0.50	3180
1991	1067	72	409	~ 0.07	0.38	2660
1992	643	103	282	0.16	0.44	2340
1993	849	54	336	~ 0.06	0.40	1970
1994	648	253	253	0.20	0.39	2140
1995	685	204	204	0.19	0.30	2170
1996	820	243	243	0.13	0.30	2060
1997	777	228	228	0.16	0.29	2070
1998	718	205	205	0.12	0.29	1930

[a]YO = year old

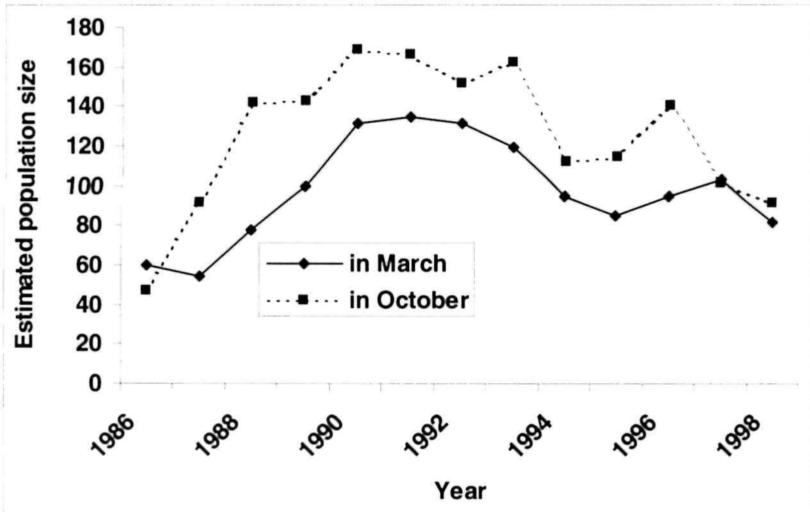

Figure 16. Estimated number of wolves, Denali National Park and Preserve, 1986-1998.

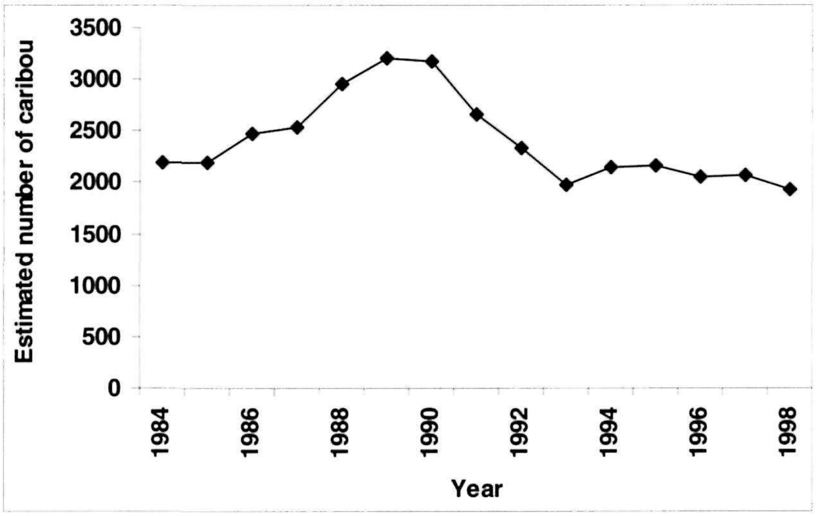

Figure 17. Estimated number of caribou, Denali National Park and Preserve, 1984-1998.

Great Plains Prairie Cluster

Prairie and Grassland Biome

L. Thomas
Cluster I&M Coordinator

M. DeBacker and S. Jenkins, Grassland Plant Communities
L. Thomas, Missouri Bladderpod
G. Wilson, Western Prairie-Fringed Orchid
B. Rizzo and E. Schneider, Aquatic Macroinvertebrates
D. Debinski and S. Mahady, Butterflies
A. Powell, Birds

Grassland Plant Communities

The objectives of plant community monitoring in parks of the Great Plains Prairie Cluster are the detection and description of long-term changes in grassland plant communities. Monitoring will also provide managers with information about the effectiveness of prescribed fire, control of exotics, and prairie restoration.

Baseline data collection began in 1997 and continued in 1998 with methods outlined in *Plant community monitoring in the Prairie Cluster LTEM parks*. Staff sampled the vegetation in 53 sites (516 10-m^2 plots) representing 19 plant communities twice during Jun-Oct (Table12 on page 74).

Baseline data revealed patterns of diversity among the prairies such as a relation between remnant size and diversity (Fig. 18 on page 75). Goat Prairies (2 ha, 5 A), Sioux Quartzite Prairi e (2 ha, 5 A) and Limestone Glade (16 ha, 40 A) are the smallest yet most diverse monitored grassland communities. Unusual edaphic conditions in these communities support an array of otherwise uncommon species in the area. Resource managers manage these unique communities with a combination of small-scale prescribed fire, selective thinning of woody species, and control of exotics.

Because most of the natural landscape has been destroyed, restoration is important in prairie conservation. All six parks in the cluster are restoring native prairie vegetation in disturbed sites. Based on data from monitoring, Scotts Bluff National Monument developed a seed combination for restoring a disturbed site in 1996-97. A comparison of the restored prairie with an adjacent undisturbed site (Table 13 on page 75) revealed successful establishment of numerous native prairie forbs and grasses but still a sharp difference between the relative composition in each site. Black-root sedge *Carex filifolia* Nutt., a co-dominant of the undisturbed prairie, is conspicuously rare in the restored site, and exotic species, particularly annual brome grass, are more prominent in the restored site than in the undisturbed site. These findings were to be expected because of the recency of the restoration but clearly indicate the need for continued management to coax the restored prairie towar the species composition of the adjacent undisturbed reference site.

A 2-year baseline is now complete for nearly half of the sample sites; collection of baseline data in the remaining sites is scheduled in 1999. The U.S. Geological Survey expects to finalize the monitoring protocol by the end of 1999.

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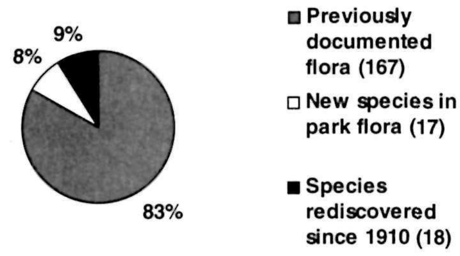
Goat prairie flora (202 species), Effigy Mounds National Monument



Short-term Benefits of Long-term Monitoring: Despite continued botanical interest in the area since the early 1900s, recent monitoring has contributed seventeen new species to the flora of Effigy Mounds National Monument (including one considered threatened in the state of Iowa). Additionally, eighteen species were rediscovered, having not been recorded for the park since approximately 1910.

Table 12. Species richness and diversity and relative cover of native and exotic species in plant communities of the Great Plains Prairie Cluster, 1998.

Park	Community type	Plots	Richness (native species only)		Diversity (native species only)		Relative cover (%)	
Agate Fossil Beds	N. Great Plains little bluestem prairie	20	78	(74)	2.49	(2.47)	99.75	0.25
National Monument	Needle and thread/ blue grama mixed	10	49	(47)	2.22	(2.21)	99.84	0.16
	grass	40	66	(60)	2.24	(2.14)	97.02	2.98
	Prairie sandreed/sand bluestem prairie	20	57	(47)	2.18	(1.87)	83.00	17.00
	Seeded grassland	10	28	(20)	1.56	(1.16)	50.67	49.33
	Western wheatgrass							
	mixedgrasspPrairie							
Effigy Mounds National	Goat prairie	46	168	(154)	3.56	(3.45)	93.53	6.47
Monument	Restored tallgrass prairie	30	90	(82)	2.73	(2.56)	90.28	9.72
Homestead National	Restored tallgrass prairie (Unit U1)	20	60	(58)	2.60	(2.59)	99.79	0.21
Monument of America	Restored tallgrass prairie (Unit U2)	20	68	(60)	2.75	(2.67)	96.19	3.81
	Restored tallgrass prairie (Unit U3)	10	29	(25)	2.21	(2.11)	95.47	4.53
Pipestone National	Native tallgrass prairie	40	89	(77)	3.32	(3.27)	83.08	16.92
Monument	Restored tallgrass prairie	30	81	(68)	3.12	(3.05)	72.90	27.10
	Sioux quartzite prairie	20	83	(70)	3.25	(3.33)	73.22	26.78
Scotts Bluff National	Degraded mixed grass prairie	40	51	(44)	1.77	(1.57)	86.51	13.49
Monument (1997 data)	Mixed grass prairie (South Unit)	30	51	(45)	1.74	(1.73)	99.88	0.12
	Mixed grass prairie (Saddle Rock Unit)	20	21	(18)	1.41	(1.36)	99.09	0.91
	Ponderosa pine Woodland	20	49	(45)	2.37	(2.28)	97.27	2.73
	Restored mixed grass prairie	20	46	(34)	2.46	(2.06)	60.24	39.76
Wilson's Creek National	Limestone glade	30	137	(111)	3.70	(3.59)	76.83	23.17
Battlefield	Oak woodland	40	126	(115)	3.27	(3.23)	99.18	0.82
	Restored tallgrass prairie	20	85	(66)	2.97	(2.76)	71.86	28.14

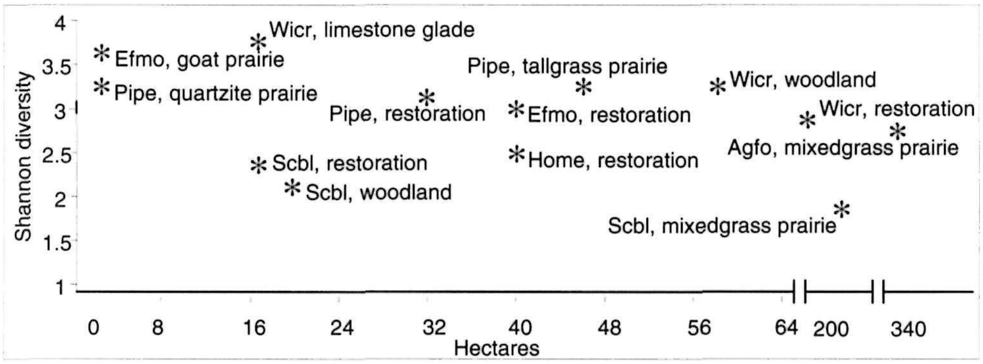
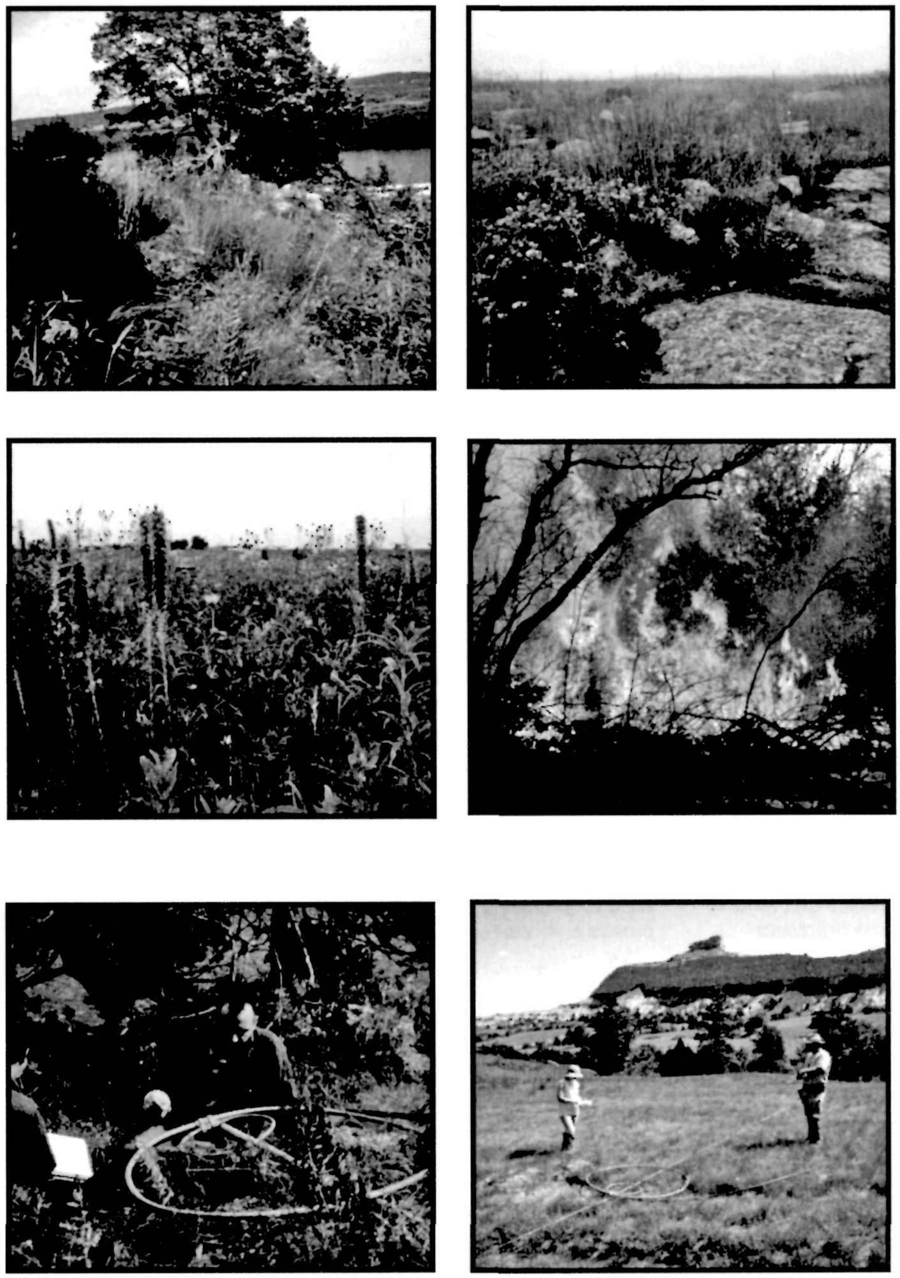


Figure 18. Relation between the Shannon Diversity and remnant size in grassland communities, Great Plains Prairie Cluster, 1998.

Table 13. Species composition of a recently restored prairie and an adjacent undisturbed prairie in Scotts Bluff National Monument, Nebraska, 1998. An asterisk denotes an exotic species.

		Importance value	
Species	*Common name*	*Restored prairie*	*Undisturbed prairie*
**Bromus spp.*	*annual brome grass*	*0.128*	*0.017*
Pascopyrum smithii	*western wheatgrass*	*0.110*	*0.087*
Sporobolus cryptandrus	*sand dropseed*	*0.105*	*0.009*
Verbena bracteata	*prostrate vervain*	*0.097*	
**Melilotus spp.*	*sweet clover*	*0.068*	
Stipa comata	*needle-and-thread grass*	*0.056*	*0.190*
Buchloe dactyloides	*buffalo-grass*	*0.040*	*0.005*
Stipa viridula	*green needle-grass*	*0.040*	
**Bromus inermis*	*smooth brome*	*0.039*	
Bouteloua gracili	*blue gramma-grass*	*0.031*	*0.012*
Bouteloua curtipendula	*side-oats gramma-grass*	*0.023*	
**Salsola spp*	*russian thistle*	*0.020*	*0.016*
**Tragopogon dubius*	*fistulous goat's beard*	*0.020*	*0.004*
Sphaeral coccinea	*scarlet mallow*	*0.019*	*0.051*
Artemisia frigida	*prairie-sagewort*	*0.017*	*0.004*
Ratibida columnifera	*columnar coneflower*	*0.016*	
Grindeli squarrosa	*curly-top gum-weed*	*0.016*	
Kraschenninnikovia lanata	*white sage, winter fat*	*0.015*	*0.068*
Amaranthus albus	*pigweed*	*0.013*	*0.004*
Carex flifoli	*sedg*	*0.013*	*0.347*



Grassland plant communities in the Great Plains Prairie Cluster. Clockweise from top left: Goat prairie in Effigy Mounds National Monument; Sioux quartzite prairie in Pipestone National Monument; prescribed fire in oak woodland on Wilson's Creek national Battlefield; vegetation sampling in Effigy Mounds National Monument; vegetation sampling in Scotts Bluff National Monument; tallgrass prairie in Pipestone National Monument.

Missouri Bladderpod

The Missouri bladderpod *Lesquerella filiformis* Rollins is a federally listed endangered plant that occurs in a narrow range of southwestern Missouri and northern Arkansas. Approximately 60 populations are known in this range. One of the largest protected Missouri bladderpod populations occurs in Wilson's Creek National Battlefield, the site of an intense Civil War battle in Aug 1861. Three smaller populations occur in the same park.

Threats to Missouri bladderpod populations include woody encroachment of glade habitat by eastern red cedars *Juniperus virginiana* L. and invasion of exotic plants including three species of annual brome grass *Bromus racemosus* L., *B. sterilis* L., and *B. tectorum* L. The annual brome grasses interfere with establishment and growth of the Missouri Bladderpod under greenhouse conditions. Recent management focused on thinning cedars, controlling exotic brome grasses, and reseeding portions of the park with native grass seed collected on site.

Drastic fluctuations in the size of Missouri Bladderpod populations have been observed on Bloody Hill and elsewhere. Such fluctuations are typical of winter annuals but complicate the identification of long-term trends in population dynamics or the evaluation of the efficacy of management.

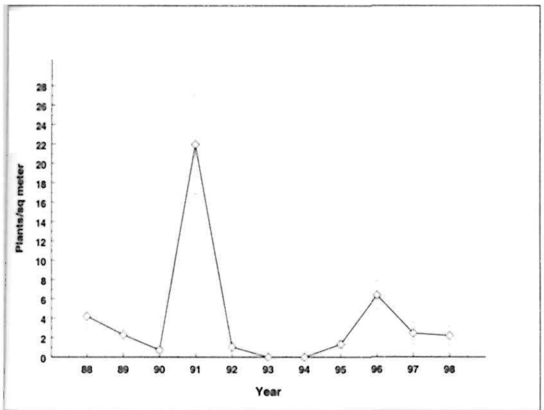


Figure 19. Mean density (± SE) of the Missouri bladderpod, Wilson's Creek National Battlefield. 1988-1998

The population density of the Missouri bladderpod has been monitored in the park since 1988. Each spring, Missouri bladderpods are counted in 30 or more 3-x-3-m (9.8 x 9.8 ft) plots. During 1988-97, plots were placed at regular intervals along permanently marked transects that were evenly spaced throughout the plant's habitat in the park. In 1998, plot placement was modified to take advantage of a permanent grid of survey points established in the park. A stratified random method was used to locate grid coordinates and distances from them for sampling. The mean density of the Missouri bladderpod has ranged from 0 to 22 plants/m^2 (0-11 plants/ft^2) during the 11 years of monitoring. The overall mean is 3.88 plants/m^2 (0.36/ft^2; Fig. 19). Applied across the 1.38-ha (3.4 A) area occupied by the population, the estimated population sizes have ranged from 0 to 303,400 and an average population size of 53,600 plants (Table 14). Several factors, including seed crop from the preceding season, seed survival in the seed bank, seedling recruitment from the seed bank, and the survival of growing plants may contribute to these fluctuations in annual population size.

Table 14. Mean density and estimated population size of the Missouri bladderpod in 1988-1998, Wilson's Creek National Battlefield.

Year	*Sample size*	*Mean density (plants/m^2)*	*Standard error*	*Estimated population size*
1988	*32*	*4.22*	*1.18*	*58 351*
1989	*32*	*2.31*	*0.61*	*31 911*
1990	*31*	*0.73*	*0.25*	*10 154*
1991	*31*	*21.96*	*5.10*	*303 446*
1992	*33*	*1.06*	*0.47*	*14 611*
1993	*31*	*0*	*0*	*0*
1994	*33*	*0*	*0*	*0*
1995	*35*	*1.34*	*0.41*	*18 514*
1996	*36*	*6.38*	*1.53*	*88 166*
1997	*34*	*2.45*	*1.16*	*33 873*
1998	*52*	*2.21*	*0.99*	*30 475*

Western Prairie Fringed Orchid in Pipestone National Monument, Minnesota

A small, isolated population of the western prairie fringed orchid *Platanthera praeclara*, Sheviak & Bowles—a federally listed threatened plant—occurs in Pipestone National Monument, Minnesota. In late spring, managers periodically burn the management unit where the orchid occurs to control the cool-season exotic grass, smooth brome *Bromus inermis* Leyss, which has invaded the prairie. The unit was burned last in late May 1997.

In July 1998, flowering western prairie fringed orchids were counted for the sixth consecutive year. In addition, the presence or absence of flowering and non-flowering orchids was recorded in permanently marked locations where orchids flowered in 1994 and 1995. In 1998, no flowering orchids were found; this is the only year without flowering orchids in the 6-year monitoring record (Table 15). The absence of flowering plants is inconsistent with counts in 1993 and 1994, when substantial numbers flowered 1 year after prescribed burns. Flowering in some orchids is believed to be influenced by rainfall in the preceding growing season. In Pipestone National Monument, orchid flowering in 1998 may have been affected by dry conditions in late summer 1997. The burn in late May 1997 also could have had an effect on flowering in 1998. Although the fire in late May and the below-normal summer rainfall in the previous year may have had an effect on orchid flowering, they did not affect the survival of the marked plants. The survival of orchids was greater in Pipestone National Monument than in another long-term study of the western prairie fringed orchid in Sheyenne National Grassland, North Dakota (Table 16).

Flowering orchids and the orchids marked in 1994 and 1995 will again be monitored in July 1999. Also in 1999, the locations of all flowering plants will be marked for future demographic monitoring.

Table 15. Number of flowering western prairie fringed orchids by year and by date of previous fires, Pipestone National Monument, 1992-1998.

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
1997	3	May 1997	0
1998	0	May 1997	1

Table 16. Number and percent of flowering western prairie fringed orchids that were found again (relocated) after permanent marking in 1994 and 1995 in Pipestone National Monument and in 1987 in Sheyenne National Grassland.

			Number (%) of plants relocated after:			
Year	Site	Number marked	1 year	2 years	3 years	4 years
1994	Pipestone	18	13 (72)	9 (50)	7 (39)	5 (28)
1995	Pipestone	34	27 (19)	13 (38)	9 (26)	
1997	Sheyenne	160	88 (55)	44 (28)	25 (16)	17 (11)

Missouri bladderpod on Wilson's Creek National Battlefield. The plant is federally listed as endangered.

Western prairie fringed orchid in Pipestone National Monument. The plant is federally listed as threatened.

Bractless blazing star in Agate Fossils Bed National Monument. This enchanting flower is characteristic of mixed grass prairie in the Great Plains.

Violet prairieclover in Pipestone National Battlefield. Members of the genus *Dalea* are widespread in the Great Plains and have been used for medicinal purposes by Native Americans and early European settlers.

Aquatic Macroinvertebrates as Indicators of Water Quality in Four Prairie Streams

Annual data from monitoring aquatic macroinvertebrates in the Great Plains Prairie Cluster are not reported until 12 months after the end of the calendar year. The delay is caused by the time schedule of the contractor.

The relation between aquatic macroinvertebrates and water quality has been well established during a more than 100-year-long history of study. Assessment of water quality with aquatic macroinvertebrate community structure has several advantages over direct monitoring of chemical water quality parameters. Most importantly, quantitative sampling of macroinvertebrates is relatively easy and costs less than chemical sampling schemes. Secondly, aquatic macroinvertebrates live sufficiently long that they integrate the spatial and temporal variability in all water quality parameters. The objectives of biomonitoring aquatic macroinvertebrates in the Great Plains Prairie Cluster are the evaluation of the current status of the prairie streams of the parks in the cluster and the identification of trends in water quality as more data become available. The parks began sampling macroinvertebrates in the late 1980s; the protocol under development is being designed to build upon and to improve previous sampling.

Aquatic macroinvertebrates are collected with either Hester-Dendy samplers (in low-gradient streams) or Surber samplers (in high-gradient streams). Taxa are identified and water quality is assessed by comparing five community metrics against those of a baseline collection year. (Sampling methods and procedures are detailed in Peterson et al. 1999.) The metrics calculated for the data include the Family Biotic Index (FBI), for which family-specific pollution tolerance values are used to calculate scores; the ratio of Ephemeroptera, Plecoptera, and Trichoptera (EPT) abundance to abundance of Chironomidae; family and genus richness; family and genus diversity, and total density of individuals. Changes in two or more of these indices since the baseline year determine whether the net assessment of the macroinvertebrate community in each park is rated as unchanged, improved, or declined.

Results of biomonitoring in 1997 (Table 17) are preliminary because researchers with the Biological Resources Division of the U.S. Geological Survey are continuing to evaluate the usefulness of incomplete historic data as a baseline. Consequently, comparisons with a baseline are not yet available. Macroinvertebrate data collected in 1998 are currently being processed and sampling will continue in 1999.

Table 17. Mean (standard deviation), family biotic index (FBI), diversity, and species richness of aquatic macroinvertebrates in four prairie streams in the Great Plains Prairie Cluster, 1997.

Park	*Metric*	*Mean*	*(S.D.)*
Agate Fossil Beds National Monument	*FBI*	*3.00*	*(0.68)*
Sample sites = 2	*Density*	*404.00*	*(281.00)*
Sample dates = 3	*Diversity*	*0.97*	*(0.30)*
	Richness	*7.83*	*(2.09)*
Homestead National Monument of America	*FBI*	*4.51*	*(1.83)*
	Density	*320.00*	*(2.47)*
Sample sites = 2	*Diversity*	*1.05*	*(0.46)*
Sample dates = 2[a]	*Richness*	*6.53*	*(2.24)*
Pipestone National Monument	*FBI*	*4.53*	*(1.21)*
Sample sites = 2	*EPT*	*0.31*	*(0.30)*
Sample dates = 3	*Diversity*	*0.94*	*(0.53)*
	Richness	*6.56*	*(4.57)*
Wilson's Creek National Battlefield	*FBI*	*5.23*	*(0.82)*
Sample sites = 3	*EPT*	*0.26*	*(0.24)*
Sample dates = 3	*Diversity*	*1.10*	*(0.45)*
	Richness	*11.30*	*(4.52)*

[a]*Incomplete replicates for 1 sample date.*

Completion of the monitoring protocol is anticipated in 1999.

References

Peterson, J., W. M. Rizzo, E. D. Schneider, and G.D. Willson. 1999. Macroinvertebrate Biomonitoring Protocol for Five Prairie Streams. Columbia, Missouri. In preparation.

Butterflies in Prairies, Glades, and Woodlands of the Great Plains Prairie Cluster

Grassland butterflies are an important resource in National Park System units. Among invertebrate groups, they are recognized and valued by park visitors for their aesthetic beauty. They fulfill an essential ecological role by pollinating many species of prairie forbs. Host-specific ovipositioning by butterflies causes selective herbivory in the plant community. Because of their high visibility and specialized habitat requirements, grassland butterflies may be indicators of prairie health and illuminate the effects of prairie management on the invertebrate community. For these reasons, butterflies are inventoried in four Great Plains prairie parks. Results will be used to determine whether long-term monitoring of butterfly communities can indicate overall prairie health.

Butterflies were inventoried in 10 community types in 4 parks: Effigy Mounds National Monument, Iowa; Homestead National Monument of America, Nebraska; Pipestone National Monument, Minnesota; and Wilson's Creek National Battlefield, Missouri. Species richness and abundance were sampled along 2-8 line transects in each community type. In 1997 and 1998, sampling in each 5-x-50-m transect was conducted for 30 min once during early summer and once during late summer. Species were usually identified in flight, but some individuals were captured to ensure accurate identification.

Data are being used to determine the influence of patch size on species richness and on local versus regional diversity. Comparisons between the parks and other remnant prairies revealed that the relation between butterfly species richness and prairie size is not strong. This may indicate the importance of management and historical land use on butterfly diversity (Table 18). A Bray-Curtis distance index was computed for five community types. The index is calculated by comparing the number of species sighted on both sites, the number of species unique to each site, and the abundance of each species on each site. Values of the index range from one to zero. A zero indicates that the number of species and the abundance of each species are exactly the same in the two sites.

In the four parks of the Great Plains Prairie Cluster, tallgrass butterfly communities were highly variable between communities and between years at the same site (Table 19). Yearly variation in butterfly communities indicated the need for intensive long-term monitoring to understand the influences of management and surrounding land use. The large variation be-

Table 18. Butterfly species richness and size of prairie, glade, and woodland communities in four parks of the Great Plains Prairie Cluster, 1998. Specilist species = number of sighted species that specialize in the indicated community type. NM = National Monument, NB = National Battlefield.

Park	Community type	Area (ha)	Species richness	Specialist species
Effigy Mounds NM	Goat prairies	0.5	24	1
	Restored prairie	20.0	15	0
Homestead NM	Tallgrass prairie	0.3	20	1
	Restored prairie	40.0	15	1
Pipestone NM	Tallgrass prarie	75.2	20	4
	Sioux quartzite prairie	2.0	10	0
	Restored prarie	12.4	11	3
Wilson's Creek NB	Limestone glades	7.4	37	2
	Oak woodland	30.2	14	1
	Restored prairie	0.2	24	2

Table 19. Comparison of butterfly species richness and representation by community type and National Park System unit with the Bray-Curtis distance index. Great Plains Prairie Cluster, 1997-1998. Values on the main diagonal indicate the similarity in species richness and abundance in a site between 1997 and 1998. Zero would indicate that in both years the exactly same species at the same abundance were present. Values above zero indicate increasing dissimilarities. NB = National Battlefield, NM = National Monument.

Park/community type	Wilson's Creek NB Limestone glades	Homestead NM Tallgrass prairie	Homestead NM Restored prairie	Effigy Mounds NM Goat prairies	Pipestone NM Tallgrass prairie
Wilson's Creek NB Limestone glades	**0.46**	0.70	0.53	0.72	0.87
Homestead NM Tallgrass prairie	0.70	**0.61**	0.54	0.86	0.76
Homestead NM Restored prairie	0.53	0.54	**0.62**	0.86	0.71
Effigy Mounds NM Goat prairies	0.72	0.86	0.68	**0.65**	0.86
Pipestone NM Tallgrass prairie	0.87	0.76	0.71	0.86	**0.66**

tween parks illustrated the importance of each park for the conservation of the regional diversity of prairie butterflies. For example, the same community type of tallgrass prairie occurs in Homestead National Monument and in Pipestone National Monument. However, the distance index in the comparison of these two community types is 0.76, indicating that these prairies share few species and the abundance of the shared species differs by site.

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Breeding Birds of the Great Plains Prairie Parks

Habitat loss and fragmentation of prairie ecosystems has changed the abundance and distribution of grassland-associated vertebrates. Data from the Breeding Bird Surveys by the U.S. Geological Survey during the last 25 years indicate that the population sizes of almost 70% of the adequately surveyed 29 grassland bird species have been declining. In 1997, the National Park Service named research on grassland birds in the central region of the National Park System a high priority. The status of grassland birds in Great Plains parks is largely unknown. Great Plains prairie parks are conducting inventories to determine the current status of grassland birds and the usefulness of long-term monitoring of bird communities for evaluation of overall prairie health.

Fixed-radius point counts were used in 1998 to survey breeding birds in Pipestone National Monument (8 points), Homestead National Monument (9 points), and Wilson's Creek National Battlefield (18 points). Points were at least 250 m apart, and their locations were recorded with global positioning systems (GPS). Standardized procedures were used for counts during late-May through June 1998. During 5-minute counts all birds within a 100-m (328 ft) radius were counted and identified by sight or sound. Point locations were distributed throughout the parks and, because of the small sizes of the parks, sampling was done in all habitats. In addition, all birds seen or heard outside of points were recorded to aid in the development of bird checklists. Relative abundance in each park was calculated from the quotient of the number of birds in a species and the sum of all species over all points and dates.

Pipestone National Monument. In 1998, 46 species were sighted and 30 of them were sighted during point counts. Eleven species (37%) of breeding birds were considered to be grassland-associated. In descending order, the most abundant species were the Common Grackle, Red-winged Blackbird, American Robin, Western Meadowlark, Brown-headed Cowbird, Common Yellowthroat, and Dickcissel (Table 20 on page 84). The highest proportion of grassland habitats and the highest proportion of grassland birds among the three parks where sampling was conducted were in Pipestone National Monument. Five of the breeding grassland species in the monument were among those with declining population-size trends according to the Breeding Bird Survey: Dickcissel, Western Meadowlark, Grasshopper Sparrow, and Clay-colored Sparrow.

Homestead National Monument. In 1998, 48 species of breeding birds were sighted and 45 of them were sighted during point counts. Seven species (16%) on point counts were grassland-associated. The most abundant species on point counts were the Dickcissel, Brown-headed Cowbird, American Goldfinch, House Wren, Northern Bobwhite, Indigo Bunting, and Blue Jay (Table 20). Two of the breeding grassland species in the monument, Dickcissel and Western Meadowlark, were among those with declining population sizes according to the breeding bird surveys. However, the abundance of the Western Meadowlark was low.

Wilson's Creek National Battlefield. In 1998, 61 species of breeding birds were sighted and 54 of them were sighted during point counts. Only 7 (13%) of the breeding birds sighted on point counts were grassland-associated. The Brown-headed Cowbird was the most abundant species, and the next most abundant species were the Indigo Bunting, Northern Cardinal, American Goldfinch, Field Sparrow, and Yellow-breasted Chat (Table 20). Two of the breeding grassland species on the battlefield, Grasshopper Sparrow and Dickcissel, were among those with declining population sizes according to the breeding bird surveys.

Highly area-sensitive grassland species, which occur in large grasslands (the minimum size of such a grassland is species-specific) but not in small grasslands, were not sighted in the three parks, except the Bobolink in Pipestone National Monument. Pipestone National Monument is unique among the three parks because it is adjacent to a wildlife management area that also supports breeding grassland birds. Homestead National Monument and Wilson's Creek Battlefield are surrounded primarily by agricultural or urban landscapes. Grassland birds with low area-sensitivity—Dickcissel, Northern Bobwhite, Red-winged Blackbird, American Goldfinch, Field Sparrow, and Common Yellowthroat—were common in these parks (Table 20). In addition, the most abundant grassland species in these sites were associated with higher densities of shrubs and medium to dense vegetation.

Grassland birds in the three parks will not be surveyed by the U.S. Geological Survey in 1999. Monitoring protocols, however, will be developed for use in these sites. Breeding birds in mixed-grass prairie parks (e.g., Scotts Bluff and Agate Fossil Beds national monuments) will be surveyed in Jun 1999 with the methods described above.

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Table 20. Relative abundance of birds in Pipestone and Homestead national monuments and in Wilson's Creek, National Battlefield, 1998.

		Relative abundance		
Common name	Scientific name	Pipestone	Homestead	Wilson's Cree
Yellow-crowned Night-heron	Nyctanassa violacea			0.001
Turkey Vulture	Cathartes aura			0.001
Wood Duck	Aix sponsa	0.003		
Red-tailed Hawk	Buteo jamaicensis			0.004
American Kestrel	Falco sparverius			0.001
Ring-necked Pheasant [a,b]	Phasianus colchicus	0.046	0.010	
Northern Bobwhite [b]	Colinus virginianus		0.049	0.008
Wild Turkey	Meleagris gallopavo			0.001
American Woodcock	Scolopax minor			0.001
Killdeer	Charadrius vociferus	0.003		
Morning Dove	Zenaida macroura	0.024	0.018	0.007
Yellow-billed Cuckoo	Coccyzus americanus			0.017
Common Nighthawk	Chordeiles minor			0.001
Chimney Swift	Chaetura pelagica		0.002	
Ruby-throated Hummingbird	Archilochus colubris			0.003
Downy Woodpecker	Picoides pubescens		0.004	0.020
Hairy Woodpecker	Picoides villosus			0.001
Pileated Woodpecker	Dryocopus pileatus			0.003
Red-headed Woodpecker	Melanerpes erythrocephalus		0.012	0.001
Red-bellied Woodpecker	Melanerpes carolinus		0.010	0.011
Northern Flicker	Colaptes auratus	0.005	0.014	0.001
Eastern Kingbird	Tyrannus tyrannus		0.004	
Great-crested Flycatcher	Myiarchus crinitus		0.008	0.008
Eastern Phoebe	Sayornis phoebe		0.002	0.007
Eastern Wood-peewee	Contopus virens		0.012	0.005
Acadian Flycatcher	Empidonax virescens			0.008
Northern Rough-winged Swallow	Stelgidopteryx serripennis			0.001
Red-eyed Vireo	Vireo olivaceus	0.003	0.004	
Yellow-throated Vireo	Vireo flavifrons		0.002	0.001
White-eyed Vireo	Vireo griseus			0.017
Warbling Vireo	Vireo gilvus		0.004	
Blue Jay	Cyanocitta cristata	0.013	0.029	0.016
American Crow	Corvus brachyrhynchos	0.013	0.016	0.032
Tree Swallow	Tachycineta bicolor	0.016		
Barn Swallow	Hirundo rustica		0.010	0.005
Warbling Vireo	Vireo gilvus		0.004	
Blue Jay	Cyanocitta cristata	0.013	0.029	0.016
American Crow	Corvus brachyrhynchos	0.013	0.016	0.032
Tree Swallow	Tachycineta bicolor	0.016		
Barn Swallow	Hirundo rustica		0.010	0.005

Table continued on next page

Table 20 cont'd

Tufted Titmouse	Baeolophus bicolor		0.004	0.029
Black-capped Chickad	Poecil atricapillus		0.012	
Carolina Chickad	Poecil carolinensis			0.035
White-breasted Nuthatch	Sitta carolinensis		0.008	0.003
Carolina Wren	Thryothorus ludovicianus		0.002	0.020
House Wren	Troglodytes aedon	0.011	0.088	0.003
Blue-gray Gnatcatcher	Polioptil caerulea		0.002	0.013
Eastern Bluebird	Siali sialis		0.002	
American Robin	Turdus migratorius	0.086	0.006	
Gray Catbird	Dumetell carolinensis	0.011	0.012	
Brown Thrasher	Toxostoma rufum	0.011	0.006	0.008
European Starling [a]	Sturnus vulgaris	0.011	0.012	
Cedar Waxwing	Bombycill cedrorum	0.032		
Black-and-white Warbler	Mniotilta varia			0.012
Northern Parula	Parula americana			0.019
Yellow Warbler	Dendroica petechia		0.012	0.001
Magnolia Warbler	Dendroica magnoli			0.001
Kentucky Warbler	Oporornis formosus			0.001
Comm Yellowthroat [b]	Geothlypis trichas	0.056	0.055	0.031
Yellow-breasted Chat	Icteria virens		0.004	0.050
Eastern Towhee	Pipil erythrophthalmus	0.003		0.043
Song Sparrow	Melospiza melodia	0.046	0.018	0.001
Savannah Sparrow [b]	Passerculus sandwichensis	0.003		
Grasshopper Sparrow [b]	Ammodramus savannarum	0.008		0.008
Clay-colored Sparrow [b]	Spizell pallid	0.022		
Field Sparrow [b]	Spizell pusilla	0.008		0.059
Dark-eyed Junco	Junco hyemalis			0.008
Northern Cardinal	Cardinali cardinali		0.021	0.079
Rose-breasted Grosbeak	Pheucticus ludovicianus		0.004	
Blue Grosbeak	Guiraca caerulea			0.003
Indigo Bunting	Passerina cyanea		0.029	0.098
Dickcissel [b]	Spiza americana	0.051	0.179	0.033
Bobolink [b]	Dolichonyx oryzivorus	0.059		
Brown-headed Cowbird [b]	Molothrus ater	0.062	0.133	0.158
Red-winged Blackbird [b]	Agelaius phoeniceus	0.091	0.016	
Western Meadowlark [b]	Sturnell neglecta	0.073	0.014	
Eastern Meadowlark [b]	Sturnella mag			0.016
Common Grackl	Quiscalus quiscula	0.191	0.006	0.003
Baltimore Oriole	Icterus galbula	0.005	0.014	
American Goldfinch	Cardueli tristis	0.038	0.119	0.080
House Finch	Carpodacus mexicanus		0.004	

[a] Exotic species.
[b] Grassland associated species.

Great Smoky Mountains National Park
Tennessee and North Carolina
Deciduous Forest Biome

K. Langdon
Park I&M Coordinator

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Air Quality

Fine Particles and Visibility

The Mar 1997–Feb 1998 annual average fine mass in Great Smoky Mountains National Park was 10.5 μg/m³, one of the highest concentrations in the IMPROVE network. Nearly 90% of that mass was sulfates (64%) and organics (25%). Sulfates are a major cause of visibility impairment in the park and in most other visibility monitoring sites in the eastern United States. During spring 1997–winter 1998, sulfates were 75% of the aerosol light extinction in the park, organics were 13%, and nitrates, soot, and soil and coarse particles each were less than 5%. The annual average standard visual range was 42 km (22 dv).

As in most eastern monitoring sites in the United States, visibility varies markedly by season in Great Smoky Mountains National Park. Visibility is worst in summer. Fine mass in summer was 15.1 μg/m³, and sulfate particles were 70% of that mass. The visibility was 33 km (25 dv) and sulfates were 80% of the aerosol light extinction. Organics contributed 12% to extinction; nitrate, soot, and soil and coarse particles contributed 8%. Visibility was best in spring. In 1997, the standard visual range in spring was 61 km (19 dv). Fine mass levels were 7.9 μg/m³, about half the level in summer. Sixty-six percent of the aerosol extinction in spring was produced by sulfates, 16% by organics, 7% by soot, 6% by soil and coarse particles, and 4% by nitrates. Total light extinction in summer (118 M/m) was nearly twice as great as in the spring (64 M/m). During Dec 1997–Feb 1998, visibility (58 km, 19 dv) and extinction levels (67 M/m) were similar to those in spring. During 1988-96, the best, average, and worst visibility days did not significantly improve or decline (Fig. 20).

Ozone

The highest daily maximum 1-h average ozone concentration on the Look Rock site in Great Smoky Mountains National Park in 1997 was 117 ppb. ppb, was the fourth highest recorded by the 40 ozone monitors in the network in 1997. The fourth highest 8-h average concentration, 99 ppb, in 1997 was the fourth highest in the network. During 19 days in 1997, the daily maximum 8-h ozone concentration on the Look Rock site exceeded 84 ppb. The 1-h ozone averages were more than or were equal to 100 ppb during 42 h in that year.

The new U.S. Environmental Protection Agency (EPA) ambient air quality standard designed to protect human health is exceeded when the 3-year average of the fourth highest 8-h daily maximum ozone concentration exceeds 84 ppb. The 1995-97 average of the fourth highest 8-h concentration in Great Smoky Mountains National Park was 95 ppb, which exceeds the EPA standard. Between 1990 and 1997, the 3-year average of the fourth highest 8-h daily maximum concentration has varied between 84 and 95 ppb at Look Rock and qualitatively suggests a 10 ppb increasing trend in the 3-year average between 1990 and 1997 (Fig. 21 on page 90). A more quantitative analysis of the May-Sep average daily maximum ozone concentrations revealed a statistically significant degrading air quality trend of 0.6 ppb/year during 1988-97.

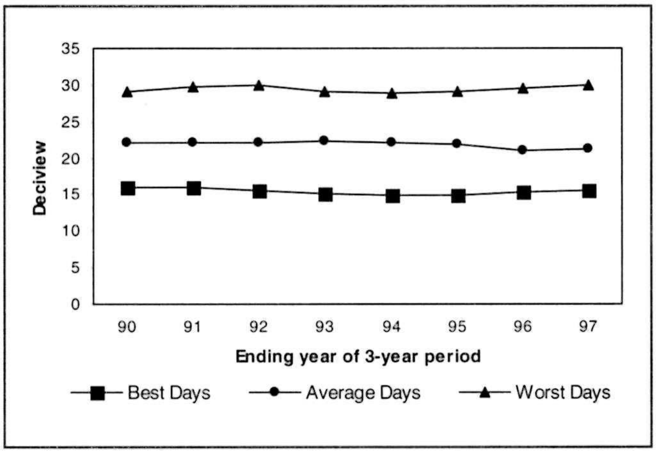

Figure 20. Three-year average deciview for best, average, and worst visibility days, Great Smoky Mountains National Park, 1990-1997.

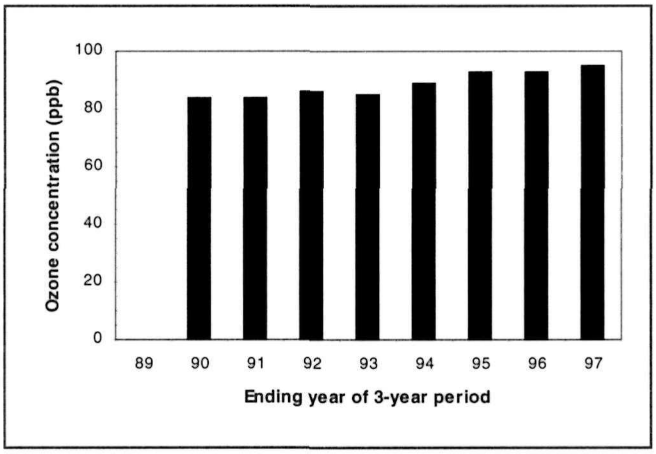

Figure 21. Three-year average of the fourth highest daily maximum 8-h ozone concentration (ppb), Great Smoky Mountains National Park, 1989-1997.

Wet Deposition

Sulfate concentrations in precipitation in Great Smoky Mountains National Park ranged from 1.0 to 2.6 mg/L during 1980-97 (Fig. 22). These elevated concentrations are similar to concentrations in other eastern parks and reflect the higher sulfur emissions in the eastern United States. Nitrate concentrations in Great Smoky Mountains National Park ranged from 0.7 to 1.3 mg/L. Nitrate concentrations were consistently lower than sulfate, however, the values are considerably higher in the eastern parks than in western parks because of higher nitrogen emissions. The theoretical pH of unpolluted precipitation is 5.6. In Great Smoky Mountains National Park, pH was much lower, ranging from 4.4 to 4.7.

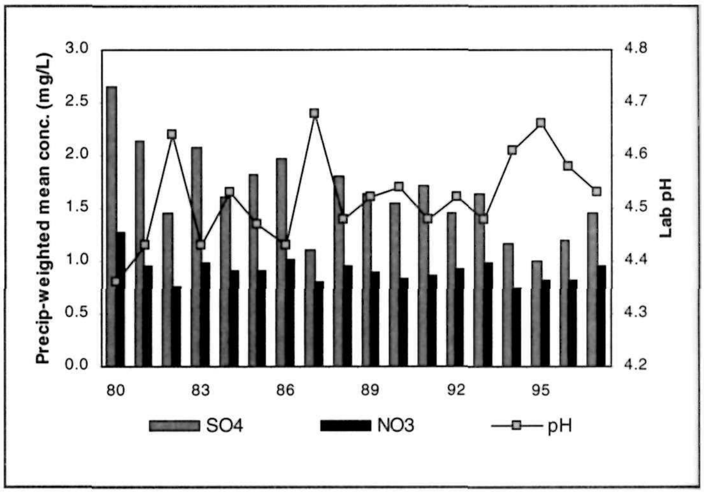

Figure 22. Annual average pH and precipitation-weighted mean sulfate and nitrate concentrations (National Atmospheric Deposition Program/National Trends Network), Great Smoky Mountains National Park, 1981-1997.

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Vegetation

Vegetation in Great Smoky Mountains National Park is monitored to determine how vegetation communities have changed in response to biotic and abiotic factors. Exotic species have been the most destructive biotic factor. Pathogens such as the chestnut blight *Cryphonectria parasitica* and more recently dogwood anthracnose *Discula destructiva* and beech bark disease *Nectria fungi* in association with beech scale *Cryptococcus fagisuga*, an exotic insect, have done severe harm. Since it was first discovered in 1954, the balsam wooly adelgid *Adelges piceae* has virtually eliminated Fraser fir *Abies fraseri* from high-elevation spruce-fir forests, and hemlock adelgid *A. tsugae* may greatly harm eastern hemlock *Tsuga canadensis* during the next decade. Acid deposition and high ozone levels further stress plant populations. Changes in disturbance regimes have altered vegetation communities. Throughout the park, plant communities continue to recover from past unregulated logging and agriculture. Fire suppression has allowed the succession of pine *Pinus* spp. stands to hardwood dominance, a process that mortality from southern pine beetle infestation often accelerates.

During 1993-98, vegetation was again sampled in 110 permanent 20-x-50 m (66 x 164 ft) or 1 ha (2.47 A) plots, established in the western park in 1977-79 by the Uplands Field Research Lab. Comparisons were made to determine the relation between present-day vegetation and past fire frequency and intensity. Overstory, understory, and ground-layer vegetation were measured. On recently burned plots, trees that seemed to have died prior to the fire were distinguished from those that seemed to have been killed by fire, allowing an approximate reconstruction of the pre-fire stands. Vegetation was again sampled in another 94 non-permanent plots established in 1936-37 to obtain early baseline data.

Between the 1930s and 1970s, canopy density, basal area, and canopy species richness increased considerably on fire-suppressed sites (Figs 23-24). During this same period, high-intensity fires decreased basal area and density, but low-intensity fires did not significantly reduce basal area and density in fire-suppressed sites. Between the 1970s and 1995, canopy density, basal area, and canopy species richness remained relatively stable in fire-suppressed and low-intensity-fire sites but increased on high-intensity-fire sites (Figs 25-26). During this period, the regeneration of shortleaf pine *Pinus echinata*, table mountain pine *P. pungens*, pitch pine *P. rigida*, and Virginia pine *P. virginiana* was heavy on some burned sites. On fire-suppressed sites, red maple *Acer rubrum*, blackgum *Nyssa sylvatica*, white pine *P. strobus*, and eastern hemlock *Tsuga canadensis* sdominated. These changes in the structure and composition of post-fire suppression stands may alter the response of vegetation to future burning and complicate attempts to restore the historical composition and structure of these communities.

In 1999, the plot network for monitoring vegetation will be expanded to include areas that were under-represented in earlier studies. Vegetation will again be sampled in Upland Lab plots and in new plots in a stratification of forest-cover types. Protocols are being developed for the selection, documentation, sampling, and re-sampling.

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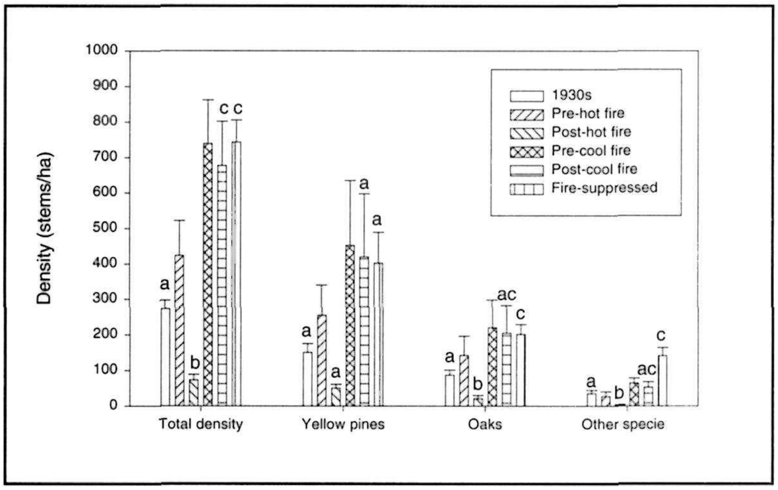


Figure 23. Mean (± SE) density of all yellow pine, oak, and other species on plots established in the 1930s and on hot-fire, cool-fire, and suppressed-fire plots established in the 1970s. Means not superscripted with the same letter are significantly different according to post-hoc multiple comparisons (Tukey HSD, p = 0.05) after 1-way ANOVA. Estimated mean densities on cool-fire and hot-fire plots before fires are offered for non-statistical comparison only and were not included in the ANOVA.

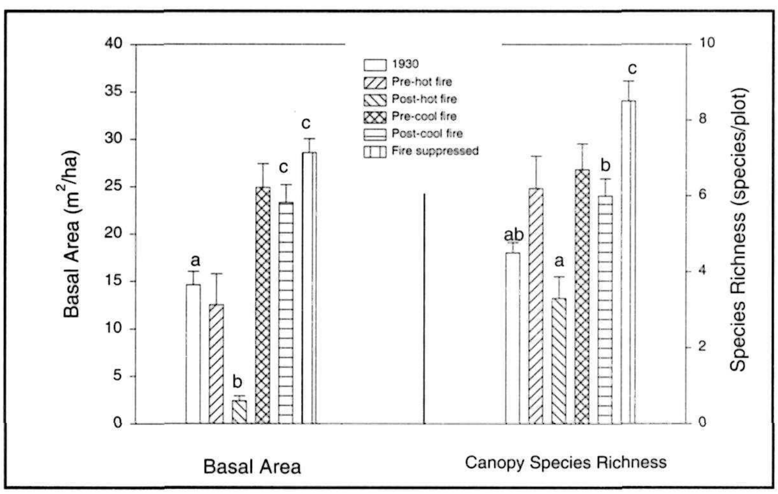


Figure 24. Mean (± SE) basal area and canopy species richness of all yellow pine, oak, and other species on plots established in the 1930s and on hot-fire, cool-fire, and suppressed-fire plots established in the 1970s. Means not superscripted with the same letter are significantly different according to post-hoc multiple comparisons (Tukey HSD, p = 0.05) after 1-way ANOVA. Estimated mean densities on cool-fire and hot-fire plots before fires are offered for non-statistical comparison only and were not included in the ANOVA.

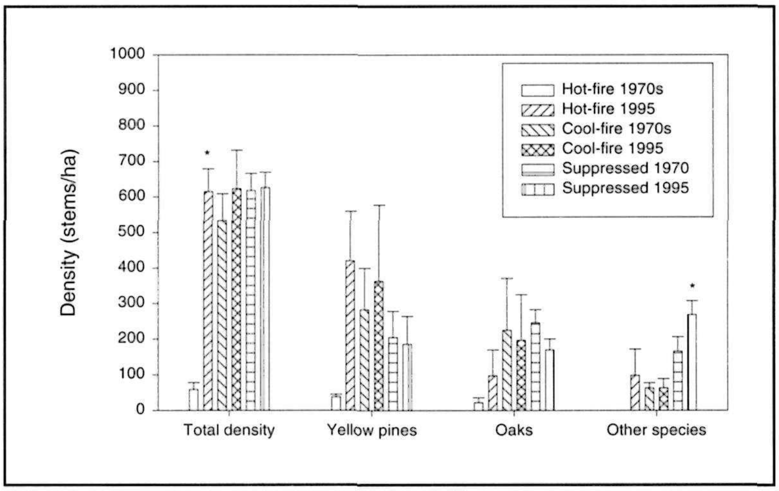


Figure 25. Mean (± SE) density of all yellow pine, oak, and other species on hot-fire, cool-fire, and suppressed-fire plots established in the 1970s and in 1995. * denotes a significant difference between means in the 1970s and in 1995 (1-way ANOVA with repeated measures, p = 0.05).

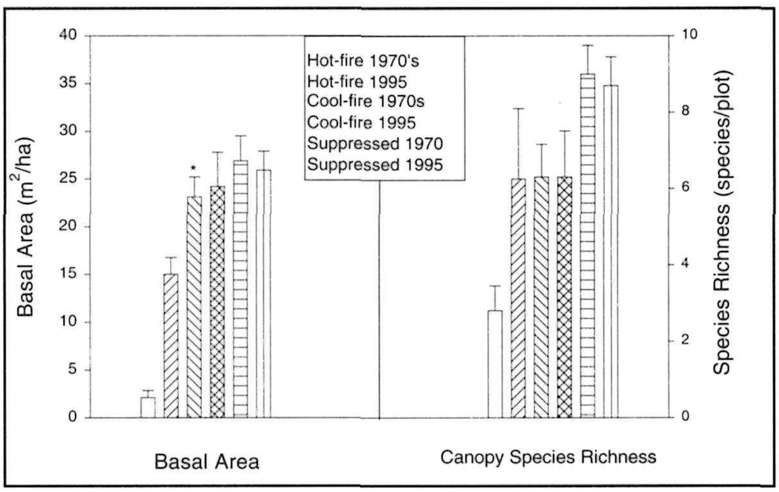


Figure 26. Mean (± SE) basal area and canopy species richness of all yellow pine, oak, and other species on hot-fire, cool-fire, and suppressed-fire plots established in the 1970s and in 1995. * denotes a significant difference between means in the 1970s and in 1995 (1-way ANOVA with repeated measures, p = 0.05).

Rugel's Ragwort

Rugel's ragwort *Rugelia nudicaulis* is a member of the Aster Family and endemic to Great Smoky Mountains National Park. It grows in openings of moist woods, usually above 1524 m (5000 ft) but sometimes below 1219 m (4000 ft) on north slopes. Most of its preferred habitat in the park is in declining Fraser fir *Abies fraseri* forests that are infested with the balsam woolly adelgid *Adelges picea*. Discovered in the park in 1963, the balsam woolly adelgid is a non-native insect that feeds on mature Fraser firs and thereby kills them. The subsequent loss of canopy affects the forest understory. Because of its global rarity and the threatened forest community in which it grows, Rugel's ragwort was listed as a *species of concern* by the U.S. Fish and Wildlife Service. Monitoring was initiated in 1989 to determine the effects of canopy loss on the ragwort.

Rugel's ragwort
Photograph by J. Boetsch

Rugel's ragwort has basal rosettes of leaves rising from a thick caudex or underground stem. The creeping habit of the plant precludes counting entire individuals. In the park, the sterile and fertile rosettes are counted instead. In 1989, six 6-x-4-m (20 x 13 ft) plots were established in Fraser fir forest that was dying from the adelgid. Three plots were on the southwest slope of Clingmans Dome where at the start of this study the fir forest was still healthy. The other three plots were established northeast of Mount Collins in a spruce-fir community where most of the mature firs were already dead. In 1989 and 1993, vegetative cover in each plot (ferns, herbs, Fraser fir seedlings, rocks, moss, or woody debris) was estimated to determine whether the number of ragwort rosettes is influenced by cover type. From 1989 through 1998, the fertile and sterile rosettes were counted in each plot.

After 10 years of data collection, some trends were identified. The number of rosettes increased during 1989-91 (Figs 27-28). Flowering peaked in 1991, particularly on Mount Collins, but decreased thereafter. The number of sterile and flowering rosettes has been lower on Clingmans Dome, and the number of flowering rosettes there was unusually low in 1992. Data in 1998 continued to support a decline in flowering and sterile rosettes. Fraser fir seedling cover did not differ (t-test) between Mount Collins and Clingmans Dome. The absence of a difference may have been attributable to the small number of sampling plots.

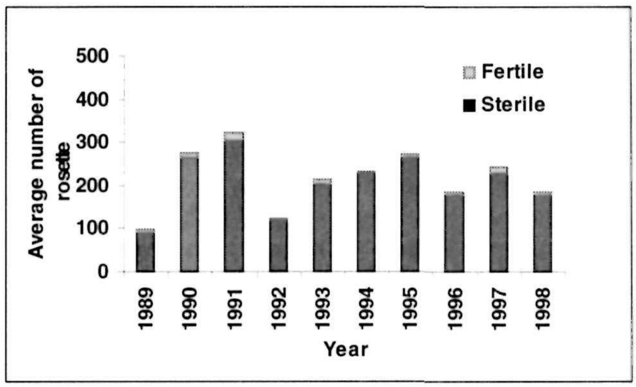


Figure 27. Average number of fertile and sterile rosettes of Rugel's ragwort on Clingmans Dome, Great Smoky Montains National Park, 1989-1998.

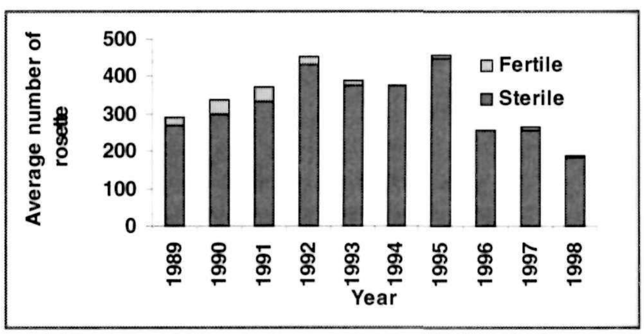


Figure 28. Average number of fertile and sterile rosettes of Rugel's ragwort on Mount Collins, Great Smoky Montains National Park, 1989-1998.

However, Fraser fir seedling cover increased during 1989-93.

When the plots were established in 1989, the fir seedlings were less than 50 cm (19.7 in.) tall. Ten years later, the firs were taller than 1 m (3.3 ft) in most plots and nearly 2 m (6.6 ft) tall on Mount Collins. The reduction in rosettes in both sites since 1995 may signal competition between regenerating fir stands and Rugel's ragwort, which has an affinity for open understories. Fraser fir is not a long-lived species; its life span is typically no more than 100 years. In response to the premature death of Fraser firs—sometimes many trees die in the same year—the increased sunlight to the forest floor promotes the release of fir germinals. When the firs are large enough to be vulnerable to the adelgid, Rugel's ragwort receives less sunlight. Adverse effects on Rugel's ragwort are unavoidable because of the large-scale change in the Fraser fir forests.

Rugel's ragwort will be monitored for several more years. In 1999, the four vegetation cover types will be estimated and a count of the remaining live mature Fraser fir trees will be made. The monitoring protocol will be re-evaluated to determine sampling on a broader scale.

Forest Pests

Forest pests in Great Smoky Mountains National Park are monitored to determine the short-term and long-term variations in the pest densities and the health of the affected tree species, the populations of pest insects or the extent of spread and resultant damage from pathogens, the cyclic variations of the pest, correlations between the pests and the health of the trees, and changes in the regeneration and species composition of American beech from beech bark disease. The park uses the information from monitoring for designing its natural resource management.

In 1998, the Balsam woolly adelgid *Adelges piceae* on Fraser's fir *Abies fraseri*, beech bark disease *Cryptococcus fagisuga* scale and *Nectria* spp. fungi on American beech *Fagus grandifolia*, and the mountain ash sawfly *Pristiphora geniculata* on American mountain-ash *Sorbus americana* were monitored.

Balsam Woolly Adelgid on Fraser's Fir

The monitoring protocol was developed in consultation with the U.S. Forest Service Forest Health personnel. In non-treatment areas on Balsam Mountain, Clingmans Dome, Mount LeConte, and Mount Sterling, the density of the adelgids is determined by examining Fraser fir trunks in 100 cm^2 (15.5 in^2) plots with 7x lighted magnifiers. The cone production of these trees is also recorded.

In 1998, the average density of the adelgid was higher on Balsam Mountain (63.8 + 124) and Mount Sterling (17.75 + 46.7) than on Clingmans Dome and Mount LeConte (Fig. 29).

Monitoring of the adelgid will be continued in 1999.

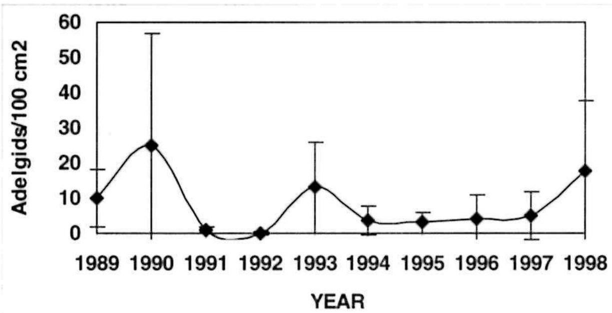


Figure 29. Average density (standard deviation) of the balsam woolly adelgid on Mt. Sterling, Great Smoky Mountains national Park, 1989-1998.

Beech Bark Disease on American Beech

Monitoring of beech bark disease on American beech in beech gaps at high elevations began in 1994. In the Great Smoky Mountains, beech gaps are unique areas dominated by beech at elevations of 1220-1800 m (4000-5900 ft). Reproduction by root sprouts is common in these gaps and suggests that genetic variation in beech in a gap is small.

American beeches in the park are sampled in ten 400-m^2 (4306 ft^2) plots to determine the crown health of each tree with a diameter that is larger than 3.5 cm (1.4 in). The monitoring is conducted in accordance with U.S. Forest Service protocols. A visual evaluation is made of the abundance and distribution of beech scale and *Nectria* spp. on each tree at 1.4 m (4.5 ft) from ground level. In each of twelve 2-x-2-m (6.6 x 6.6 ft) subplots, all woody species that are at least 1.4m (4.6 ft) tall and have a diameter of at least 3.5 cm (1.4 in) are tallied. In each site, seedlings that are at least 1 year old and 1.4 m (4.5 ft) tall or shorter are tallied in three 1-x-1-m (3.3 x 3.3 ft) plots.

The number of dead beeches was 30.6% greater in 1998 than in 1997. The mortality of trees with a diameter of at least 3.5 cm (1.4 in) was 30.1%. Crown dieback, described as recent death of branches with fine twigs in the upper portion of a tree, is a symptom of recent stress. The number of trees in the 0-10% and 11%-50% crown dieback classes declined since 1996 (Fig. 30). The number of trees in the greater than 50% dieback class increased.

American beech will not be monitored again until 2000.

Mountain-Ash Sawfly on American Mountain-Ash

American mountain-ash is one of the few deciduous tree species that occurs at the highest elevations of the Great Smoky Mountains. The European mountain-ash sawfly is an exotic fly larvae that feeds gregariously on leaflets. The reduced photosynthesis by the leaves impairs the overall health of the trees.

American mountain ash is sampled in eleven 20-x-20-m plots (66 x 66 ft) in seven locations. The foliage of each tree is visually evaluated for crown health in accordance with U.S. Forest Service protocols. As many as three different stem and crown damages are recorded. The number of fruit clusters is counted with 7X binoculars.

Defoliation damage and resultant crown dieback have been minimal in recent years (Fig. 31). Unlike in 1995, seed crops were abundant in 1998. The average number of fruit clusters/tree was 0.25 $\pm$ 2 in 1996 and 25.1 $\pm$ 30.3 in 1998.

Mountain ash will not be monitored again until 2000.

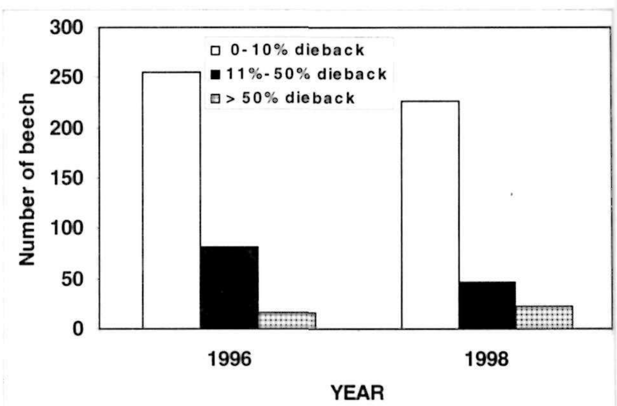


Figure 30. Number of beech by class of crown dieback, Great Smoky Mountains National Park, 1996 and 1998.

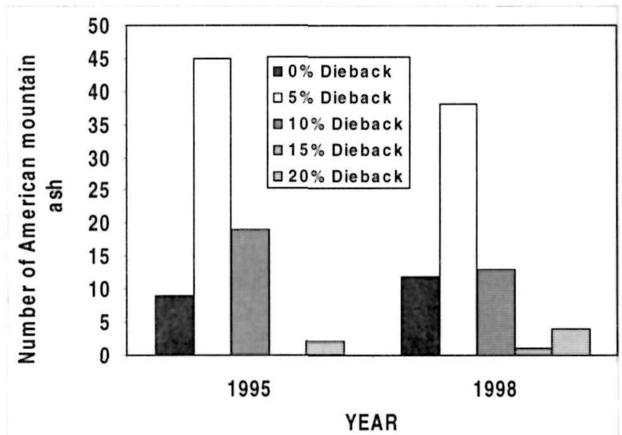
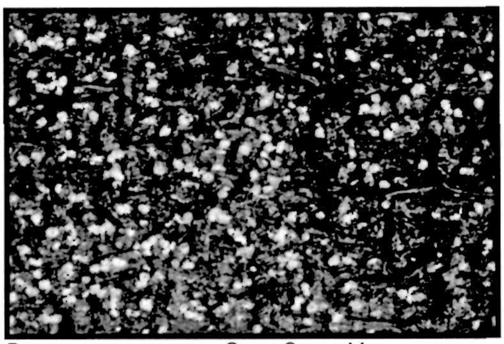


Figure 31. Number of American mountain ash by class of crown dieback, Great Smoky Mountains National Park, 1995 and 1998.



Balsam woolly adelgid, Great Smoky Mountains National Park. *Photograph by G. Taylor*

Fir wasted by the balsam woolly adelgid in Great Smoky Mountains National Park. *Photograph by G. Taylor*

American beech wasted by beech bark diseasse on Balsam Mountain Road, Great Smoky Mountains National Park. *Photograph by G. Taylor*

Vernal Pond Amphibians

The abundance of amphibians is declining in many parts of the world and monitoring the status of the animals provides basic information for management to reverse such declines. In Great Smoky Mountains National Park, the annual breeding of the wood frog *Rana sylvatica* and spotted salamander *Ambystoma maculatum* is monitored to gain a better understanding of natural population variations and to determine true population size trends. Egg mass is counted in six vernal ponds.

The 6-year study revealed synchronized change in metapopulations of wood frogs and spotted salamanders in the park (Figs 32-34), which differed from patterns elsewhere, and true declines in abundance for the first time. For example, wood frogs have declined by 68% since 1993. Whether these declines are elements of natural population cycles or reflect declines from increased ultraviolet rays, acid deposition, or other stressors will become much clearer after 3-4 more years of monitoring.

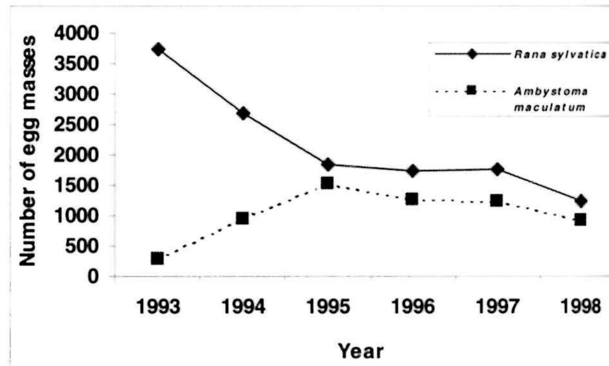


Figure 32. Number of egg masses of the woodfrog and spotted salamander, Great Smoky Mountains National Park, 1993-1998.

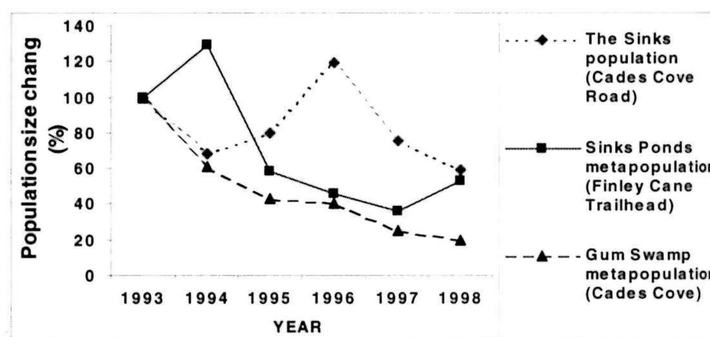


Figure 33. Population size trends in the woodfrog metapopulation, Great Smoky Mountains National Park, 1993-1998.

Woodfrog in Great Smoky Mountains National Park

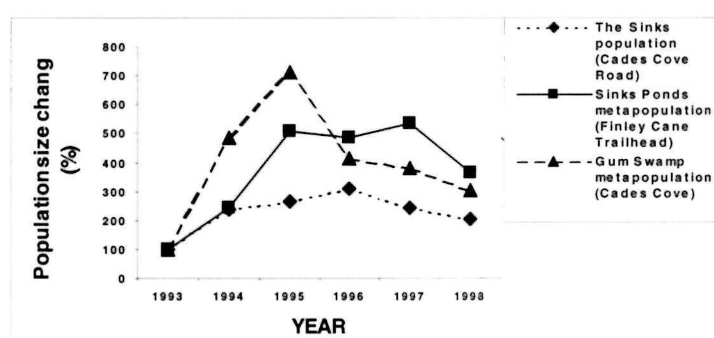


Figure 34. Population size trends in the spotted salamander, Great Smoky Mountains National Park, 1993-1998.

Brook Trout

In 1989, brook trout *Salvelinus fontinalis* in Great Smoky Mountains National Park were sampled in 34 sites in 14 first-third order streams at elevations of 616 and 1501m (2020 and 4925 ft). Because allopatric and sympatric populations occur in these sites, the variation in populations can be evaluated and attributed to either abiotic or biotic factors or to the effects of non-native salmonids. Information obtained from monitoring is used in management of brook trout.

The brook trout density ranged from 0.039 to 0.563/m^2 (0.005-0.052/ft^2). Young-of-the-year (YOY) comprised 5-77% of the allopatric brook trout populations. The 1998 year-class varied greatly by watershed because of the effects of floods during March 1998. The population characteristics in most streams showed no significant changes from previous years. Sympatric brook trout and rainbow trout *Oncorhynchus mykiss* populations in several acidified streams underlain by pyritic rock formations (i.e., anakeesta) declined 49-84% during 1998. Recent data suggested that the number of rainbow trout in several sympatric populations has been stable since 1989. Although encroachment by rainbow trout continued in some streams, recent data suggested that it may be limited because reproductive success declined in years with heavy flooding when alevins are vulnerable. Numbers of brook and rainbow trout in other sympatric populations have not changed significantly in the last 5-10 years. Typically, brook trout populations significantly decline only in years of major storms between November and March, whereas rainbow trout typically decline in years with major storms between February and May.

Comparisons of density and biomass of brook trout among streams indicated substantial variation in the number of trout per kilometer (0.6 mi) of stream. The average density was in the range of 25-901/km (40-1450/mi). However, the average density in most streams was 249-311/km (400-500/mi). Adult brook trout in the park rarely live beyond 4 years of age and seldom exceed 20.0 cm (8 in.) in length. In any given year, less than 10% of all collected brook trout are greater than 27.5 cm (7 in.). Monitoring of brook trout will be continued in 1999.

Large-Stream Fish Communities

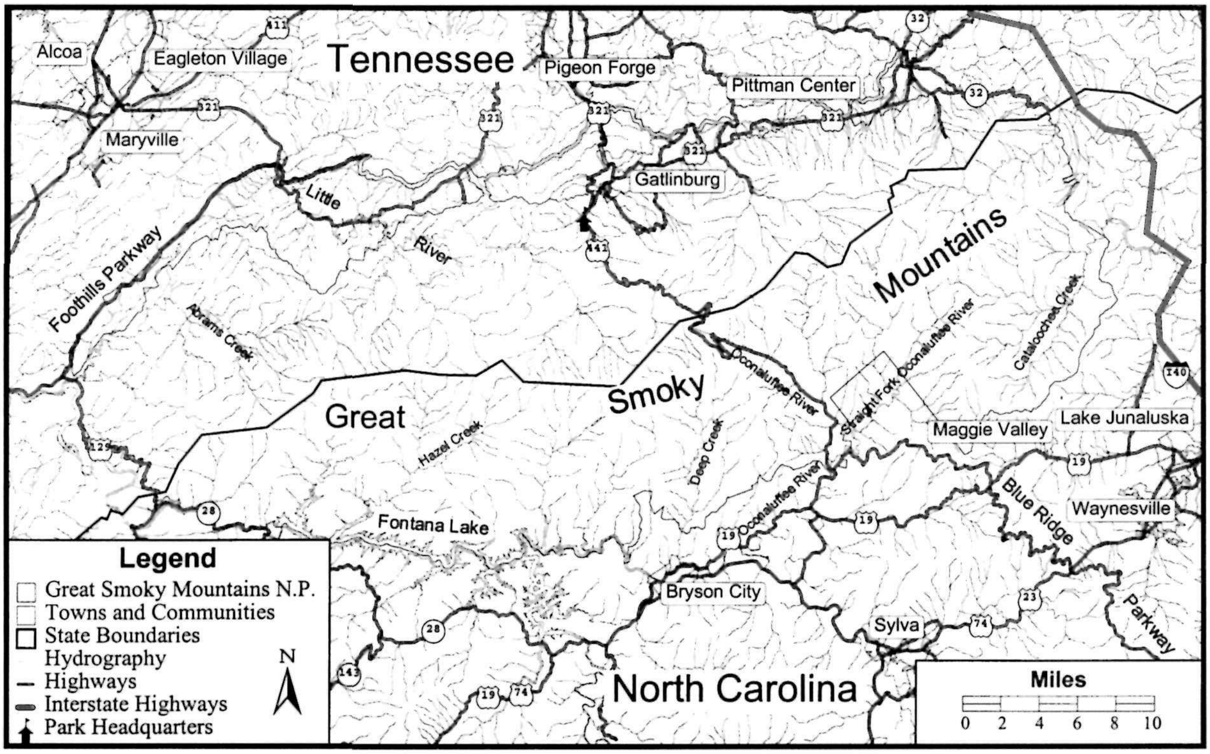
In 1998, fishes in Great Smoky Mountains National Park were sampled in five large streams: Abrams Creek, Cataloochee Creek, Hazel Creek, Little River, and Straight Fork (map on page 100). All are in the Tennessee River basin, which is one of the most biodiverse rivers in the temperate zone. The fishes are monitored to gain an understanding of natural population variation and to determine the effects from acid deposition, exotic trout, and local site disturbances.

Current and historical species composition among large stream sites has not significantly changed since the early 1970s. Species richness indicates excellent habitat and water quality in each stream.

In 1998, the abundance of sensitive species groups such as salmonid and dace did not change from that in previous years. The density of brown trout *Salmo trutta* was in the range of 0.54-2.80 fish/100m^2 (/10.8 ft^2), and the density of rainbow trout *Oncorhynchus mykiss* was in the range of 0.69-16.73 fish/100m^2. Age-0 brown trout were 14-71% of the population, and age-0 rainbow trout were 28-77% of the population, indicating strong year classes in both species.

Annual changes in density and biomass of the populations seem to be attributable to droughts and floods. Young-of-year salmonid production is driven by large flood events (> 283 L/s, >1000 cfs). The annual mortality of 1-4 year old rainbow and brown trout was in the range of 60-70%.

In 1998, the biomass of rockbass *Ambloplites rupestris* and smallmouth bass *Micropterus dolomieu* in Abrams Creek had declined since 1997. However, more than 75% of the smallmouth bass and 55% of rockbass were young of the year, indicating excellent reproduction that had been absent in recent years. Low reproduction in previous years may have been attributable to poor spawning habitat as a result of sedimentation from Cades Cove. Cades Cove is a 15-km^2 (5.5 mi^2) cultural resource area in the western park where 500 animal units of cattle are kept



MAJOR STREAMS IN GREAT SMOKY MOUNTAINS NATIONAL PARK
MAP BY J. GREGSON

under a special-use permit and about 80 horses are kept as part of a concessions operation. The livestock have caused significant stream bank and sheet erosion. Instream habitat on this site favors the young of the year of both bass species but lacks cover for adults. The biomass of smallmouth bass and rock bass in this area steadily declined during 1988-96 but has increased since 1996. Evidence of reproductive success in both species indicated that a reduction of sediment loading from stabilization of stream banks in 1994-96 was successful.

BREEDING BIRD COMMUNITIES

Breeding birds in Great Smoky Mountains National Park are monitored to produce accurate distribution maps of breeding bird species; to determine the effects of large-scale changes such as loss of forest trees from exotic diseases, air pollution, climate, and the invasion of Brown-headed Cowbirds *Molothrus ater* or exotic species; to predict the degree to which site disturbances from development or management affect particular breeding bird species; and to evaluate the importance of the park as a regional population source of declining bird species. Monitoring is expected to increase an understanding of the needs of Neotropical migratory birds in the Southern Appalachians.

Stratified sampling of birds by slope, aspect, elevation, and dominant plant community has been conducted in 3500 GPS-referenced census points throughout the park. The initial phase of the program will be completed in 1999. To date, data revealed patterns in the annual variability of species abundance that can be used to refine future monitoring. A subset of the combined data from 1996 and 1997 was used to compare the bird communities in old-growth and second-growth forests in the park (Figs 35-36). Data from 200 points in old-growth forest were com-

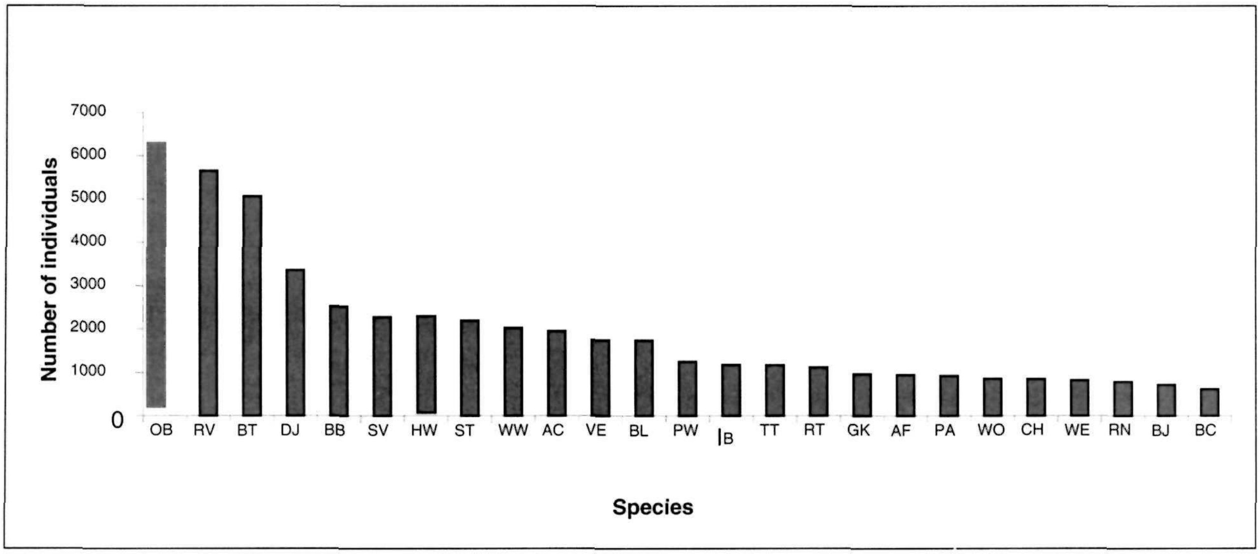


Figure 35. Total number of individuals of each bird species observed during point counts, Great Smoky Mountains National Park, 1998. Ovenbird = OB, Red-eyed Vireo = RV, Black-throated Green Warbler = BT, Dark-eyed Junco = DJ, Black-throated Blue Warbler = BB, Solitary Vireo = SV, Hooded Warbler = HW, Scarlet Tanager = ST, Winter Wren = WW, American Crow = AC, Veery = VE, Black and White Warbler = BL, Pileated Woodpecker = PW, Indigo Bunting = IB, Tufted Titmouse = TT, Easter Towhee = RT, Golden-crowned Kinglet = GK, Acadian Flycatcher = AF, Northern Parula = PA, Wood Thrush = WO, Chestnut-sided Warbler = CH, Worm-eating Warbler = WE, Red-breasted Nuthatch = RN, Blue Jay = BJ, Black-capped Chickadee = BC, Carolina Chickadee = CC, Canada Warbler = CN, Brown Creeper = BR, Yellow-throated Warbler = T, Chimney Swift = CS.

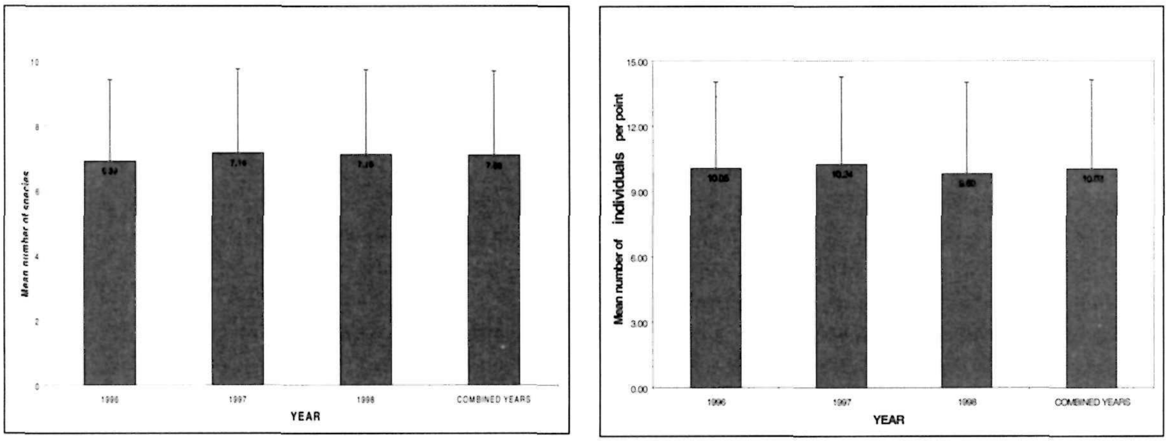


Figure 36. (a, left) Mean number of sighted bird species, and (b) mean number of birds per sampling, Great Smoky Mountains National Park, 1981-1998.

pared with data from 200 points in second-growth forest. These areas are at least 60 years old and possibly 100 years old.

Data from birds in old-growth and second-growth forests were matched by habitat type, elevation, and weather. Four vegetation types were included in the analysis: cove hardwood, mixed mesic hardwood, northern hardwood, and mesic oak. Comparisons of bird abundance and species richness in the four habitat types revealed significant differences between birds in old-growth and in second-growth forests. In general, the number of birds and the number of bird species was higher in old-growth forests than in second-growth forests. Because old-growth forest predominates, Great Smoky Mountains National Park provides important habitat for Neotropical migratory birds.

Black Bears

Black bears *Ursus americanus* in Great Smoky Mountains National Park are monitored by mark-recapture and aerial telemetry method to determine changes in demographics including sex and age structures, mortality, natality, and movement patterns; by bait-station surveys to obtain population size indices and to determine changes in bear distribution; and by a hard mast survey to obtain a food-availability index and to determine the availability of important foods like acorns in fall and their influence on the bears' population dynamics.

In 1998, fair to good mast production in the park provided refuge for a significant portion of the black bear population in the Southern Appalachians. Increasing demands for timber and recreation on national forest lands around the park, increased development on adjacent private land, illegal hunting, legal hunting outside the park, and increasing recreational demands in the park are hardships on the bears.

From Dec 1997 until Mar 1998, female bears were located in their winter dens. No evidence of cubs was seen in any of the visited dens. Because of the poor mast in fall 1997, the decrease in reproduction in previous years was expected. In fact, only one female bear with a single cub was captured during summer.

From 1 Jun to 11 Aug, 57 bears (34 males and 23 females) were captured in 732 trap nights (7.9 trap nights/capture). Visitation of bear bait-stations dur-

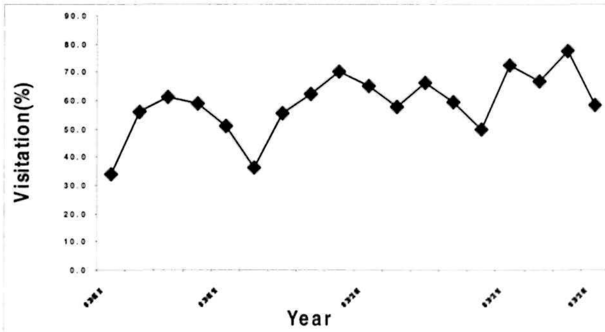


Figure 37. Percent of bait stations visited by black bears, Great Smoky Mountains National Park, 1993-1998.

ing 1-21 Jul ranged from 0% to 91.7%. The overall visitation, which is the quotient of the total number of baits visited by bears and the total number of baits in the park, was 58.5% (Fig. 37).

The hard mast survey during 10-21 Aug revealed good overall acorn production. Acorn production by white oaks was poor and acorn production by red oaks was good. In response to the sufficient red oak mast crop, adult female bears are expected to reproduce in winter 1998-99.

The size of the black bear population in the park and in the southern Appalachians has increased significantly in recent years. The current estimated population size in the park is 1700 bears (95% confidence interval = 600 individuals; Jolly-Seber modeling with data collected since 1970 and remote camera re-sight evaluations). Although this represents a 30% decrease from the all-time high abundance in 1997, it also represents a 84% increase since 1990 and a 160% increase since 1972. The increase in the bear population in the park can probably be attributed to the maturation of the forest and a concomitant greater abundance of food, increased availability of mast from a reduction in the number of exotic wild hogs, decreased poaching, better management of bears in the region, and improved techniques for determining bear densities.

The intensive mark-recapture study in the southwestern park concluded in 1998. Radio collars were removed from two adult females during summer. The remaining collars will be removed, if possible, during den inspections in winter 1998-99. The bait-station survey and hard mast survey will be continued indefinitely.

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The White-tailed Deer Herd in the Cades Cove Area

White-tailed deer *Odocoileus virginianus* occur throughout Great Smoky Mountains National Park, but their density is highest in the Cades Cove area. Haying and cattle grazing in Cades Cove maintain open vistas and a cultural landscape that favor deer. Managers fear that the large deer herd is not in balance with the carrying capacity of the environment and that browsing by so many deer may degrade habitat, shift tree species composition, and alter the community structure of unique plants. The transmission of disease from deer to humans and collisions of vehicles with deer increase with the density of the animals. Nevertheless, the deer in Cades Cover are valued by visitors and are important prey for large carnivores such as coyotes *Canis latrans*. The deer herd is monitored to determine its population dynamics and its response to large carnivores. The information is used for designing management of the deer herd that prevents environmental damage and harm to the deer and visitors.

The deer in Cades Cove are counted every 2 weeks throughout the year unless the weather is too inclement. Spotlighting at night is used to locate the deer. During 1998, the estimated deer densities ranged from 0.085/ha to 0.391/ha (0.210-0.966/A; Fig. 38). The mean deer density was 0.170/ha (0.07/A). If the use area for deer in Cades Cove is 2454 ha (6064 A), the overall estimated deer population was 417 (95% confidence interval = 64). The estimated deer density suggests that the herd in Cades Cove continued to decline (Fig. 38). The decline may be caused by predation from coyotes that are relatively new carnivores in the park.

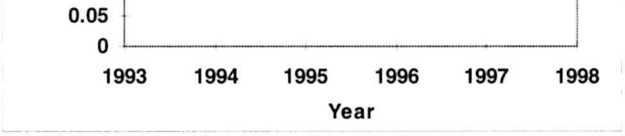

Figure 38. Density (deer/ha) of white-tailed deer in Cades Cove, Great Smoky Mountains National Park, 1993-1998.

The health of the deer is examined every other year and was not examined in 1998. However, a serological survey to investigate the presence of lyme disease *Borrelia burgdorferi* in the Cades Cove deer herd was completed. The survey was initiated because of two reported cases of human lyme disease. Of 665 deer sera samples from 1980-97, four were positive for antibodies to *Borrelia burgdorferi*, and another sample was suspected to be positive. The results indicated that the agent of lyme disease has existed in the park since at least 1980 and that visitors and staff must take protective measures to prevent tick bites and possible infection.

Monitoring of the white-tailed deer herd in the Cades Cove area will be continued indefinitely. Herd health checks will be performed during 1999.

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Shenandoah National Park, Virginia
Deciduous Forest Biome

T. Blount
Park I&M Coordinator

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Air Quality

Fine Particles and Visibility

Shenandoah National Park has operated a site in the IMPROVE visibility monitoring network since 1988. Particulate matter and optical properties such as light extinction are measured and are critical for understanding the role that air pollutants play in the degrading visibility in the park. The Mar 1997 - Feb 1998 annual average fine mass was 9.6 μg/m³, about five times that in Denali National Park and Preserve. Nearly 90% of that mass was sulfates (66%) and organics (23%). Sulfates are a major cause of visibility impairment in the park and in most other visibility monitoring sites in the eastern United States. During spring 1997–winter 1998, sulfates were 80% of the light extinction in Shenandoah National Park, whereas organics were only 9%. Nitrates, soot, and soil and coarse particles each contributed less than 5%. The annual average standard visual range is 36 km (24 dv).

Visibility in Shenandoah National Park varies seasonally. Visibility is worst during summer. Fine mass in summer was 14.9 μg/m³, and sulfate particles were 72% of that mass. The visibility was 21 km (29 dv); sulfates were 88% of the aerosol light extinction in summer. Organics contributed 7% to extinction; and nitrate, soot, and soil and coarse particles comprised the rest. Visibility was best in winter. The standard visual range during Dec 1997-Feb 1998 was 72 km (17 dv). Fine mass levels were 4.5 μg/m³, about 10 μg/m³ less than the level in summer. Sixty-seven percent of extinction in winter was produced by sulfates, 13% by nitrates, 11% by organics, 6% by soot, and 3% by soil and coarse particles. In 1998, the total light extinction (190 M/m) was nearly four times greater in summer than in winter (54 M/m). During 1988-97, the days with average visibility improved about 0.1 dv/year. The best and worst visibility days did not significantly improve or decline (Fig. 39).

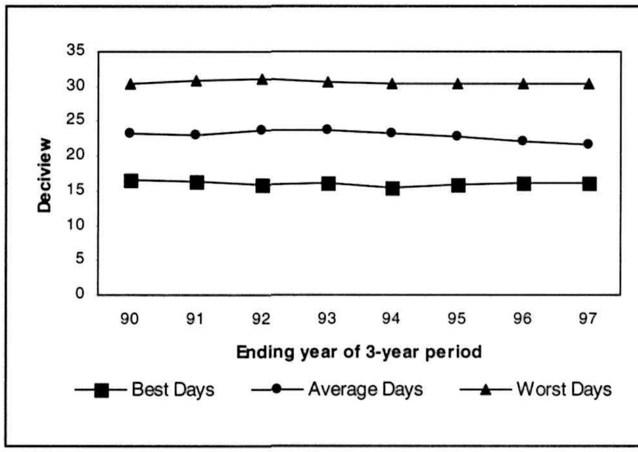

Figure 39. Three-year average deciview for best, average, and worst visibility days in Shenandoah National Park, 1990-1997.

Ozone

The highest daily maximum 1-h average ozone concentration in Shenandoah National Park in 1997 was 104 ppb. The second highest daily maximum 1-h value, 101 ppb, was the 15th highest recorded by the 40 ozone monitors in the network in 1997. The fourth highest 8-h average concentration, 89 ppb, in 1997 was the ninth highest in the network. During 4 days in 1997, the daily maximum 8-h ozone concentrations in Shenandoah National Park were greater than 84 ppb. The 1-h ozone averages during 4 h in 1997 were greater than or equal to 100 ppb.

The new U.S. Environmental Protection Agency (EPA) ambient air quality standard designed to protect human health is exceeded when the 3-year average of the fourth highest 8-h daily maximum ozone concentration exceeds 84 ppb. The 1995-97 average of the fourth highest 8-h concentration in Shenandoah National Park was 85 ppb, which just exceeds the EPA standard. During 1989-97, the 3-year average of the fourth highest 8-h daily maximum ozone concentration in Shenandoah National Park has varied between 80 and 86 ppb (Fig. 40 on page108). This qualitatively suggests a small increase in the 3-year average between 1991 and 1997. A more quantitative analysis of the May-September average daily maximum ozone concentrations in Shenandoah National Park did not reveal statistically significant improving or degrading trends during 1988-97.

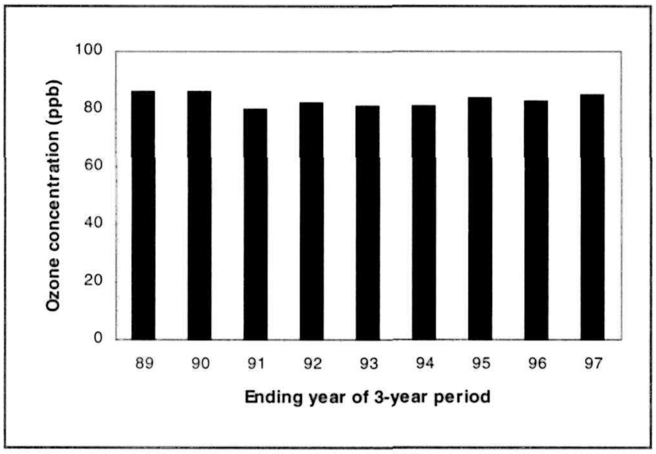

Figure 40. Three-year average of the fourth highest daily maximum 8-h ozone concentration (ppb), Shenandoah National Park, 1993-1997.

Wet Deposition

Sulfate concentrations in precipitation in Shenandoah National Park from 1981 to 1997 were elevated, ranging from 0.80 to 2.4 mg/L (Fig. 41). These concentrations reflect the higher sulfur emissions in the eastern United States. From 1985 to 1993, however, sulfate and hydrogen ion concentrations in precipitation decreased significantly (pH increased; $p < 0.05$). Concentrations of nitrate ranged from 0.6 to 1.2 mg/L. The decline in sulfate concentrations and the increase in precipitation pH suggest that recommendations made by the Clean Air Act Amendments are improving air quality in the park.

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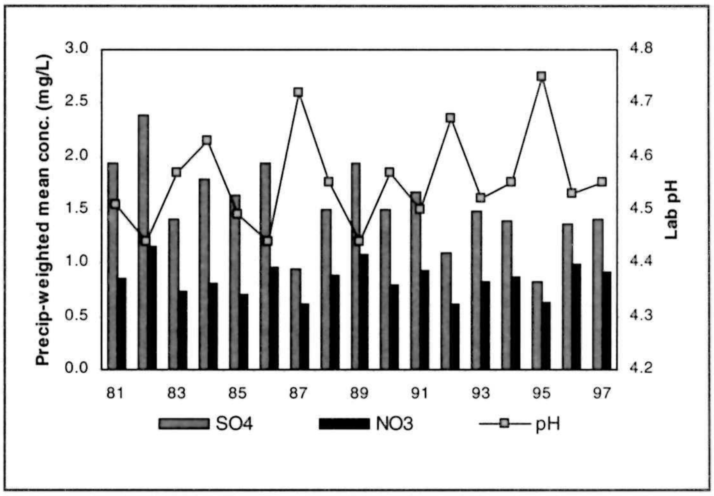

Figure 41. Annual average pH and precipitation-weighted mean sulfate and nitrate concentrations (National Atmospheric Deposition Program/ National Trends Network), Shenandoah National Park, 1998.

Water Quality

The headwaters of three river drainages are within the boundaries of Shenandoah National Park. Mountain streams that originate high on the ridges of the Blue Ridge crest and tumble down the mountainsides often form spectacular waterfalls and are cherished by visitors. These cool, clear, and highly oxygenated streams support excellent populations of brook trout *Salvelinus fontinalis* and therefore are the destination of many anglers.

Acid deposition from anthropogenic sources of air pollution poses a serious threat to the ecological integrity of many mountain streams in the park. The low acid-buffering capacity of many of the soils provides limited protection from acid deposition. Because of the sensitivity of its streams to acidification, the park initiated long-term monitoring of stream water chemistry and hydro-biogeochemical processes in 1979. Monitoring since then has been done in cooperation with the University of Virginia and is known as the *Shenandoah Watershed Study*. The university collects, maintains, and interprets the hydro-biogeochemical data. The park collects data about 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.

Stream water chemistry is closely linked to the underlying bedrock geology. Data that represent the spatial and temporal variation in hydro-biogeochemical conditions of the streams and watersheds in the park are collected. Intensive (weekly) and extensive (quarterly) sampling is conducted in watersheds dominated by each of the three major bedrock classes: siliciclastic, granitic, and basaltic. Park staff collect quarterly samples in 8 sites and coordinate their sampling with sampling of 55 additional stream sites outside the park in the western Virginia mountains in the Virginia Trout Stream Sensitivity Study by a cooperative, externally funded agent.

For the determination of long- and short-term trends in the hydro-biogeochemical status of streams, weekly stream water samples for chemical analysis are collected in 6 sites. Automated sampling at 8-h intervals during high flow conditions is done in 3 sites (funded by external sources) and discharge is gauged continuously in 5 sites.

Weekly stream water analyses include pH, alkalinity, conductivity, calcium, magnesium, potassium, sodium, sulfate, chloride, nitrate, and silica. Quarterly and episodic stream water analyses also include analysis of total and organic monomeric aluminum and seston. Dissolved organic carbon is sampled in irregular intervals. Precipitation analyses include ammonium and all stream water parameters excluding silica, aluminum fractions, dissolved organic carbon, and seston that are typically present in only trace amounts.

In 1985, the *Model of Acidification of Groundwater in Catchments* was developed and calibrated for application to the White Oak Run watershed in Shenandoah National Park. The model has subsequently been applied to many international locations and in conjunction with the National Acid Precipitation Assessment Program and the Southern Appalachian Mountain Initiative, a regional multi-stakeholder reduction of air pollution. Projections with the model indicate that a 70% reduction in sulfur deposition from 1991 levels is necessary to retain about 50% of the brook trout *Salvelinus fontinalis* streams in Virginia, including streams in the park, in a non-acidic condition.

During the mid-1980s, gypsy moths *Porthetria dispar* began to defoliate trees in the park. By the early 1990s, gypsy moth defoliation had moved through the entire 161-km (100 mi) length of the park. In a recent study, scientists examined the temporal variability of dissolved nitrate fluxes from five small (area < 15 km^2) forested watersheds in the mid-Appalachians, including Shenandoah National Park. In all sites, nitrate concentrations increased significantly during stormflow events, and nitric acid contributed to significant depressions of the pH and the acid neutralizing capacity. Annual nitrate fluxes were dominated by high-discharge periods. Inter-annually, the patterns of nitrogen leakage displayed considerable synchrony with outbreaks of defoliation by the gypsy moth caterpillars. However, poor documentation of defoliation rather than premature nitrogen saturation of intact forest ecosystems is a possible explanation of nitrogen leakage from forested watersheds in the mid-

Appalachian region and elsewhere. Because nitrates can be introduced to surface waters by anthropogenic sources and by natural sources, short-term increases in nitrates have encumbered the interpretation of trends of stream water biogeochemistry in the 1990s. Monitoring of nitrate levels will be continued.

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Aquatic Macroinvertebrates

(Annual data from monitoring aquatic macroinvertebrates in Shenandoah National Park are not reported until 12 months after the end of the calendar year. The delay is caused by the time schedule of the contractor.)

Aquatic macroinvertebrates in Shenandoah National Park are monitored to determine changes in aquatic insect diversity in relation to changes in water chemistry and flow (flood and drought). Because aquatic insects have short life cycles and are numerous, are directly affected by chemistry and flow changes, and are easily sampled, they are excellent indicators of aquatic ecosystem health.

Insect taxa richness or the number of species in a sample usually declines with a decrease in water quality. Taxa richness was examined in three geologically different watersheds with different acid neutralizing capacity (ANC, the ability of the soil or rock to neutralize acids in the water). Very low ANC is 10 meq/L and moderate ANC is 175 meq/L. All streams with less than 200 meq/L ANC are considered sensitive to acid deposition. Streams with less than 50 meq/L have almost no ability to buffer acid inputs. ANC was about 175 meq/L in the Piney River watershed (Catoctin geologic formation), 75 meq/L in the Staunton River watershed (Pedlar geologic formation) and about 10 meq/L in the Paine Run watershed (Hampton geologic formation).

The taxa richness of the macroinvertebrates in the three watersheds was measured with the EPT index, which is the number of Ephemeroptera (mayflies), Plecoptera (stoneflies), and Tricoptera (cadisflies) in a sample. These insects are sensitive to pollution. Also determined was the percent of Ephemeroptera in a sample because this group of insects is generally the most sensitive to pollution. The number of taxa that are intolerant to acidification is an important indicator of acid deposition in streams. The EPT index differed between the Paine Run watershed and the Staunton River and Piney River watersheds but not between the Staunton River and Piney River watersheds (Table 21).

Table 21. Differences among samples of macroinvertebrates from three watersheds in Shenandoah National Park, 1989-1995. Means (ranges) are from several sampling sites. An asterisk denotes values that do not differ ($p > 0.01$) between the Piney River and Staunton River watersheds. $p = 0.01$ was chosen because of the large number of comparisons.

Metric	Paine Run watershed	Piney River watershed	Staunton River watershed
Sample size	33	25	22
ANC	10	175	75
Taxa richness	14.8 (27.8)	22.8[a] (23.3)	21.3[a] (18.3)
EPT Index	9.8 (18.8)	15.1[a] (15.0)	13.7[a] (10.4)
Percent Ephemeroptera	3.7 (6.8)	5.9a (5.5)	5.3[a] (5.5)
Number of intolerant taxa	12.0 (20.8)	19.3[a] (19.5)	18.8[a] (15.8)

[a] A relatively conservative level of significance ($p = 0.01$) was chosen because of the large number of comparisons.

Sampling aquatic macroinvertebrates in the Piney River in Shenandoah National Park

Statistical inquires and summaries of the data collected to date are still in the beginning stages. A study of the differences between the watersheds is planned and is expected to provide early indications of impaired water quality and possible risks to aquatic resources such as fishes.

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Forests

Forests in Shenandoah National Park are monitored to evaluate changes in vegetation composition, structure, regeneration, and growth as influenced by natural and anthropogenic factors over time. The creation of 405 permanent plots throughout the park and sampling by park personnel in accordance with methods in *Shenandoah National Park Long-Term Ecological Monitoring System Forest Component User Manual, 1st Edition* (1990) began in 1988.

The park is reviewing the location of sampling plots and sampling procedures. Plans are made to increase the distribution of the plots throughout the park, to streamline the sampling procedures, and to add new measurements that will be useful to other functions in the parks such as fire management and control of exotic species. Under consideration are the tagging of trees, the creation of transects for investigating the fuel load for fires, and the survey of exotic species. In 1998, the consolidation of all historic data of monitored terrestrial plants into a single database was completed. The data are currently being validated and standardized in preparation for analysis.

Chestnut Oak Forests

In February 1998, storms coated much of the forest in the park with a thick layer of ice that severely damaged the crowns of many trees. After the storm, the tree canopy throughout much of the park appeared devastated. To determine the degree of damage to the park's most abundant forest cover type, the chestnut oak *Quercus prinus* association, sampling was conducted in 30 plots in 10 terrestrial monitoring sites and the damage was compared between the crowns of trees at high (745-942 m, 2444-3091 ft) and low (350-547 m, 1148-1795 ft) elevations.

The damage to the crown of trees was significantly greater at high elevations (11.3%) than at low elevations (0.8%; t-test, $p = 0.02$; Fig. 42), although the total number of live stems and the number of undamaged stems per hectare were not significantly different between forests at high and forests at low elevations.

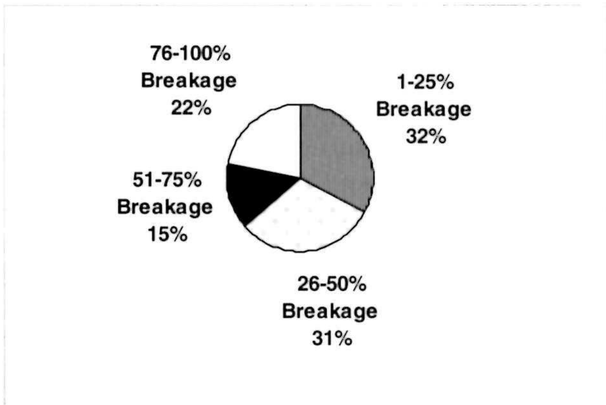

Figure 42. Mean density of trees that were damaged or remained undamaged by ice in a chestnut oak forest at low (350-547 m) and high (745-942 m) elevations, Shenandoah National Park, 1998.

The average amount of crown loss per tree at high elevation was 6.9 ± 2.7%. Overall, damaged trees were significantly larger (30.7 ± 2.3 cm [153 in.] diameter at breast height) than undamaged trees (17.7 ± 0.6 cm [86 in.] diameter at breast height), supporting the general assumption that larger trees tend to be taller and have more canopy exposed to ice damage.

Thirty-seven percent of the damaged trees at high elevations sustained greater than 50% crown loss (Fig. 43). However, certain tree species seemed to be more tolerant of ice accumulation (Fig. 44). In the chestnut oak forest at high elevations, red maple *Acer rubrum*, white oak *Quercus alba*, chestnut oak, and red oak *Q. rubra* were particularly susceptible to damage, whereas pignut hickory *Carya glabra*, American chestnut *Castanea dentata*, and eastern hemlock *Tsuga canadensis* were more resistant to damage. In future field seasons, park staff will sample the growth of seedlings, saplings, and herbaceous vegetation in response to the increased light and exposure from the damage to the canopy.

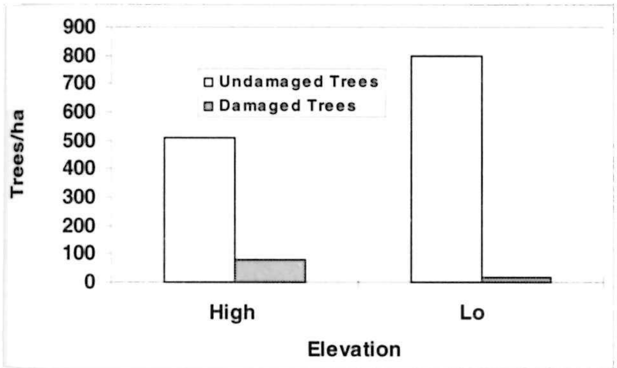

Figure 43. Severity of crown damage sustained by ice damaged trees in chestnut oak forests at high elevation (745-942 m), Shenandoah National Park, 1998.

Hemlock woolly adelgid in late fall development. Note some individuals with woolly mass.

Eastern Hemlock

The introduced Asian hemlock woolly adelgid *Adelges tsugae* is a lethal pest of eastern hemlocks *Tsuga canadensis*. It was first identified in Shenandoah National Park in early 1988 and has caused extensive morbidity and mortality to hemlocks. In response to the adelgid's presence, eastern hemlocks in the park have been sampled annually since 1992. During this time, the number of dead hemlocks per hectare has significantly increased (paired t-test, $p = 0.01$). However, the decrease in the number of live trees per hectare has not been significant (Fig. 44).

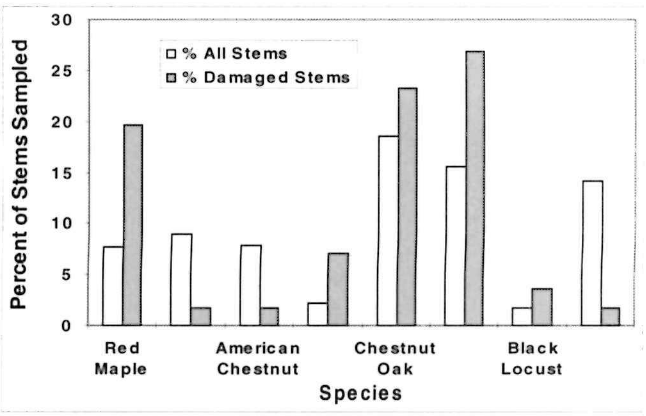

Figure 44. Comparison between the percent of all stems and percent of damaged stems in eight common tree species in chestnut-oak forest at high elevation. Values combine data from all trees taller than 5 m, Shenandoah National Park, 1998.

A supplemental survey funded by U.S. Forest Service was implemented in 1990 to obtain information from throughout the park. All 94 hemlock stands in the park are sampled and the crown health of each tree is determined (to a maximum of 100 trees/stand). By 1993, all hemlock stands were infested with the Asian hemlock woolly adelgid, indicating a steady decline of the health of hemlocks (Fig. 45). Whereas in 1990-91, 77% of the hemlocks had full healthy crowns, only 1% of the sampled trees since then have had such crowns. Partially crowned hemlocks (50% - 89% intact foliage) prevailed in 1992. Since then, the healthy crown portion of these trees has declined substantially (1-49% intact foliage). Without the emergence of an adaptation or biocontrol to reverse the vulnerability of the hemlocks to the adelgid, the hemlock stands will die. Operational methods for a forest-wide suppression of the adelgid do not yet exist. At this time, the objective of management is to save hemlock groves and trees accessible by road to ensure a seed source for future outplantings.

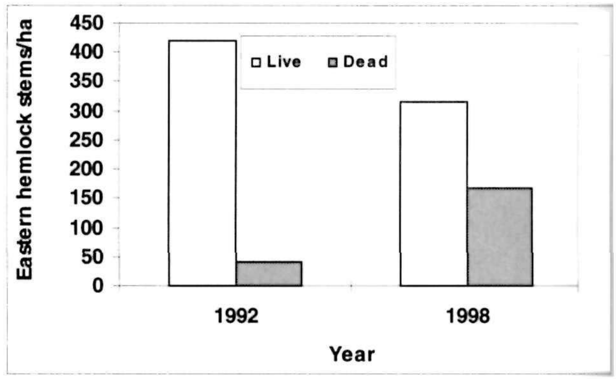

Figure 45. Density (trees/ha) of live and dead Eastern hemlock stems in a forest infested by the hemlock woolly adelgid, Shenandoah National Park, 1992 and 1998.

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Big Meadows, a Rare Plant Community

Big Meadows is a 50-ha (123.5 A) ridge-top meadow along Skyline Drive in Shenandoah National Park. It is a native opening with a wetland in its center. But the meadow is not just any meadow. Rare plant populations and historic settlement sites impart natural and cultural values to the meadow. As the only large non-forested area in the park, the meadow is also a haven for wildlife and plants that need open habitat. Although the meadow is only 0.06% of the size of the entire park, it supports 18% of the rare plant species of the park and two animal species that are on Virginia's list of rare animals.

Since establishment of the park in 1935, shrubs have encroached on the meadow and substantially reduced its size. Cost-effective management of the meadow to maintain the integrity of its natural and cultural resources and its esthetically pleasing appearance as a meadow is one of the many challenges of park management. In 1998, an inventory of the vegetation in the meadow was implemented to gather baseline data for the development of vegetation management and for the monitoring of the effects of such management.

A georeferenced color infrared aerial photo mosaic was prepared. The meadow was divided into four areas for stratified random sampling. Shrubs, trees, and trail cover were sampled along 40 randomly located 50-m (164 ft) transects and in 200 2.0-x-0.5-m (6.6 x 1.6 ft) plots. Substrate was sampled in 1000 point-intercept locations.

Preliminary data analyses revealed that the mean shrub cover of the meadow increased to 17.4%±2.4% since 1975 when mowing ceased under revised management. Five of 15 shrub species composed more then 1% of the shrub cover in the meadow: Panicled dogwood *Cornus racemosa*, maleberry *Lyonia ligustrina*, broad-leaved spirea *Spirea latifolia*, upland low blueberry *Vaccinium pallidum*, and deerberry *V. stamineum*. Overall, the shrub density is greater in the northern and central meadow than in the western and southern meadow (Fig. 46).

To date, 161 plant species have been identified in the groundcover of the meadow. Cover that consisted of all herbs and of woody species of less than 0.5 m (1.6 ft) height were measured. The average richness was 15±1 species/plot. Five species or groups of species comprised 50% of the cover (Fig. 47 on page 116). The cover value variability was greater of clumped species such as wild onion *Allium cernuum*, hay scented fern *Dennstaedtia punctilobula*, and upland low blueberry than of more ubiquitous species such as sedges *Carex* spp., common cinquefoil *Potentilla simplex*, yarrow *Achillia millefolium*, and sheep sorrel *Rumex acetosella*.

Aerial images suggested that a large portion of the meadow was covered by trails. However, trails were only 1.7% ± 0.3% of the meadow area. Beneath the vegetative cover, 89% ± 2.4% of the substrate was organic litter and 8.1% ± 1.6% moss. Rocks and lichens were beneath the vegetative cover in the remaining area.

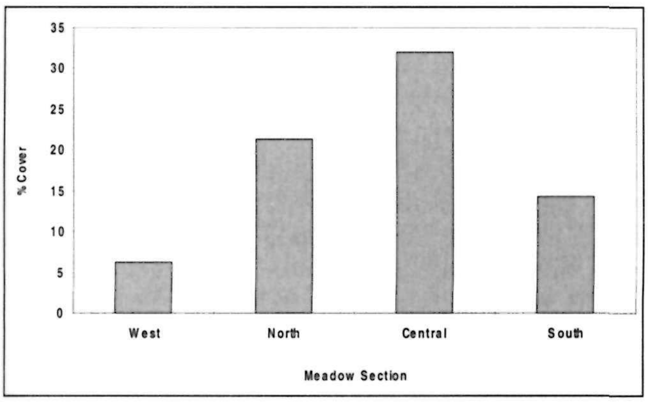

Figure 46. Mean shrub cover in four sections of Big Meadows, Shenandoah National Park, 1998.

In 1999, the survey of herbaceous species will be expanded and the study of botanically rich areas of the meadow will be intensified.

Rare Plant Species

In 1998, Shenandoah National Park revitalized the documentation of the status of its rare plant populations and protection of the plants. Most populations had not been examined since their documentation by the Virginia Department of Natural Heritage during 1989-91. Since then, plant communities in the park have been heavily impaired by gypsy moths *Lymantria dispar*, severe ice storms, a hurricane, and drought.

Fifty populations including 29 of the 46 state-listed species that occur in the park were monitored during 1998. Plant populations were relocated, plants were counted, and plant locations were mapped with a global positioning system. Volunteers under the nonprofit Appalachian Trail Conference that manages the Appalachian Trail monitored seven populations of the rare Rand's goldenrod *Solidago simplex* spp. *randii* (Porter) Ringius, a fall-flowering species that occurs on exposed high-elevation greenstone outcrops.

During 1998, the park initiated a computerized and paper-tracking system to organize location information and population status reports of all its rare plant species. In addition, the park entered a cooperative agreement with the Virginia Department of Natural Heritage to design a more formal schedule of monitoring state-listed rare plants. Populations of the remaining 17 state-listed rare species will be monitored in 1999.

Sword-leaved Phlox

Sword-leaved phlox *Phlox buckleyi* is a globally and state-listed rare perennial endemic to mountainous

Sword-leaved phlox in the southern district of Shenandoah National Park. *Photograph by W. Cass.*

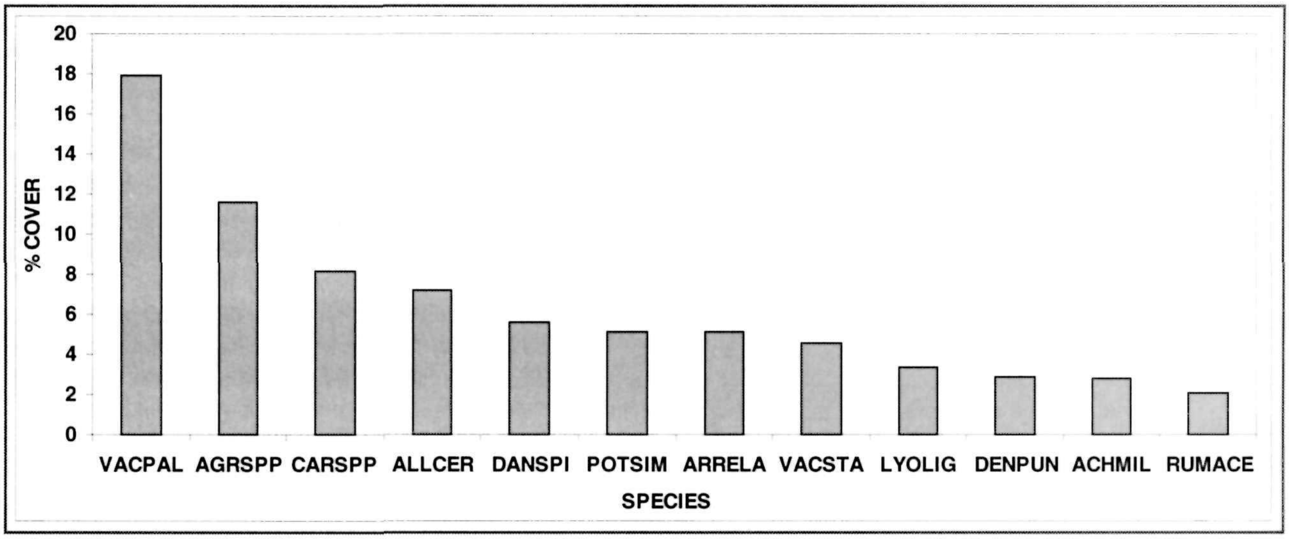

Figure 47. Mean percent cover of the 12 most common species or groups of species of ground cover in Big Meadows, Shenandoah National Park, 1998. VACPAL = upland low blueberry *Vaccinium pallidum*, AGRSPP = bent grass *Agrostis* spp., mainly *Agrostis capillaris*, CARSPP = All sedge species Carex spp. combined, ALLCER = wild onion *Allium cernuum*, DANSPI = poverty oat grass *Danthonia spicata*, POTSIM = common cinquefoil *Potentilla simplex*, ARRELA = tall oat grass *Arrhenatherum elatius*, VACSTA = deerberry *Vaccinium stamineum*, LYOLIG = Maleberry *Lyonia ligustrina*, DENPUN-hay scented fern *Dennstaedtia punctilobula*, ACHMIL = yarrow *Achillia millefolium*, RUMACE = sheep sorrel *Rumex acetosella*.

areas of West Virginia and Virginia. Plants typically occur in dry open habitats on gravelly soil and roadside banks. The greatest threats to the survival of sword-leaved phlox are roadside mowing and maintenance and too much shading from forest succession.

Two populations of sword-leaved phlox in Shenandoah National Park occur in the area along Skyline Drive that is mowed. Since their discovery in 1990, both populations have been periodically censused and the number of non-flowering and flowering plants have been recorded (Table 22). Over the years, population sizes have fluctuated drastically. One of the two populations (Population 2) declined sharply after its discovery in 1990. Plants were last found on the site in 1995 and seem to have been completely eliminated by competing roadside vegetation or changes in the mowing regimen. The remaining population (Population 1) has consisted of 0-80 flowering plants since its discovery in 1989. Results from the survey in 1998 indicated that the population is continuing its recovery from a low of zero plants in 1996 and that the number of flowering plants is now equal to that in1990. Yearly fluctuations in plant numbers may be due partially to changes in sampling personnel through the years but also to drought and overshading by trees. In 1998, the embankment where Population 1 occurs was mowed during the dormant season. Decisions about additional management will be made after monitoring the status of the population in 1999.

Exotic Vegetation

In 1997, Shenandoah National Park initiated a 4-year assessment of the distribution and preponderance of exotic vegetation. The objectives of extensive sampling have been the determination of the extent of infestation by 40 highly invasive species, the documentation of exotic epicenters, and the identification of priorities in future treatments. The cover in circular plots spaced in 50-m (164 ft) intervals along one or more 300-m (984 ft) transects was sampled to determine the presence of exotic trees, shrubs, and forbs. In anticipation of future monitoring and opera-

Table 22. Number of flowering and non-flowering stems in 2 populations of the sword-leaved phlox, Shenandoah National Park, 1990-1998. The populations were not monitored in 1991,1992, and 1994.

Year	Date	Population 1	Population 2
1990	10 Jun	15 flowering numerous non-flowering	60 flowering numerous non-flowering
1993	15 Jun	80 flowering unknown number of non-flowering	5 flowering unknown number of non-flowering
1995	14 Jun	25 flowering 127 non-flowering	2 flowering 54 non-flowering
1996	10, 20 Jun 16 Jul	none	none
1997	24 Jun	2 flowering 9 non-flowering	none
1998	16 Jun	13 flowering 187 non-flowering	none

tional needs, a global positioning system was used to document the locations of transects and plots. Because most exotics are sun-loving and were introduced by people, the park has concentrated sampling in developed areas, road right-of-ways, old home sites, and the boundary of the park. To date, sampling has been conducted along 103 transects.

Amphibians

Since the late 1980s, researchers of amphibians around the world have reported size reductions of their study populations. Many declines are attributable to habitat loss and habitat degradation from environmental contaminants. However, declines in protected areas suggest that subtle stressors such as acid deposition and ultraviolet radiation may have a direct effect on the animals. Amphibians are sensitive indicators of environmental change because of the permeability of their skin across which they respire. Furthermore, the life histories of many amphibian species comprise an aquatic larval stage and a terrestrial adult stage. Consequently, amphibians—unlike exclusively terrestrial or amphibious organisms—are exposed to a much broader range of stressors during their lifespan. In the mid-Atlantic region of eastern North America, a declining abundance of amphibians has been attributable to habitat loss. However, aquatic and terrestrial habitats in this region are turning more acidic and may be expected to intensify the decline.

Fourteen salamander and 10 frog and toad species occur in Shenandoah National Park (Table 23). Much of the diversity is attributable to the range of habitats at various elevations and aspects of the landscapes as they rise to ridge top areas from the Piedmont Plateau in the east and from the Shenandoah Valley in the west. The species range from the southern red-backed salamander *Plethodon cinereus*, American toad *Bufo americanus*, and wood frog *Rana* silvatica, which are abundant throughout much of eastern North America, to the federally listed Shenandoah salamander *Plethodon shenandoah*, known only from three scattered populations in the center of the park.

The Virginia Natural Heritage Program and the U.S. Fish and Wildlife Service assisted with the initial assessments of the Shenandoah salamander and associated habitats. Site specific maps in GIS (Geographic Information System) compatible format of the known range and distribution of the Shenandoah salamander were made and detailed field notes including museum records were compiled.

Since 1995, the amphibians have been monitored monthly from April through October in the Paine Run, Staunton River, and Piney River watersheds. The objectives are the evaluations of published monitoring protocols to determine the amphibians' status, relative abundance, and responses to the different degrees of acidification in the three watersheds. This work is done as part of the Legacy 2000 project, funded by the Department of Defense, to investigate the decline of amphibian abundance in the mid-Atlantic region. Time constrained searches were the simplest and most effective monitoring technique for streamside salamander populations.

The most frequently encountered salamander species pooled for all sites in descending order were the dusky salamander *Desmognathus fuscus*, seal salamander *D. moniti cola*, two-lined salamander Eurycea bislineata, and spring salamander Gyrinophilus porphyriticus. The composition of salamander species between the three watersheds was similar. The diversity of frog species was greatest (Table 24) in the Paine Run watershed, which has the least buffering capacity. Six frog species occurred in the Staunton River watershed and two species in the Piney River watershed. Larval stages of most species were sighted in all three watersheds, which indicated that the species were maintaining breeding populations. The low pH values of 4.98-5.21 at Paine Run were seemingly not low enough to impair survivorship or cause embryological damage to the amphibian species there.

Table 23. Amphibian species in Paine Run, Staunton River, and Piney River. Shenandoah National Park, Virginia, 1995-1997. A = abundant >20, C = common 5-19, U = uncommon <5. Blank spaces denote no observations.

Species	Paine Run				Staunton River				Piney River			
Frogs:	94	95	96	97	94	95	96	97	94	95	96	97
Acris crepitans		U		U								
Bufo americanus		U						U				
B. fowleri		U	U				A					
Hyla versicolor			U				A					
Pseudacris crucifer		U										
Rana catesbeiana		U	U									
R. clamitans			U	U		U	A	U		U		
R. palustris	U	C	C	U				U		U	U	U
R. sylvatica	U	C	U				U					

Fishes

Fishes are monitored to obtain a scientifically based understanding of changes in their abundance and distribution, to determine anthropogenic influences, and to develop responses by management that ensure their persistence in the streams of the park.

In 1998, fishes were sampled in 40 annual monitoring sites along 18 streams. The streams included Pass Run, the Moorman's River, the sNorth Fork, and the Rose, Rapidan, and Staunton rivers. Three-pass depletion electrofishing in the standard monitoring sites and single-pass electrofishing in some additional

Table 24. Amphibian species in Shenandoah National Park, 1998.

Broadly distributed amphibians	
Aquatic salamanders	
Northern dusky salamander	*Desmognathus fuscus fuscu*
Virginia seal salamander	*Desmognathus monticol jeffersoni*
Northern two-lined salamande	*Eurycea bislineata*
Northern spring salamander	*Gyrinophilus porphyriticus porphyriticus*
Northern red salamander	*Pseudotrito ruber*
Terrestrial salamanders	
Red-backed salamander	*Plethodon cinereus*
Slimy salamander	*Plethodon cylindraceus*
frogs and toads	
American toad	*Bufo americanu americanu*
Green frog	*Rana clamitans melanota*
Pickerel frog	*Rana palustris*
Wood frog	*Rana sylvatica*
Localized or uncommon amphibians	
Northern cricket frog	*Acris crepitans crepitan*
Fowlers toa	*Bufo woodhousi fowleri*
Eastern gray	*Treefrog Hyla versicolor*
Northern spring peeper	*Pseudacris crucifer crucifer*
Upland chorus frog	*Pseudacris triseriata feriarum*
Bullfro	*Rana catesbeian*
Jefferson salamander	*Ambystoma jeffersonianum*
Spotted salamande	*Ambystoma maculatu*
Long-tailed salamander	*Eurycea longicaud longicauda*
Four-toes salamander	*Hemidactylium scutatum*
Red-spotted new	*Notophthalmus viridescens viridescen*
Shenandoah salamander	*Plethodon shenandoa*

SHENANDOAH SALAMANDER IN SHENANDOAH NATIONAL PARK.
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sites followed *Standardized Sampling Guidelines for Wadable Trout Streams* by the Southern Division of the American Fisheries Society.

From mid-June to early August, 4504 brook trout *Salvelinus fontinalis* were captured in 22 streams. About 26% were juveniles in one of the lowest juvenile to adult ratios. In 1997, the juvenile trout were 85% of the fish populations throughout the park. Heavy rains and swollen streams in late January probably harmed fry at the peak of hatching.

Fishes had not occurred in the lower Staunton River and in the lower Rapidan River since 1995. However, 53 juvenile brook trout were captured in the lower Staunton River in 1998. Insufficient shading of the stream and prolonged droughts in summer and fall 1998 probably impaired recolonization. Immediately downstream on the lower Rapidan River, 3355 fishes representing 16 species were captured in a 100-meter (328 ft) monitoring site. The catch was dominated by blacknose dace *Rhinichthys atratulus* and torrent suckers *Moxostoma rhothoecum* but also included 5 brook trout.

Perhaps the most noteworthy discovery was made on 18 Jun in Pass Run. In addition to brook trout and rainbow trout *Oncorhynchus mykiss*, blacknose dace, longnose dace *Rhinichthys cataractae*, creek chub *Semotilus* atromaculatus, mottled sculpins *Cottus bairdi*, and fantail darters *Etheostoma flabellare*, all of which are known inhabitants of Pass Run, three large greenside darters *Etheostoma blennioides* were captured. Fishery biologists from the Virginia Department of Game and Inland Fisheries confirmed the identification. In Virginia, the greenside darter has a split range. The principal range is the southwestern counties of Virginia. However, a population occurs in the Potomac watershed where it may have been introduced. The occurrence of the greenside darter is novel not only in waters of Shendandoah National Park but in any tributary in the Shenandoah Valley south of Front Royal.

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Exotic Fishes

Streams in Shenandoah National Park are monitored for the presence of introduced non-native fishes, sometimes referred to as exotics. The exotics are removed to protect the integrity of the native fish assemblages.

In 1998, 433 brown trout *Salmo trutta*, 147 rainbow trout *Oncorhynchus mykiss*, and one tiger trout *S. trutta x Salvelinus fontinalis* were removed from five streams in the park (Fig. 48). The tiger trout was captured in the Rose River and was the largest known (23.5 cm, 9.25 in) from any stream in the park. Since 1982, 10 trout presumed to have been tiger trout have been collected from the Hughes, Moorman's, North Fork and Conway, and Rose rivers where populations of brook trout and brown trout coexist. The exotics were removed with at least two backpack electrofishing units, starting at the park boundary and proceeding upstream to the first major natural barrier in the streambed above the exotic trout population.

For the first time since the flood in 1995, exotics were removed from the North Fork Moorman's River where no brown trout had been sighted in the interim. Most of the lower section of the Moorman's River, downstream from Big Branch was sampled twice during 2 days and 34 brown trout and 1 rainbow trout were removed. Most of the brown trout were yearlings.

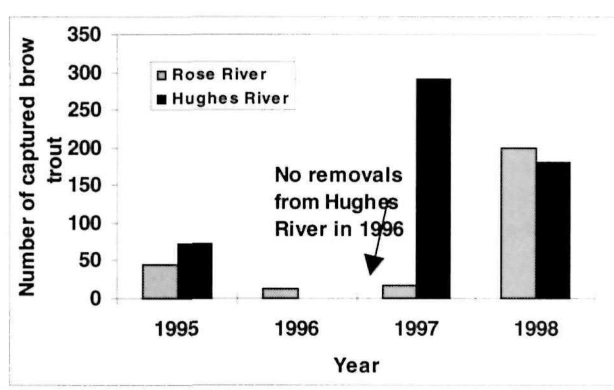

Figure 48. Number of brown trout removed from two rivers in Shenandoah National Park, 1998.

In response to reports from anglers, a 4.8-6.4-km (3-4 mi) reach of the Rapidan River was sampled for exotics for the first time. However, no exotics were sighted.

Attempts to keep streams in the park free of exotic trout species has had mixed results. The park has no control over populations of exotics immediately downstream from its boundary. Occasional high stream flows in late spring ease the upstream move of exotics; in the absence of natural or constructed barriers at or near the park boundary, exotics cannot be kept from entering stream reaches in the park.

Termination of the removal of exotics in 1999 is being considered. Instead, the response of brook trout to the encroachment of brown trout may be evaluated.

Land Bird Populations

Surveys of breeding birds since 1969 have revealed range-wide declines of abundance in several species of land birds, particularly some of the Neotropical migratory species. Anthropogenic loss or degredation of habitat and widespread environmental contamination have long been implicated in the decline of bird population sizes. Forest fragmentation is one of the principal causes of harm to bird populations in much of eastern North America where unlike in the West, few large parks, refuges, or other lands protect habitat from natural resource extractions or major developments.

Shenandoah National Park is a notable exception. The park's 79,380-ha (196,000 A) forested upland habitat along the spine of the Blue Ridge is a major refuge and breeding area for Neotropical migrants in one of the principal migration corridors in the East. Neotropical migrants represent more than one-third of the 205 bird species recorded in the park (Table 25). The principal objectives of bird monitoring include measurement of the annual adult population structure and size, annual post-fledging productivity, and adult survivorship to understand the bird community structure in the park and the processes that influence trends in the park's bird population.

General bird population and community level data have been collected in the park from four non-randomly located routes of the breeding bird survey since 1990 and from six permanent plots associated with the Monitoring Avian Productivity and Survivorship (MAPS) Program since 1992. The breeding bird survey generates an index of primarily singing male birds, recorded from 200 points along the Skyline Drive and other roadside areas in the park. Breeding bird survey methods in the park follow the *Instructions for Conducting The Breeding Bird Survey* by the U.S. Fish and Wildlife Service. The survey favors bird species that frequent forest edges where shrub thickets and grasses represent the dominant ground cover. The ten most frequently encountered birds from the breeding bird survey since 1990 in descending order are the Eastern Towhee *Pipilo erythrophthalmus*, Wood Thrush *Hylocichla mustelina*, Indigo Bunting *Passerina cyanea*, Ovenbird *Seiurus aurocapillus*, American Redstart *Setophaga ruticilla*, Veery *Catharus fuscescens*, Red-eyed Vireo *Vireo olivaceus*, Eastern Wood Pewee *Contopus sordidulus*, Scarlet Tanager *Piranga olivacea*, and Chipping Sparrow *Spizella passerina*.

Patterned after the British Constant Effort Sites Scheme, MAPS uses constant-effort mist netting and banding in large plots of homogenous habitat. The six stations in the park were located in forest cover types that were most representative of park-wide forest structure and species composition at mid to upper elevations. Each station represents an area of approximately 20 ha (50 A) including a core area of 9 ha (22 A), each containing an array of 16 permanent net lanes. Methods for conducting MAPS in the park follows the *MAPS Manual: Instructions for the Establishment and Operation of Stations as part of the Monitoring Avian Productivity and Survivorship Program* by The Institute for Bird Populations.

Analyses of MAPS data from the continent-wide network of stations during the preliminary years of the program (1989-91) identified a group of target species in each major geographic region that could be expected to be captured in numbers sufficient to calculate valid population indices. Determinations of pooled productivity indices for each species and for all species combined were made by the percentage

Table 25. Common and scientific names of birds in descending order of abundance, Great Smoky Mountains National Park, Tennessee and North Carolina, 1998.

Common name	Scientific name	Observed abundance
Ovenbird	*Seirurs aurocapillus*	6091
Red-eyed Vireo	*Vireo olivaceus*	5659
Black-throated Green Warbler	*Dendroica virens*	5065
Dark-eyed Junco	*Junco hyemalis*	3363
Black-throated Blue Warbler	*Dendroica caerulescens*	2524
Solitary Vireo	*Vireo solitarius*	2277
Hooded Warbler	*Wilsonia citrina*	2227
Scarlet Tanager	*Piranga olivacea*	2203
Winter Wren	*Troglodytes troglodytes*	2026
American Crow	*Corvus brachyrhynchos*	1958
Veery	*Catharus fuscescens*	1743
Black-and-white Warbler	*Mniotilta varia*	1741
Pileated Woodpecker	*Dryocopus pileatus*	1256
Indigo Bunting	*Passerina cyane*	1177
Tufted Titmouse	*Parus bicolor*	1173
Rufous-sided Towhee	*Pipilo erythrophthalmus*	1121
Golden-crowned Kinglet	*Regulus satrapa*	968
Acadian Flycatcher	*Empidonax virescens*	947
Northern Parula	*Parula americana*	926
Wood Thrush	*Hylocichla mustelina*	860
Chestnut-sided Warbler	*Dendroica pensylvanica*	852
Worm-eating Warbler	*Helmitheros vermivorus*	827
Red-breasted Nuthatch	*Sitta canadensis*	785
Blue Jay	*Cyanocitta cristata*	721
Black-capped Chickadee	*Parus atricapillus*	613
Carolina Chickadee	*Parus carolinensis*	513
Canada Warbler	*Wilsonia canadensis*	509
Brown Creeper	*Certhia americana*	492
Yellow-throated Warbler	*Dendroica dominica*	470
Chimney Swift	*Chaetura pelagica*	430
Blackburnian Warbler	*Dendroica fusca*	393
Hairy Woodpecker	*Picoides villosus*	360
White-breasted Nuthatch	*Sitta carolinensis*	327
Eastern Wood-pewee	*Contopus virens*	317
Rose-breasted Grosbeak	*Pheucticus ludovicianus*	286
Carolina Wren	*Thyrothorus ludovicianus*	207
Great Crested Flycatcher	*Myiarchus crinitus*	174
American Goldfinch	*Carduelis tristis*	136
Downy Woodpecker	*Picoides pubescens*	135
American Robin	*Turdus migratorius*	135

Table 25 cont'd

Common nam	Scientific name	Observed abundance
Yellow-billed Cuckoo	*Coccyzus americanus*	123
Blue-gray Gnatcatcher	*Polioptila caerulea*	122
Northern Cardinal	*Cardinalis cardinalis*	122
Red-bellied Woodpecker	*Melanerpes carolinus*	116
Cedar Waxwing	*Bombycilla cedrorum*	111
Gray Catbird	*Dumetella carolinensis*	110
Northern Flicker	*Colaptes auratus*	106
Louisiana Waterthrush	*Seiurus motacilla*	104
Common Raven	*Corvus corax*	101
Pine Warbler	*Dendroica pinus*	96
Mourning Dove	*Zenaida macroura*	92
Pine Siskin	*Carduelis pinus*	82
Broad-winged Hawk	*Buteo platypterus*	76
Ruby-throated Hummingbird	*Archilochus colubris*	70
American Redstart	*Setophaga ruticilla*	59
Yellow-throated Vireo	*Vireo flavifrons*	56
Chipping Sparrow	*Spizella passerina*	47
Barred Owl	*Strix varia*	46
Song Sparrow	*Melospiza melodia*	45
Red-winged Blackbird	*Agelaius phoeniceus*	44
Ruffed Grouse	*Bonasa umbellus*	39
Eastern Phoebe	*Sayornis phoebe*	36
Brown Thrasher	*Toxostoma rufum*	26
Wild Turkey	*Meleagris gallopavo*	26
Eastern Meadowlark	*Sturnella magna*	24
Swainson's Thrush	*Catharus ustulatus*	23
Swainson's Warbler	*Limnothlypis swainsonii*	22
Brown-headed Cowbird	*Molothrus ater*	20
Black-billed Cuckoo	*Coccyzus americanus*	20
Yellow-breasted Chat	*Icteria virens*	18
Red Crossbill	*Loxia curvirostra*	17
Least Flycatcher	*Empidonax minimus*	15
Belted Kingfisher	*Ceryle alcyon*	13
Common Grackle	*Quiscalus quiscula*	13
Barn Swallow	*Hirundo rustica*	10
Field Sparrow	*Spizella pusilla*	10
Eastern Bluebird	*Sialia sialis*	9
Purple Finch	*Carpodacus purpureus*	8
Eastern Screech-owl	*Otus asio*	7
Yellow Warbler	*Dendroica petechia*	7

Table 25 cont'd

Common name	Scientific name	Observed abundance
Common Yellowthroat	*Geothlypis trichas*	6
Eastern Kingbird	*Tyrannus tyrannus*	5
Blue Grosbeak	*Guiraca caerulea*	5
Olive-sided Flycatcher	*Contopus borealis*	5
Red-shouldered Hawk	*Buteo lineatus*	5
Red-headed Woodpecker	*Melanerpes erythrocephalus*	5
White-throated Sparrow	*Zonotrichia albicollis*	5
Yellow-bellied Sapsucker	*Sphyrapicus varius*	5
Canada Goose	*Branta canadensis*	4
Red-tailed Hawk	*Buteo jamaicensis*	4
Cerulean Warbler	*Dendroica cerulea*	3
Green-backed Heron	*Butorides striatus*	3
Hermit Thrush	*Catharus guttatus*	3
Kentucky Warbler	*Oporornis formosus*	3
Summer Tanager	*Piranga rubra*	3
Golden-winged Warbler	*Vermivora chrysoptera*	2
Rough-winged Swallow	*Stelgidopteryx serripennis*	2
Turkey Vulture	*Cathartes aura*	2
White-eyed Vireo	*Vireo gilvus*	2
American Kestrael	*Falco sparverius*	1
Cooper's Hawk	*Accipiter cooperii*	1
European Starling	*Sturnus vulgaris*	1
Great Blue Heron	*Ardea herodias*	1
House Wren	*Troglodytes aedon*	1
Killdeer	*Charadrius vociferus*	1
Ruby-crowned Kinglet	*Regulus calendula*	1
Magnolia Warbler	*Dendroica magnolia*	1
Northern Bobwhite	*Colinus virginianus*	1
Peregrine Falcon	*Falco peregrinus*	1
Prairie Warbler	*Dendroica discolor*	1
Sharp-shinned Hawk	*Accipiter striatus*	1
Saw-whet Owl	*Aegolius funereus*	1

of young in the catch. The annual survival and recapture probabilities were estimated of 15 common breeding species in the park (Veery, Wood Thrush, Gray Catbird *Dumetella carolinensis*, Blue-headed Vireo, Red-eyed Vireo, Chestnut-sided Warbler *Dendroica pensylvanica*, Black-and-white Warbler *Mniotilta varia*, Worm-eating Warbler Helmitheros *vermivorus*, Hooded Warbler *Wilsonia citrina*, Ovenbird, American Redstart, Scarlet Tanager, Indigo Bunting, and Eastern Towhee) for which an average of eight adult captures per year were recorded from all six stations combined during 6 years (1993-98).

To date, MAPS captured and banded 6674 birds representing 66 species. A total of 1931 previously banded birds were recaptured and an additional 332 birds were either released or escaped unbanded. Most of the unbanded birds were Ruby-throated Hummingbirds *Archilochus colubris* and other non-target species that require band sizes outside of the range authorized for the program. The most abundant species in 1998 from all six of the stations combined as determined by the number of adults per 600 net hours in decreasing order were: American Redstart, Veery, Ovenbird, Dark-eyed Junco *Junco hyemalis*, Red-eyed Vireo, Hooded Warbler, Eastern Towhee, and Wood Thrush. This ranking remains similar but not identical from year to year, which suggests the composition of breeding bird communities in the park tends to be relatively stable.

In contrast to declining range-wide population size trends among Neotropical migratory birds, population sizes of several species in the park including the Veery, Wood Thrush, Solitary Vireo *Vireo solitarius*, American Redstart, Worm-eating Warbler, Ovenbird, Hooded Warbler, and Canada Warbler *Wilsonia canadensis* increased substantially after 1993. Most of these species are either ground or shrub nesting forest species that favor the dense understory vegetation of the ridgetop forest community after peak canopy defoliation by the gypsy moth (1989-93). These increases were interrupted in 1997 and 1998 by significant decreases in productivity in summers 1996 and 1997 and the concomitant depression of adult population sizes in 1998.

Populations of many adult birds in the park increased consistently between 1993 and 1996 (Fig. 49) and then decreased from 1996 to 1998. Productivity patterns were directly inverse of adult populations, generally decreasing between 1993 and 1996 and increasing between 1996 and 1998. The opposing trends between population size and productivity have been observed at many MAPS stations and suggest that increased breeding success leads to higher recruitment, which is then followed by lower reproductive success. These patterns are generally influenced by meteorological and phenological conditions. The

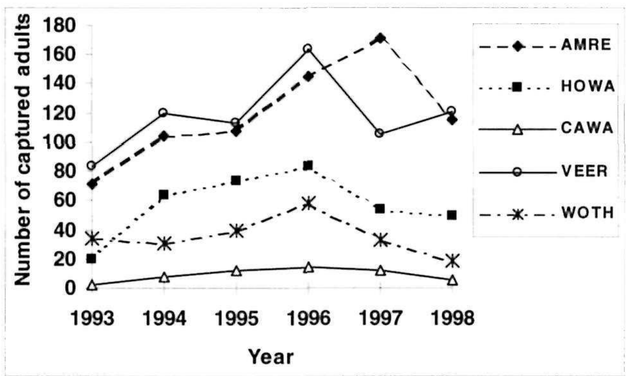

Figure 49. Number of individuals of five common bird species captured in mist nets, Shenandoah National Park, 1998. AMRE = American Redstart; HOWA = Hooded Warbler; CAWA = Canada Warbler; VEER = Veery; WOTH = Wood Trush.

productivity crash of 1996 was attributed to cool, wet conditions that coincided with the peak of the nesting season from mid-May to late June.

In contrast, adult population sizes of the Dark-eyed Junco and Indigo Bunting declined during the same 6-year period. The abundance of the Dark-eyed Junco as indexed by the number of captured adults has steadily declined since 1993. The relative declines seem closely linked to productivity from the previous year. The reason for declining junco populations remains a mystery because these birds tend to be shadow-loving ground nesters. However, the large populations of juncos and buntings after defoliation by the gypsy moth during 1989-93 may have declined to more typical levels. All species considered, bird population dynamics in the park have become fairly consistent, which suggests the habitat is beginning to stabilize after the gypsy moth. A strong correlation is emerging between adult population sizes and the productivity in the preceding year in many bird species.

Data from 6 years of monitoring suggest that MAPS provides reliable annual indices, estimates, and long-term trend of adult population size, productivity, and survivorship of many species in the park. Additionally, MAPS data from the park are invaluable to region-wide estimates of population size, productivity, and survivorship in land birds of eastern North America.

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Black Bears

The black bear *Ursus americanus* is the largest remaining native carnivore and a critical organism of the ecological communities in Shenandoah National Park. The bear populations increased from rare occurrences in the late 1930s to one of the highest reported densities (300 bears or about 1 bear/2.6 km^2 [1 bear/mi^2]) in North America during the 1980s. The increase was attributed to the maturation of the park's hardwood forest to mast-producing age, to the availability of corn, apples, and other agricultural crops along the boundary, and to the protection of the bears from hunting in the park. The popularity of bears as game and as a popular viewing species but also their damage to personal property and agricultural crops place a high priority on monitoring bear populations in the park. However, budgetary constraints had precluded monitoring of the bears since 1994.

In 1998, a revision of the protocol for monitoring bears with bait stations was initiated. The park's geographic information system was used to relocate bait stations for meeting new standards established by a 1994 peer review and the addition of three new transects. The GIS component and the printing of field maps for each transect was completed in December. Geo-referencing of each station and tree-tag installation will begin during spring 1999.

VIRGIN ISLANDS-SOUTHERN FLORIDA CLUSTER
TROPICAL-SUBTROPICAL BIOME

Cluster I&M Coordinator
vacant position

Contributors:
Z. Hillis-Starr and B. Phillips, coral reef communities and sea turtles

Coral Reefs in Buck Island Reef National Monument

Monitoring of coral reefs in Buck Island Reef National Monument began in the late 1970s to collect information on coral ecology, geology, and reef fishes. Studies have been concentrated on all major reef habitats along the southeastern and northeastern barrier reef: shoreline reef, lagoon, backreef, reef crest, and forereef seaward to the haystack formations.

From 1988 to 1991, 15 sampling sites were established along five cross-reef transects to monitor the population dynamics of the three most common coral species *Diploria strigosa, Montastrea annularis,* and *Porites astreoides* and in three linear chain transect sites to monitor the benthic community and the population dynamics of elkhorn coral *Acropora palmata*, to visually census fishes, and to determine the barrier reef formation and age of the underlying marine geology. The National Park Service and the U.S. Geological Survey are now updating the monitoring methods and evaluating the addition of sampling sites.

Effects of Hurricanes on the Coral Reef Community

Since the beginning of monitoring in the monument, Hurricane Hugo struck the Virgin Islands in 1989, Hurricanes Luis and Marilyn in 1995, and Hurricane George in 1998. The damage to coral reefs was more moderate by Hurricane George than by the other hurricanes. Nevertheless, tagged coral colonies evidenced impact scars or were tumbled. Branches of 5-8 year old of elkhorn coral recruits were severed. The severed branches may re-establish themselves on the dead reef structure. Damage was low on the recruitment site on the southern side of the shallow forereef slope. This slope has been the most severely damaged by all three hurricanes. However, species richness and cover have increased in the open spaces that the hurricanes created.

Bleaching

In 1988, 12 sampling sites were established in 350 coral colonies of three species. Coral colonies in each site were tagged and have been sampled routinely there since then. After significant natural events such as hurricanes or coral bleaching, the status of each coral colony (health, storm damage, extent of bleaching, fish bite damage, evidence of disease, etc.) is recorded, the tags are checked and if necessary replaced, and all colonies are photographed. A full set of vertical and panoramic photographs of the tagged coral colonies is now archived. Underwater 4-x-6 color images of colonies are talen and laminated. The laminated pictures can be taken underwater to identify specific colonies. Maps of each tag site have been unfailingly used to locate the coral colonies for monitoring. During bleaching in Sep-Nov 1998, the water temperature in several sites reached 30° C (Fig. 50 on next page). Two of the three species of tagged corals, *D. strigosa* and *M. annularis*, throughout the monument were bleached. In one site on the backreef, 15 of the 28 *D. strigosa* heads sustained some bleaching.

> Coral Bleaching
>
> Corals turn white when they lose their symbiotic algae, Zooxanthellae. Zooxanthellae live inside the soft transparent tissue of their host coral. They are photosynthetic and provide nourishment to their host—the coral. Bleaching has been attributed to environmental stresses. Mass bleaching has almost always followed extended periods of high temperature, low wind, low cloudiness, and low rainfall. High temperatures are thought to be the most probable cause of bleaching. However, disease, oxygen toxicity, high ultraviolet light exposure, and pollution are also potential causes. Bleaching has taken place in shallow and in deep coral areas and has positively and negatively correlated with El Niño's influences.

Future Monitoring

Biologists of the U.S. Geological Survey in Virgin Islands National Park are evaluating the AquaMap™ underwater tracking system for monitoring coral reefs. The system includes software that can choose random points in a predetermined grid and guide the diver to that location. Tests are being conducted to

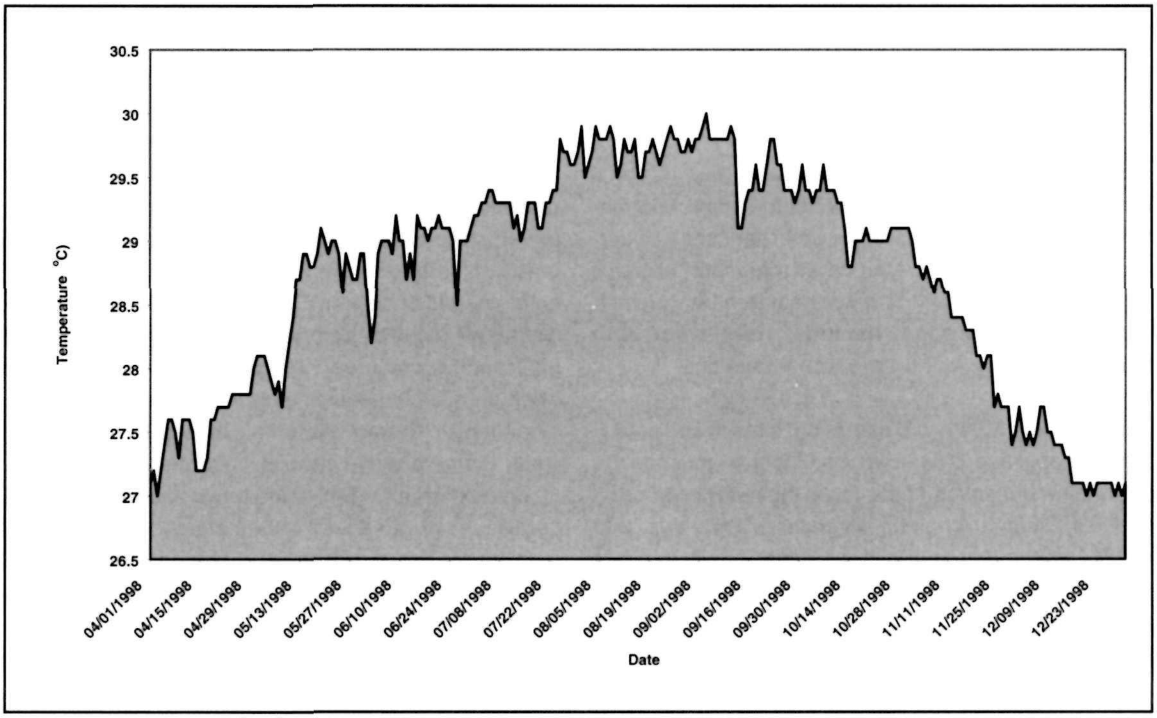

Figure 50. Water temperature (°C) on coral reefs during bleaching, Buck Island Reef National Monument, Sep-Nov 1998.

determine whether this sonar technology, which uses underwater baseline stations and a mobile station that the diver carries, facilitates reliable and repeatable navigation to a specific point. Monument staff continues to test better ways to document the condition of coral colonies over time and during unusual events. Video monitoring is useful for documenting the condition of reefs when time and personnel are limited. Replacement of the transect marker pins during Fiscal Year 1999 is planned.

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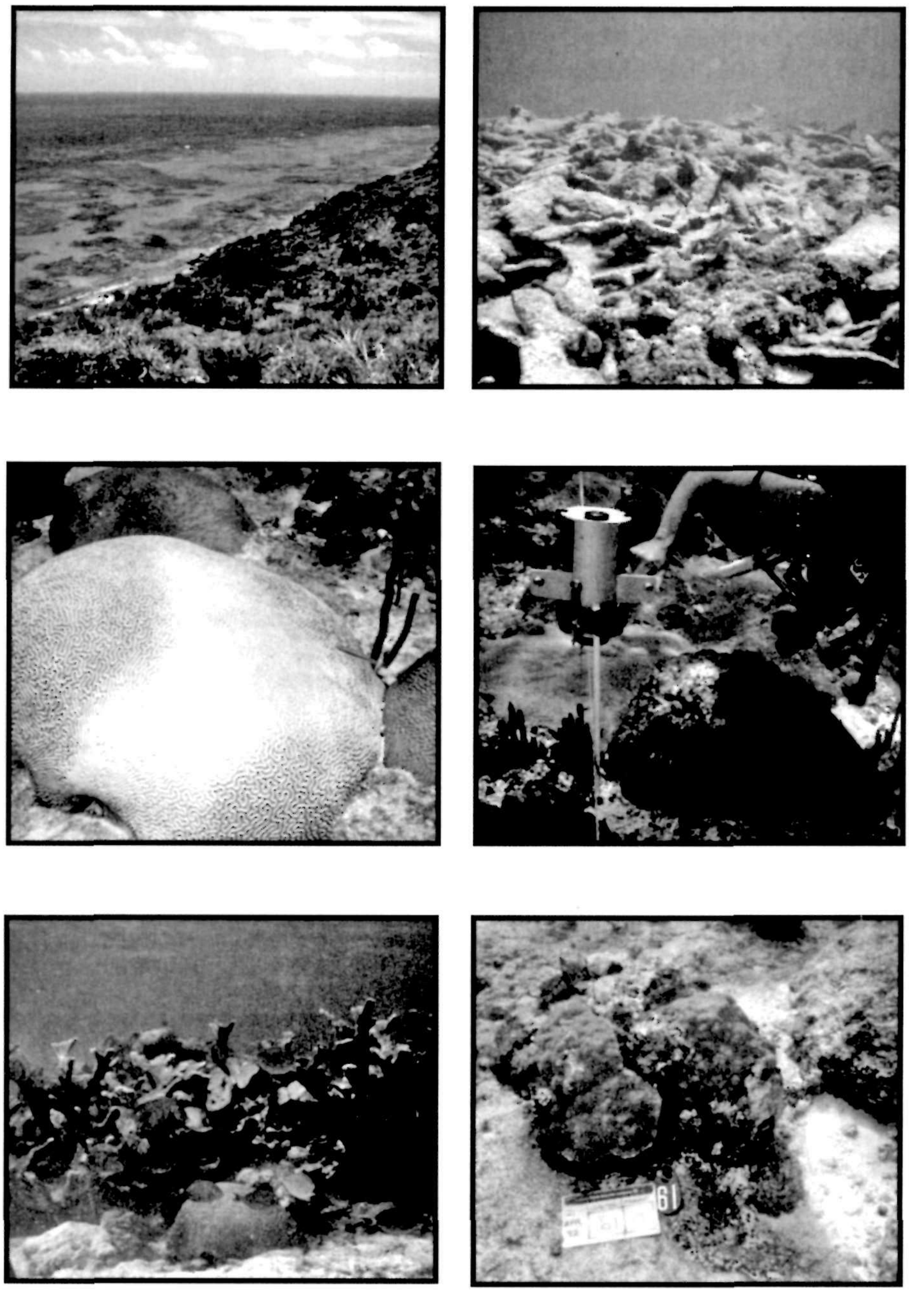


Clockwise from top left: Reef system off Buck Island Reef National Monument; elkhorn reef crest (photograph by J. Bythell); underwater sampling with a video camera; tagged *Porites asteroides;* blue tangs on elkhorn coral reef (photograph by Z. Hillis); bleached *Diplora strigosa.*

Sea Turtles in Buck Island Reef National Monument

Nesting Sea Turtles

In 1987, Buck Island standardized the protocol for collecting information on sea turtles. At first, beaches were patrolled on foot 2-3 times/week but only during daytime, and all sea turtle activities were recorded on standardized data sheets. Beginning in 1988, the beaches were also patrolled at night. Since then, nesting is recorded and nests are excavated during daytime from January to June and from October to December. Nesting is defined as any attempt to nest and consists of selecting the nest site and digging a cavity. If the female deposits a clutch into the cavity, she covers the eggs with the excavated substrate. During the peak of the nesting season of the hawksbills *Eretmochelys imbricata* in July-September, the beaches are patrolled every night.

Information is collected on tagged and untagged nesting females, nesting, site selection and fidelity, migration intervals (in and between seasons), fecundity (number of clutches, egg size and weight), growth, weight, hatchlings (weight, size, number of scutes), and hatch success. Every effort is made to prevent impairment of hatch success. Eggs are relocated if they are threatened by inundating seawater, erosion, desiccation, recreation, or predation. All clutches are monitored until hatching, at which time the nest is excavated to determine the extent of the hatch success and emergence success.

In 1998, 356 nesting attempts and 127 completed nests of all species of sea turtles were observed on 1.5 km (0.9 mi) of nesting beach in Buck Island Reef National Monument. Twenty-seven hawksbills were identified (16 returned migrants, 11 untagged individuals; Tables 26 and 27). Stormy seas from the hurricane buried two nests of hawksbills and 12 nests of green sea turtles *Chelonia mydas* with huge amounts of sand (Table 28). None of the eggs in these nests hatched. A tropical depression in November inundated or washed out 3 nests of hawksbills and 1 nest of a green sea turtle in an area with heavy run-off.

Nine green sea turtles were sighted (Tables 29 and 30). This number exceeds the number of previously sighted green sea turtles in the monument, which had been no larger than three in any given year. Four of the 9 turtles were tagged returned migrants, 4 were recruits to the nesting population, and 1 was a turtle that had been tagged on an eastern beach of St. Croix and had come ashore on Buck Island Reef but did not nest (Fig. 51 on page 135).

> Nests are excavated to determine percent hatch success and emergence success. *Hatch success* is the number of hatchlings that leaves the egg shells. *Emergence success* is the number of hatchlings that actually emerge from the nests. During excavations, nest contents are removed from each nest and sorted into groups of live-trapped hatchlings, dead hatchlings, shells from hatched eggs, pipped eggshells (the hatchling partially broke through the shell but then died), and unhatched eggs. Each group is counted and recorded, so that hatch success and emergence success can be estimated.
>
> Hatch Success = (number of hatched shells ÷ total number of incubated eggs) x 100. Emergence Success = ([number of hatched shells - number of live trapped - number of dead hatchlings] ÷ number of incubated eggs) x 100.

Table 26. Characteristics of nesting hawksbills, Buck Island Reef National Monument, 1998. CCL=curved carapace length, CCW= curved caraapce width.

Characteristic	*N*	Mean	Range
CCL (cm)	26	90	80-97
CCW (cm)	26	80	68-86
Weight ($\pm$ 2 kg)	24	67	50-84
Migration interval (years)	16	2	2-6
Number of clutches/female	27	2	1-4
Clutch size number of eggs)	84	150	83-215
Hatch success of in situ clutches (%)	54	70.1	0-100
Emergence of in situ clutches (%)	54	67.6	0-98.0
Hatch success of re-located clutches (%)	23	53.7	0-90.0
Emergence of re-located clutches (%)	23	43.6	0-90.9

Table 27. Nesting attempts and distribution by month and beach and destruction of nest by type, month, and beach in green sea turtles, Buck Island Reef National Monument, 1998.

Month	Numbeer of nesting attempts	Distribution by beach (%)	Destruction by type in all months combined	
Jul	70	NS 32	Buried by sand	14
Aug	89	WB 21	Washed out	4
Sep	76	SS 31	Predated by rats	1
Oct	49	TB 16	Unknown	2

NS = North shore SS = South shore WB = West beach
TB = Turtle bay

Table 28. Nesting distribution by month and beach and destruction of nest type in a species of sea turtles, Buck Island Reef National Monument, Virgin Islands, 1998.

	Number of				
Species	Recorded nesting activities	Confirmed deposition of Eggs	Suspected establishment of nests	Nesting without deposition of eggs	Other[a]
Hawksbills	288	91	30	158	2 dead 7 swimming
Green sea turtles	66	31	1	32	2 swimming
Leatherbacks	1	0	1	0	none

[a]The database by the National Marine Fisheries Service listed two female hawksbills as having been captured and dead One of the females was captured in Cayo Guayama, Nuevitas, Cuba, and the other was captured at the Southeast Rock in the Miskito Cays, Nicaragua. Nine females swam along the shoreline but did not come ashore.

Table 29. Characteristics of nesting green sea turtles Buck Island Reef National Monument, 1998. CCL=curved carapace length, CCW = curved carapace width.

Characteristic	*N*	Mean	Range
CCL (cm)	8	108.6	103.0-118.2
CCW (cm)	7	102.8	96.1-109.4
Migration interval (years)	4	2	1-4
Number of clutches/female	8	3	1-5
Clutch size (number of eggs)	19	112	77-150
Hatch success of in situ clutches (%)	10	64.5	0-97.5
Emergence of in situ clutches (%)	10	59.6	0-96.7
Hatch success of re-located clutches (%)	11	31.7	0-77.9
Emergence of re-located clutches (%)	11	29.5	0-77.9

Table 30. Number of juvenile hawksbills by size class, average carapace length (CCL), and weight, Buck Island Reef National Monument, 1998.

Size class (cm)	Number	Average CCL (cm)	Average weight (kg)
20-30	7	27.1	1.93
30-40	25	35.3	4.96
40-50	14	45.9	9.82
50-60	18	55.3	17.58
60-70	9	64.6	27.83
70-80	3	73.9	41.0

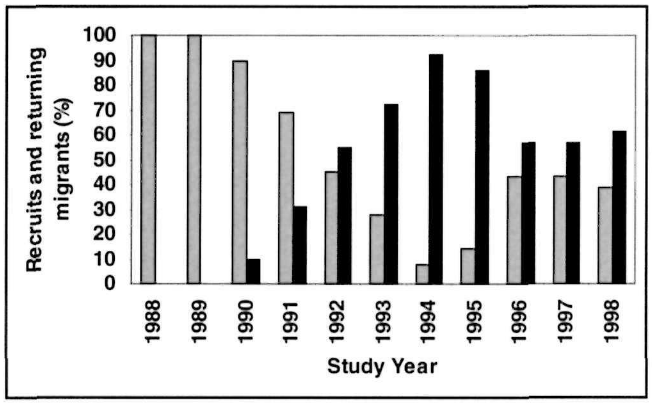


Figure 51. Number of recruits (gray) and returning migrant nesting hawksbills, Buck Island Reef National Monument, 1988-1998.

Juvenile Sea Turtles

When sighted, 37.5% of the turtles were swimming, 35.9% were resting on reefs, 20.8% were feeding, 4.7% were surfacing to breathe, and 1.1% (2 green sea turtles) were mating. The longest known residency to date was 46 months by two turtles. The male was tagged in September 1994 when his curved carapace length (CCL) was 64.6 cm (25.4 in.) and his weight 27 kg (59.5 lbs). In 1998, he was 72 cm (28.4 in.) CCL and weighed 39 kg (86 lbs). The female was tagged in October 1994 when she was 35.5 cm (14.0 in.) CCL and weighed 4 kg (8.8 lbs). In 1997, she was 49.6 cm (19.5 in.) CCL and weighed 12.5 kg (27.5 lbs).

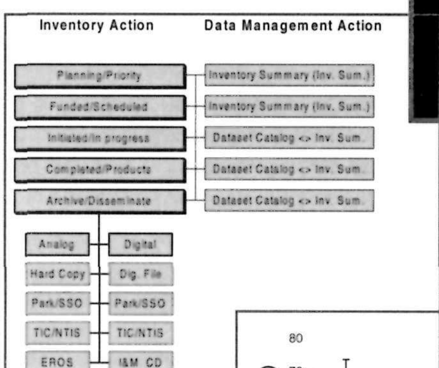
In 1998, the number of tagged juvenile hawksbills reached 76 (Table 30). During snorkel surveys in 1998, 182 juvenile hawksbills and 10 juvenile green sea turtles were sighted. Thirty-six juvenile hawksbills were captured for data collection. Eighteen of them had previously been tagged in the monument. The remaining 18 were tagged. Many of the 36 individuals were recaptured during the year. The genetic analyses of juvenile hawksbills tagged in the monument reached 60 in 1998. The population includes genetic lineage from Antigua, Belize, Cuba, Mexico, Puerto Rico, the U.S. Virgin Islands, and other eastern Atlantic populations.

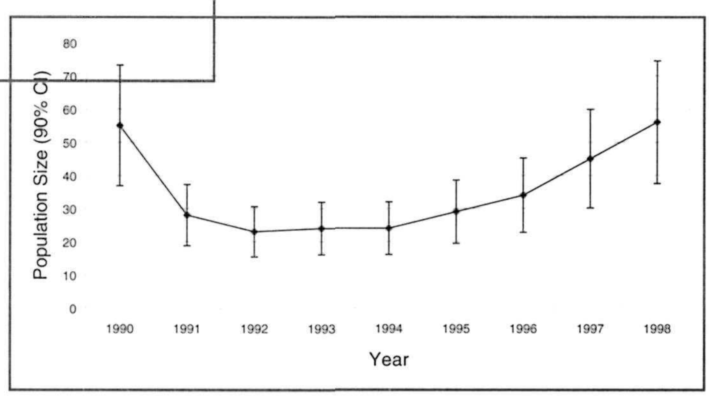
Future Monitoring

In 1998, a draft protocol for the monitoring of nesting sea turtles in Buck Island Reef National Monument was submitted for peer review. Monitoring of sea turtles in the monument will be continued throughout the year to provide data toward the species recovery in the Carribbean. When recovery goals are met, the sea turtles on Buck Island Reef will be monitored in a less intense manner to identify population changes.

Graduate student from the Virginia Institute of Marine Science releasing a radio-tagged juvenile hawksbill, Buck Island Reef National Monument.

Data Management in the I&M Program





Section cover. The Information Management Specialist of the I&M Program. *Photograph by E. Rockwell.*

The Inventory and Monitoring Program manages information from several natural resource inventories and therefore must develop policies, standards, and software to document and describe the collected data, to exchange and distribute data with others inside and outside the National Park Service, and to archive and store data for ready access. Because many of the natural resource inventory data are spatial, the I&M and GIS programs and others are jointly developing standards and guidelines to deliver natural resource data systems and to acquire the hardware, software, and technical expertise for maintaining the data and making them available to users and cooperators.

The goals of data management by the I&M Program are the development and implementation of multilevel strategies for planning, integrating, and preserving natural resource data for present and long-term information needs in National Park Service management. The program is approaching this goal in several ways: Central office staff is (1) assisting parks with developing uniform data management protocols and tools, (2) developing service-wide I&M data management and data archiving capabilities (3) implementing user-friendly GIS and database systems for the I&M natural resource inventories, and (4) providing up-to-date information about the I&M Program activities and accomplishments on the World Wide Web.

Assistance to Parks

Data Management Protocols

Data Management Protocols was drafted in 1996 and 1997 with assistance from data managers in National Park System (NPS) units. The document features instructions for developing data management plans, database structures and software for cataloging active and legacy data sets (Dataset Catalog), and generalized data handling procedures for park-based and central office data sets. The first chapter addresses the current status of resources, goals, implementation, and budget for developing a park-specific data management plan. The second chapter documents the Dataset Catalog. The catalog is a database of natural resource data sets that incorporates abbreviated metadata for general use. The database is NPS-unit-specific but can be aggregated for service-wide needs. The original database was developed in Microsoft Access but was adapted into an intranet system that is accessible over the World Wide Web. Both systems include an automated data input form, links to other data and information, and a one-page report. The final chapter of the protocols document describes general guidelines for managing natural resource data sets. The procedures cover tasks such as data entry, verification, validation, backup, and editing as well as more complex tasks such as documentation, archiving, and dissemination of data.

The draft *Data Management Protocols* is presently under review by park data managers and I&M coordinators. It was presented in the I&M Training course in 1996, 1997, and 1998. About 100 copies of the draft have been given to various National Park Service staff, and a version is available for review on the World Wide Web (http://www1.nature.nps.gov/im/dmproto/joe40001.htm). The final document will be disseminated to NPS units and made available on the I&M web site. Copies of the draft protocols and the Dataset Catalog software are available by request.

Data Management Tools for Park Use - New ArcView Data Browser for I&M GIS Data

NPS GIS developers from the Alaska Support Office, WASO Cultural Resources and the Natural Resource Program Center met with a representative of the Environmental Systems Research Institute in Fort Collins, Colorado, in February. The purpose of the workshop was to share recent work with ArcView and other GIS development and to advise the I&M Program about developing I&M GIS data and applications. The participants demonstrated and discussed the Air Quality Information Management System (AQUIMS), the Alaska GIS Data Browser and tools, the Cultural Resources MAPIT GIS interface, and the GIS data themes acquired by the I&M Program. The group discussed and initiated a proposal for NPS-wide acquisition of ESRI GIS products, including substantial new licenses for ArcView and Map Objects. The group also discussed adoption of AQUIMS as a standard interface for other applications. The participants recommended and assisted with development of a standard data structure for the I&M GIS data. Other recommendations included the systematic structuring and reformatting of I&M GIS data for delivery on CD-ROM, development of an I&M data browser for I&M GIS products, and acquisition of a GIS specialist to perform these tasks. After the meeting, the Alaska Support Office staff modified the Alaska Data Browser for more generalized use in the National Park Service. I&M staff are continuing development of the ArcView Data Browser and have developed working examples for Tallgrass Prairie National Preserve, Craters of the Moon National Monument, and Black Canyon of the Gunnison National Monument/Curecanti National Recreation Area (geology only). These pilot projects are providing valuable GIS applications that can be modularized, adapted, and enhanced for all NPS units.

Archiving of I&M Data

After several years of funding and initiating many service-wide inventories, the I&M Program is experiencing a significant and rising flow of data that must be managed and archived to protect the products and the investment in the program. I&M staff have been implementing a plan to provide near- and long-term management and archiving of inventory and monitoring data to best meet the needs of parks, the I&M Program, and the National Park Service in general. The plan includes data acquisition, handling, conversion, and storage in the central office of the I&M Program and the Natural Resource Information Division in Fort Collins, Colorado, and distribution to other NPS units. Acquisition of new equipment has facilitated recording digital inventory data on CD-ROM; scanning and digitizing maps, images, and aerial photographs (still in work); serving and maintaining service-wide databases that are critical to the I&M Program; and timely providing of data and archived products to parks and other cooperators. With the archiving facility substantially in place and functional, the increased database, GIS, and graphical capabilities will allow greater utility and synthesis of I&M data for more efficient resource and program management. Most of the work is being done with the assistance from student employees from the Colorado State University under supervision of the I&M Information Manager. During 1998, the I&M Program acquired two new workstation class computers with supporting software and hardware, one Internet server with Lotus Notes/Domino software, and other hardware and software upgrades. Four student assistants were phased in as technical resources were acquired and inventory projects initiated.

Archiving and data formats are coordinated with other National Park Service and Department of the Interior programs. Data are archived on CD-ROM and stored in-house at the central office. Copies of the data are also supplied to the Technical Information Center in Denver, Colorado, various field technical support centers throughout the country, and relevant NPS units. This combination of offsite and multiple-site archiving ensures the integrity of I&M data products and is discussed in more detail below.

Role of the Technical Information Center

The Technical Information Center (TIC) of the National Park Service in Lakewood, Colorado, provides a microfilm storage and computerized information system to manage technical information and products for the service. It has been designated by the service as the central repository for many drawings, graphics, documents, and technical reports. The I&M Program identified TIC as the main repository for inventory data and has been working with the center to coordinate data flow and to formulate an archiving policy. Coordination with TIC is critical to avoid duplication of effort and to minimize the effects of limited budgets, personnel, and technical resources. For archiving and subsequent access of digital products, the I&M Program will provide digital data to TIC on CD-ROM media. TIC and the I&M Program will coordinate data formats and other technical issues to provide long-term compatibility and access to inventory data. TIC will handle external requests for archived natural resource inventory data, and the I&M Program will duplicate data for internal NPS users.

TIC and the I&M Program are developing on-line Internet data services for distributed access to catalogs and information with the Lotus Notes/Domino server platform. These applications will allow remote access to selected data and will track information for

National Park System units. Cooperative application projects that are targeted for on-line service by the I&M Program and TIC are the Dataset Catalog (for cataloging natural resource data sets) and baseline water quality reports (WWW browsing and searching, hard copies at TIC).

Role of the Field Technical Support Centers

The roles of field technical support centers are the establishment and support of a GIS program in all NPS units. The centers coordinate GIS among NPS units and the service-wide program; provide technical support to parks; and receive, disseminate, and implement basic cartographic products. GIS support is also obtained by cooperative agreements with universities such as the Pennsylvania State University, North Carolina State University, Northern Arizona University, University of Wisconsin-Madison, and University of New Mexico. FTSCs coordinate local support partnerships and broker spatial data and information for the NPS units.

The field technical support centers facilitate the use and development of GIS throughout the system. The GIS Program and the field technical support centers are cooperating with the I&M Program to deliver all newly acquired digital cartographic data to the national office for duplicating, distributing, and archiving. The I&M Program has recently validated data records in the NPS Quadrangles (Quads) database with assistance from the field technical support centers. In addition, the I&M Program has adapted the quads database to document the acquisition of base cartographic products (i.e., the Quad Products database). For efficient data archiving and retrieval, acquired base cartography is copied or duplicated to CD-ROM for storage at TIC before being disseminated to the centers and NPS units for implementation. Similarly, the I&M Program is coordinating with the centers and parks to catalog and archive existing data. In addition, the I&M Program plans to convert, archive, and disseminate the basic GIS data layers routinely produced in its natural resource inventories. The I&M Program will continue to coordinate data formats and other technical issues with the NPS GIS community to provide long-term compatibility and access to base cartographic data. The service-wide GIS Program and field technical support centers are cooperating with I&M staff on the development of a GIS data browser as previously discussed.

Service-wide Management of Inventory Data

The I&M Program manages several baseline inventories of natural resource data. The goal is to provide resource managers with baseline data as a basis for more in-depth studies. Timely access to resource data is often critical for decisions in resource management, and the inventories are designed to provide data that improve management. In general, each inventory consists of several steps from planning to archiving the completed products (Fig. 52). The final step is the archiving of data in a process similar to that illustrated. Along with each inventory action, each project must be tracked by a data management action. The Inventory Summary table lets managers quickly view the status of each inventory by NPS region and unit. The Dataset Catalog provides a brief metadata record of each inventory project that can be updated as the inventory and archiving are completed. To date, more than 2800 data sets have been acquired and cataloged by I&M staff.

Base Cartographic Data

The inventory of base cartogrtaphic data provides digital cartographic data, primarily digital elevation models (DEM), digital line graphs (DLG), digital raster graphics (DRG), and digital orthophoto quads (DOQ), for NPS units with significant natural resources.

Data Archiving

Digital products for the base cartographic inventory are purchased for NPS units and systematically provided to the I&M Program for duplicating, distributing, and archiving before they are given to the field technical service centers and the NPS unit. USGS quadrangles of interest to NPS units and available digital data are tracked with the NPS Quadrangles database. Acquired cartographic data products are tracked in the NPS Quad Products database and cata-

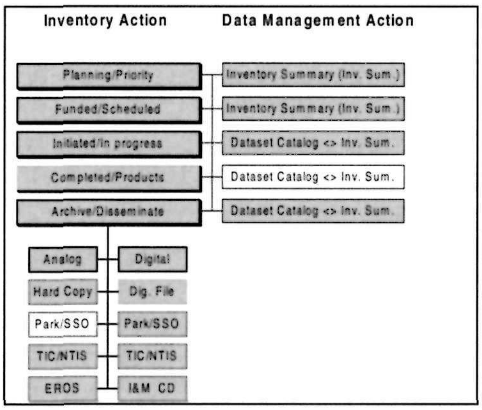


Figure 52. Natural resource inventory process.

loged in the I&M Dataset Catalog on WWW. On-line access to the tracking and product lists by parks, support offices, regions, and central offices still needs to be implemented to maximize the usefulness of the cartographic inventory. In addition, periodic updates of the tracking databases and archiving of long-term data are ongoing needs that must continually be addressed. A concerted effort to obtain and archive cartographic data that are already in the possession of parks and field technical support centers is a primary long-term inventory goal.

Baseline Water Quality Data

Drawing on existing Environmental Protection Agency (EPA) databases, particularly STORET, the national water quality database, *Baseline Water Quality Data Inventory and Analysis Reports* are being prepared for all units of the National Park System containing significant water resources. These reports provide a complete inventory of all water quality data; descriptive statistics and graphics characterizing annual, seasonal, and period-of-record central tendencies and trends; and comparisons of park data with relevant EPA national water quality criteria and NPS-75 "Level I" water quality parameters. The entire report (text, tables, and graphics) and all databases (water quality data; hydrography; and water quality station, water gage, facility discharge, drinking intake, and water impoundment locations) are being provided in both analog and digital format to encourage additional analysis and incorporation into park geographic information systems.

Relations with Data Standards and Programs

All known and available water quality data are assembled by NPS unit and uploaded into STORET before a report is produced. Also produced and maintained by the NPS Water Resources Division is a digital park boundary data set based on National Park Service land status maps or on GIS data obtained from the NPS unit. However, the Water Resources Division does not routinely provide GIS data with the reports. The GIS data are in Atlas GIS format and require conversion for import into more widely used GIS software such as ArcView. In addition, the archiving of published geologic maps with the Water Resources Division has been discussed to aid with ongoing and future water quality, geomorphology, hydrology, and groundwater studies.

Data Archiving

Analog and digital products are being produced, delivered, and archived by the NPS Water Resources Division. However, at present, the I&M Program is not systematically acquiring and archiving the associated GIS data. The I&M Program is coordinating with the Water Resources Division to acquire and convert the existing Atlas GIS data to ArcView format, archive the data on CD-ROM as part of a GIS data browser, and distribute them to the field technical support centers and NPS units. I&M staff are working on cataloging completed reports, data, and GIS coverage, but the full text of each report should be made available service-wide. On-line access to the report and data catalog by NPS units, regions, support offices, and central offices will maximize the usefulness of the data. Preliminary plans are being discussed to accomplish these goals.

Geologic Resource Data

Geologic Resource Bibliographies (GeoBib)

The GeoBib project is rolling-up individual park bibliographies and publishing the data on a secure intranet database system. Bibliographic searches of the Georef and Geoindex databases for each park were conducted by the U.S. Geological Survey and converted to Procite data files. On-going work is converting the Procite data for the intranet system, validating and editing the map citations, and preparing a geologic resources bibliography file and index map of associated geologic maps. When complete, the GeoBib database will contain about 100,000 references to geologic resource literature in an on-line database. Bibliographies for more than 50 parks have been validated, edited for duplicate map citations, and used to compile a list of park-associated geologic maps. Bibliographies for additional parks are also in progress. After validation and editing, geologic map citation lists are prepared for each park and used to develop index maps that show the footprint of associated geologic maps in relation to park unit boundaries.

Digital Geologic Map Coverages

A few agencies are digitizing geologic maps with conventional methods and with vectorization or heads-up digitization of scanned images. The National Park Service is evaluating these methods to allow versatile data acquisition. Scanning and heads-up digitization of geologic map masters have been successfully contracted in a pilot digitizing project of four geologic maps of Craters of the Moon National Monument by GIS personnel of the Columbia Cascades Support Office and the I&M Program. In addition, the I&M Program and the Geologic Resources Division have obtained conventional digitizing technology and will digitize some geologic maps in-house. I&M Program staff are developing a standard geology-GIS data model and GIS tools to facilitate uniform digital geologic map products.

Relations with Data Standards and Programs. The goal of producing digital geologic maps of each NPS unit at a 1:24 000 scale is compatible with similarly specified scales for base cartography, soils, and vegetation maps. However, suitable map scales are determined case-by-case for compatibility with existing products, specific needs of units, and available funds. The U.S. Geological Survey is digitizing some maps, but digitization of geologic maps of all NPS units cannot be accomplished without substantial in-house or contracted work by the I&M Program. Digital geologic data will be integrated into the GIS data browser with other spatial data produced by the natural resource inventories.

Data Archiving

Digital map data will be archived and distributed on CD-ROM. Tracking of geologic map data is done by creating digital index maps and entering the completed projects into the I&M Dataset Catalog and the NPS spatial metadata clearinghouse. Access to the geologic index map database by NPS units, support offices, regions, and central offices would maximize the usefulness of the data.

Species Information

NPSpecies System Model

The NPSpecies database model consists of a series of integrated records to allow NPS units to document the plants, animals, fossils, and other species and related observations that occur in park areas. The basic design of NPSpecies incorporates three levels of documentation for species occurrence (Fig. 53 on next page) and extensive help with standard nomenclature authorities, software assistance, and additional species references. The three levels of documentation include (1) species reference documents with systematic taxonomy, (2) park species records with voucher and abundance data, and (3) park observation records to document individual park observations. The final data model for the database will be determined by available import data, needs identified by resource staff and scientists, and access security for sensitive resources. The pilot NPSpecies database is being developed as a desktop PC database. Once fully developed, the database will be implemented via an intranet system model that will

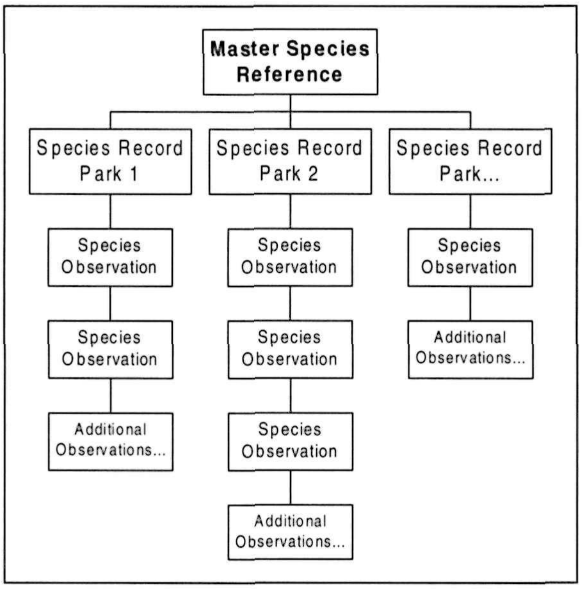


Figure 53. NPSpecies database organization.

allow distributed access to the database over the Internet while maintaining individualized access, input, and edit control for users.

Data Archiving

Before species lists can be archived, the NPFlora and NPFauna databases must be restructured and the data for each park verified and validated. Once incorporated into a standardized database system, dynamic updates of the data with routine system backup and archiving will be possible. WWW access to the data by all NPS units, offices, and cooperators will maximize the usefulness of the species information. In addition, a coordinated system with new inventory data input and long-term archiving will ensure data integrity.

I&M Internet Service

The World Wide Web home page of the Inventory and Monitoring Program (http://www.nature.nps.gov/im/index.html) links to the electronic copy of Natural Resource Inventory and Monitoring in National Parks brochure. The brochure features general information about the natural resource inventories and long-term environmental monitoring in the National Park Service. In addition, the I&M Program home page links to fact sheets, ecological monitoring information, the draft *Data Management Protocols*, and the two previous I&M Program annual reports. The publications web page of the Natural Resource Information Division (http://www.nature.nps.gov/pubs/facts/findex.htm) features links to fact sheets that describe the status of each inventory. The link to *Monitoring Natural Resources in Our National Parks* (http://www.nature.nps.gov/sfancy) provides information to parks for designing and implementing long-term monitoring of natural resources. The web site includes a database of monitoring protocols developed by parks that conduct prototype monitoring. The I&M web pages also contain links to partners and other National Park Service entities associated with inventory and monitoring. In addition to program information, I&M staff are planning to provide on-line access by the public to selected inventory data. Public access is already available to the Dataset Catalog (http://165.83.36.151/parksvc/dcat.nsf) and Geologic Bibliographies (GeoBib; http://165.83.36.151/biblios/geobib.nsf) databases discussed earlier.

THE I&M TRAINING PROGRAM

SECTION COVER: I&M TRAINING IN SHENANDOAH NATIONAL PARK, VIRGINIA. *PHOTOGRAPHS BY J GREGSON.*

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 Natural Resource Inventory and Monitoring Guideline*, and training in appropriate designs and implementation of inventory and monitoring is provided in the *Natural Resource Inventory and Monitoring* course.

The course presents a systematic and holistic approach to inventory and monitoring and is designed to (1) describe alternative approaches, strategies, and methods for I&M studies at the park level; (2) identify major ecosystem components for inventory and long-term monitoring; and (3) provide guidelines for data administration and reporting.

The course was designed primarily to meet 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 course are:

- the introduction of the concepts of ecology as applied to an integrated I&M program
- the presentation of a systematic approach to developing an integrated, holistic 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 parkneeds
- a discussion of the experimental design, statistical analyses, quality control, and assurance needs of an I&M program
- discussion of the role and methods of information management in an I&M program
- a presentation of a diversity of I&M case studies from parks.

When the 36-hour course was last conducted during 31 Aug – 4 Sep 1998 in Luray, Virginia, several prominent scientists and managers from the National Park Service and other agencies presented lectures. Gary Davis, Senior Scientist from Channel Islands National Park, reviewed the ecological basis of I&M and provided a conceptual overview of the development process of an I&M program. Rob Sutter, Director of Biological Conservation with The Nature Conservancy, presented a session on establishing I&M goals and objectives and a session on establishing I&M priorities. Dr. Hugh Devine, Professor of Forest Resources from North Carolina State University. provided a session on managing spatial data, and Dr. Paul Geissler from the USGS Patuxent Wildlife Research Center offered a session on *Analysis and Synthesis of Data* that included sampling designs, statistics, and quality control-quality assurance. Joe Gregson, Information Management Specialist with the servicewide I&M Program, presented a session on *Information Management, Data Management Systems,* and *Metadata.* Kathy Schwemm from Channel Islands National Park concluded the sessions. With a presentation on producing reports for managers, she focused on information management. Dr. Chris Ros from the Smithsonian Institute described some of the cooperative opportunities in I&M available through that organization.

Karen Wade, Superintendent of Great Smoky Mountains National Monument, gave an informative account of the critical need for long-term inventory and monitoring data sets and their roles in park management and resource protection. A presentation of case studies was also an important component of the course. It included a one-day field trip led by Tom Blount to have participants observe some of the long-term ecological monitoring projects that are parts of the *Prototype Ecological Monitoring Program* in Shenandoah National Park. In addition to observing first-hand some of the monitoring in Shenandoah National Park, the participants were introduced to similar monitoring in the *Prairie Cluster Prototype Monitoring Program* by Lisa Thomas and in Montezuma Castle National Monument by Dr. Charles Drost. Research Ecologist Dr. Tom Stohlgren with the USGS Biological Resources Division concluded the course with a session on putting all of the separate components together in a unified I&M program.

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Tentatively, *Natural Resource Inventory and Monitoring* will again be offered for 25-30 participants during September 1999 in Gatlinburg, Tennessee.

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

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