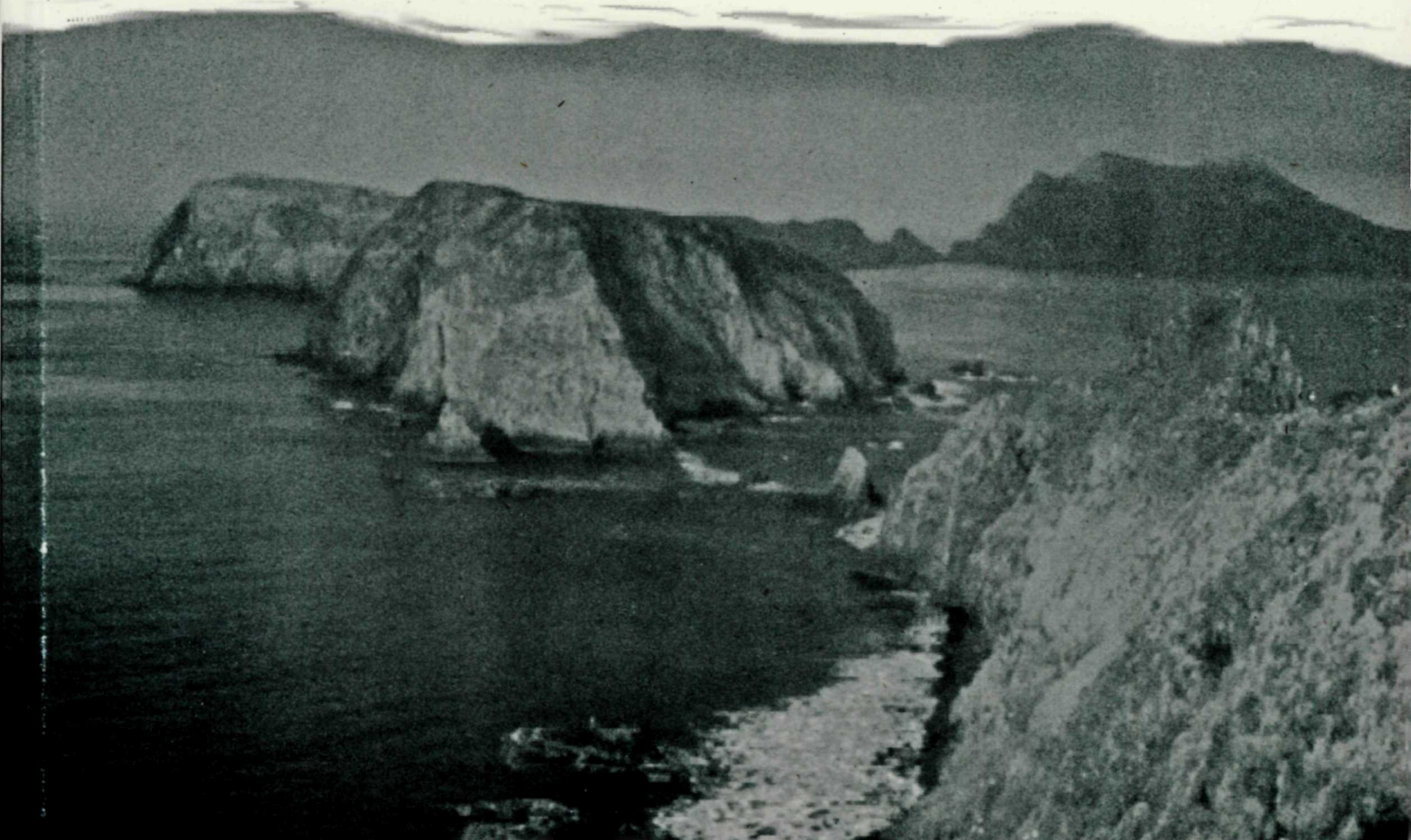
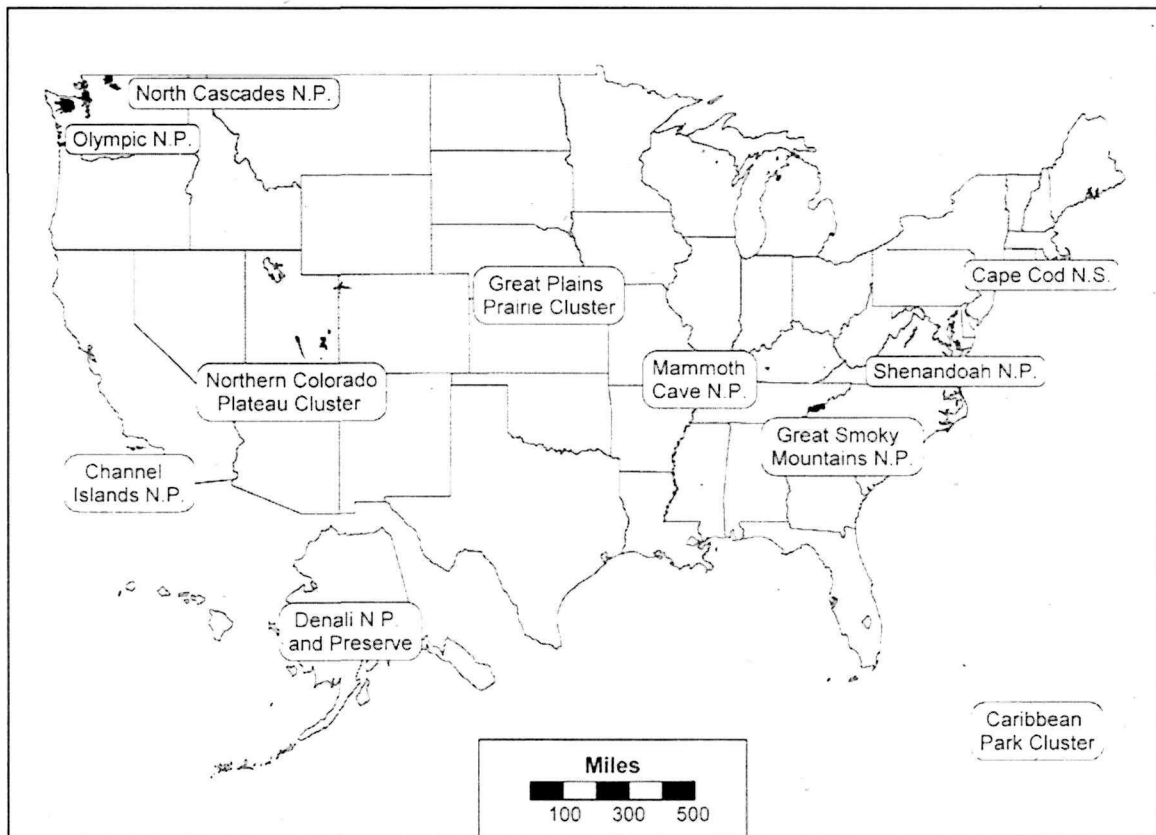


INVENTORY AND MONITORING PROGRAM
ANNUAL REPORT

NATIONAL PARK SERVICE
NATURAL RESOURCE INFORMATION DIVISION
ELIZABETH ROCKWELL, EDITOR



COVER: CHANNEL ISLANDS NATIONAL PARK, CALIFORNIA.



NATIONAL PARK SYSTEM UNITS SELECTED FOR
PROTOTYPE EXPERIMENTAL MONITORING OF NATURAL RESOURCES

MAP BY J. GREGSON

INVENTORY AND MONITORING PROGRAM
ANNUAL REPORT
FISCAL YEAR 1997

NATIONAL PARK SERVICE
NATURAL RESOURCE INFORMATION DIVISION
ELIZABETH ROCKWELL, EDITOR

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

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.aqd.nps.gov/pubs>

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FOREWORD

In 1987, the Evison Task Force conceived the principal design of inventory and monitoring of natural resources in the National Park Service and identified the need for national leadership in implementing it. In 1990, an inventory and monitoring program was given a programmatic and systematic footing from a second task force effort, and systematic inventorying was instituted. When in 1992, the National Park Service initiated its prototype ecological monitoring in four parks, it responded to a long-standing need for basic information about the resources it manages.

In 1995 and 1996, the National Park Service and the Biological Resources Division of the US Geological Survey, which is responsible for program designs, evaluated the first four prototype ecological monitoring programs. The reviews revealed excellent progress as well as the need for greater proficiency in the identification of objectives, development of conceptual models, integration of all monitoring components, identification of potential stressors and triggers, regular reviews by statisticians, scrutiny and synthesis of monitoring results by the scientific community, and reporting of the findings to park managers. Experience with the first four prototype monitoring programs benefited the next three units in the I&M Program and is now an indispensable guide for the three prototype programs in the research and development stage.

Since 1992, the I&M Program has had annual \$1-2 million dollar increases in most years. Because the program had an initial annual budget of less than \$1 million dollars and an inventory expense of more than a \$100 million, the increases have not permitted the comprehensive inventories and monitoring that can effect the preservation of natural resources for future generations. Nonetheless, now—unlike when the Evison Task Force first met—the program and its importance are widely recognized in the National Park Service.

This, the second annual report, is evidence of the program's maturing. Inventory and monitoring are eliciting even congressional attention. Questions about the program after the hearing on the FY 1999 appropriations bill reflected an unfortunate concern for cost and a lack of understanding for the duration of data acquisition. Such questions highlight the need for better explanations of the benefits of sound inventory and determination of natural resource status and better transmittal of the information to the Congress and the public.

The immediate priorities of the Inventory and Monitoring Program are (1) more assistance for non-prototype parks with understanding available tools and lessons learned; (2) better articulation of the needs for and benefits of information; and (3) assistance for parks with developing conceptual plans that will be the basis of future monitoring.

In 1998, the Office of the Secretary of the Department of the Interior approved the publication of the I&M Annual Report as a series. The report provides valuable information for resource managers and administrators, and I thank present and future contributors for their assistance with the dissemination of the information about the status of natural resources in the nation's parks.

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THE INVENTORY AND MONITORING PROGRAM



COVER: SAMPLING IN CHANNEL ISLANDS NATIONAL PARK, CALIFORNIA.

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 376 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 System¹. 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 1997, the servicewide 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 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.

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

PARTNERSHIPS

Prototype monitoring and basic inventories are being implemented in a close partnership between the National Park Service and the Biological Resources Division of the US 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.

BUDGET

The I&M Program is funded by annual line-item appropriations from the Congress. The Fiscal 1997 I&M Program budget was \$4.89 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 miles) 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 acres) 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 un-

common, and the species that occupy them are correspondingly rare. Prototype monitoring was initiated in 1996 to address five major ecological communities: (1) shoreline margins; (2) barrier islands, spits, and dunes; (3) estuaries; (4) freshwater kettle ponds and vernal pools; and (5) maritime heathlands and forests. Monitoring in each community is designed to address 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 US 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. Ongoing projects are addressing shoreline change, estuarine nutrient dynamics, salt marsh restoration, and the creation of a kettle pond data atlas. Full implementation of monitoring and integration of monitoring with natural resource management are immediate goals.

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, distribu-

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-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, Washington	Rivers and Lakes
Northern Colorado Plateau Cluster, Colorado and Utah	Arid Lands

tion, 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)

In 1992, the 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.

During Fiscal Year 1997, the Biological Resource Division of the US Geological Survey coordinated the peer reviews of the protocols for monitoring weather, air quality, stream channel morphometry and water chemistry, glaciers, vegetation, small mammals, and land birds (2 protocols) and the protocol for data man-

agement. National Park Service staff conducted operations in the Rock Creek watershed and on glaciers, and the Biological Resource Division continued the development of protocols for the monitoring of soils and benthic macroinvertebrates. Park staff also began to organize, verify, and validate information about water chemistry, hydrology, and vegetation. Long-term ecological monitoring of golden

eagles (*Aquila chrysaetos*), wolves (*Canis lupus*), moose (*Alces alces*), caribou (*Rangifer tarandus*), and Dall sheep (*Ovis dalli*) that present concerns for management was continued. Two significant goals of resource inventories were reached: the analyses of data from a park-wide, 3-year inventory of water chemistry were completed, and an inventory of soils was started. Data from the inventories permit stratification of watersheds throughout the park.

Great Plains Prairie Cluster (Prairie and Grassland Biome)

The first of three clusters was established in 1994 when monitoring in the Great Plains Prairie Cluster was funded. Monitoring is conducted in a cluster of six small prairie park units in the Midwest: Agate Fossil Beds National Monument, Homestead National Monument of America, and Scotts Bluff National Monument in Nebraska; Effigy Mounds National Monument in Iowa; Pipestone National Monument in Minnesota; and Wilson's Creek National Battlefield in Missouri. Wilson's Creek National Battlefield is the leading park of the cluster. The overall goals of the monitoring are the assessment of the effectiveness of resource management and the detection of degradation from external threats. The protocols address three high-priority management issues: (1) sustainability of small remnant and restored prairie ecosystems, (2) the effects of external land use and watersheds on small-prairie preserves, and (3) the effects of fragmentation on the biological diversity of small-prairie parks.

Monitoring in the Great Plains Cluster is still in the initial phase of protocol design and development and is therefore primarily funded and staffed by the Biological Resources Division of the US Geological Survey.



Cape Cod National Seashore, Massachusetts



Mt. McKinley, Denali National Park and Preserve, Alaska

Protocols are currently being developed for monitoring macroinvertebrates of prairie streams, weather and local climate, prairie plant communities, rare plants, prairie butterflies, grassland birds, and black-tailed prairie dogs.

Great Smoky Mountains National Park (Deciduous Forest Biome)

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

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

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.

Shenandoah National Park (Deciduous Forest Biome)

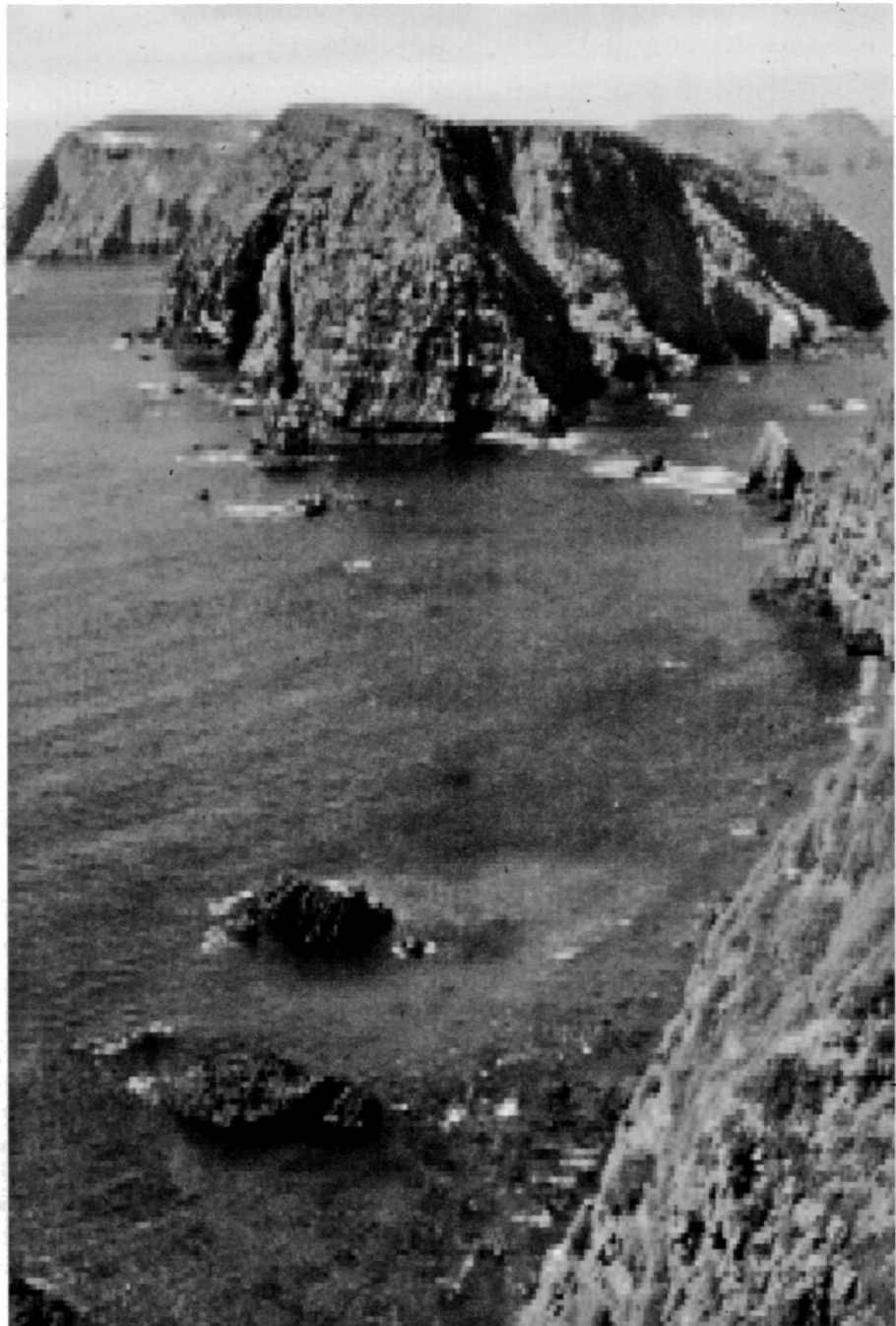
Shenandoah National Park is in the northern Blue Ridge Mountains of Virginia. It is the largest protected area in the mid-Atlantic region (79,380 ha; 196,000 acres) and the site of the historic Skyline Drive. Because of the park's long narrow shape and proximity to large metropolitan areas, protection of its resources is challenging.

Prototype inventory and long-term ecological monitoring has been fully integrated into the Resource Management Program of the park. Monitoring results are integral components of interpretation, education, and resource protection. In 1997, I&M data were used to revise fishing regulations in the park, to evaluate large-scale effects of flooding, to determine the health of hemlock trees that are threatened by the introduced pest hemlock woolly adelgid (*Adelges piceae*), and to support information in adult seminars that are coordinated by the interpretation and education office.

Immediately prior to Fiscal Year 1997, the I&M Program in the park was critically reviewed. The results of the review are still used to refine inventory and monitoring protocols.

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

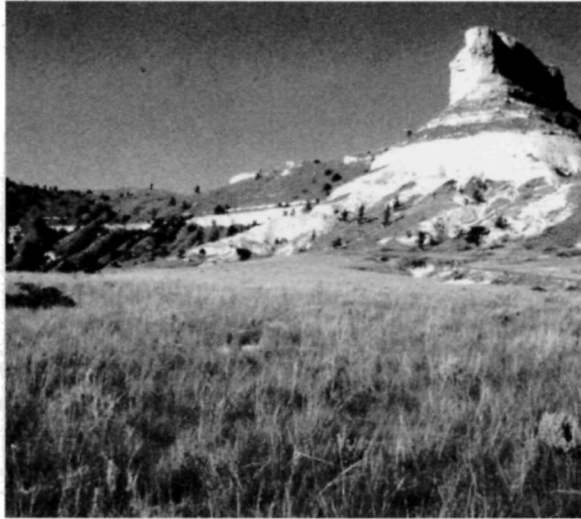
The Virgin Islands-Southern Florida Cluster (identified as *Caribbean Park Cluster* in the frontispiece) consists of Virgin Islands National Park and Buck Island Reef National Monument in the Greater Antilles and Dry Tortugas National Park in Florida. In 1997, the draft of a plan for prototype inventory and monitoring of natural resources in the tropical and subtropical biomes of the Virgin Islands-Southern Florida Cluster was completed, development of the protocol for monitoring coral reefs with analog and digital video cameras began, and protocols for monitoring water quality were finalized and implemented. Monitoring revealed several, as yet unclassified diseases of coral reefs. Research into the potential connection between these diseases and bacterial contamination from Sahelian dust is being proposed. Coral



Channel Islands National Park, California
Photograph by J. Gregson



Scenic views in Great Smoky Mountains National Park
Tennessee and North Carolina



Crown Rock, Scotts Bluff National Monument
Great Plains Prairie Cluster



Northern red oak, *Quercus rubra* L., forest with dense ground cover of
hay-scented fern, *Dennstaedtia punctilobula* (Michaux) Moore
Shenandoah National Park, Virginia

reef fish populations have been monitored extensively. The effects of terrestrial erosion and sedimentation on coral reefs and the dynamics of the tropical dry forests are monitored when possible.

Buck Island Reef National Monument was designated in 1961 for the bank-barrier coral reef surrounding the island's east end. This uninhabited island lies 2.4 km (1.5 miles) northeast of the island of St. Croix in the US Virgin Islands (17...47° N, 64...37° W) and includes 71 ha (176 acres) of land and 285 ha (704 acres) of water and coral reef system. Most of the water is designated *marine garden* that is closed to fishing and all collecting. The monument is developmental habitat for juvenile hawksbill sea turtles (*Eretmochelys imbricata*) and a nesting site for several other endangered and threatened species including the leatherback sea turtle (*Dermochelys coriacea*), green sea turtle (*Chelonia mydas*), brown pelican (*Pelecanus occidentalis*), and least tern (*Sterna antillarum*). 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 acres) 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 es-

tablished 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.



Buck Island Reef
National Monument
US Virgin Islands

INVENTORIES OF NATURAL RESOURCES



COVER: INVENTORY IN A REEF COMMUNITY IN BUCK ISLAND REEF NATIONAL MONUMENT, US VIRGIN ISLANDS.

INVENTORY OVERVIEW

The I&M Program is committed to conducting inventories in about 250 National Park System units with significant natural resources. Since 1992, the program has funded 380 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 geology in all natural-resource parks also were funded. The assessment of baseline water quality was funded jointly with the Water Resources Division of the National Park Service.

Twelve natural-resource data elements are the core set of the minimum information for park management, planning, and natural resource protection (Table 3).

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 plant
Species list of vertebrates and vascular plants
Vegetation map
Water body location and classification
Water quality data

The I&M Program will complete the basic resource data sets for each natural resource park unit. For cost effectiveness and quality control, most of the inventories are done by other agencies under national-level contracts and cost-sharing arrangements. Specialized inventories of other resources, for example, invertebrates or fossils, are the responsibility of parks.

Park priorities for each separate resource inventory were initially developed during 1993. Plans are now

underway to reconsider and update those priorities because of the completion of some inventories by some parks; the need for more explicit information about sensitive species and geology data; a better understanding of the linkages among inventories; new activities, threats, and issues that increased the urgency of some inventories; and new opportunities for leveraging to complete more inventories with existing funds.

As in the 1996 annual report, 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 during the 1997 calendar year. Hard copies were distributed to various entities of the National Park Service, including all parks with significant natural resources. In addition to posting them on the Natural Resource Bulletin Board and on the Natural Resource web site of the National Park Service (<http://www.aqd.nps.gov/facts/findex.htm>), the fact sheets were also posted on the IN TOUCH Bulletin Board in 1997. 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.

AUTOMATED NATURAL RESOURCE BIBLIOGRAPHIC DATABASE

(Fact Sheet 98-2, April 1998)

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

Standards and Products

The citation information is used to produce a natural resource bibliography theme (commonly referred to as NRBIB) for each of the park units in the program. Each

park unit receives a ProCite database with a thesaurus of keywords and the procedures for keeping the information current. The database is installed at the park unit to ensure accessibility by managers. The I&M Program has distributed ProCite software and the NPS ProCite manual to each park and trains on-site staff to use and maintain the databases.

Copies of each park's completed database are transmitted to the NPS I&M Program in Fort Collins for conversion and integration into a servicewide bibliographic database system. The I&M Program is developing an intranet database system to serve distributed NPS users from a central location. Through Internet and dial-up access, managers will have easy access to data from every park in the National Park System. Although park units will have ready access to input, edit, and delete bibliographic data, the quality of the data depends on the regularity with which each park updates its information.

Partnerships

Data entry and database development are proceeding on schedule under arrangements with the Colorado State University, Idaho State University, North Carolina State University, Penn State University, Rhode Island State University, University of Hawaii, and University of Northern Arizona. The I&M Program is funding work with the Columbia Cascades Support Office (CCSO) Library to transfer, maintain, and update the servicewide database.

BASE CARTOGRAPHIC DATA

(Fact Sheet 97-39, November 1997)

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 US Geological Survey and by procurement contracts.

Program Status

Since 1993, complete or partial base cartographic data from more than 178 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 Internet at <http://www.aqd.nps.gov:82/quad/quad.htm>

BASLINE WATER QUALITY STATUS AND TRENDS

(Fact Sheet 97-34, October 1997)

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 US 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 from 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 November 1997, 104 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 97-33, October 1997)

Maps of selected geophysical features, including bedrock and surficial geology, are included in the baseline inventory of natural resources for each park. Ulti-

mately, geology maps will be provided for all natural resource NPS units.

Partnerships

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

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

Program Status

Because field mapping of geologic features is extremely costly, efforts have focused on first obtaining data from other sources. Database searches are completed in all three regions of the US Geological Survey. Data files were downloaded from GEOINDEX and GEOREF databases and converted into a format that can be uploaded into park-specific ProCite files. Data entry and data conversion were completed under an arrangement with the Cooperative Park Studies Unit at the Colorado State University.

ProCite databases developed by the American Association of State Geologists will be completed for all parks by December 1997. The project has compiled a total of 4,892 references from 46 states. The other four states either contained no National Park Service lands or had no references for those lands.

A workshop in November 1997 addressed several programmatic questions related to the geology component of the I&M Program. The workshop provided recommendations related to: (1) geologic information that should be included in Level I inventories for all parks, e.g., whether surficial/bedrock geology is needed for all parks and to what extent geo-hazards and geologic features should be mapped, (2) the evaluation of the quality and applicability of existing geologic informa-

tion, and (3) value that can be added to geologic maps by interpreting the management implications of the data. The workshop participants also developed recommendations for map acquisition, digitizing existing maps, and exploring additional partnership opportunities.

SOIL MAPPING

(Fact Sheet 97-29, August 1997)

Maps of selected geophysical features such as soils are being produced for each natural resource park. The National Park Service is working with the Natural Resource Conservation Service to complete Order 3 soil surveys in all parks, except where more detailed surveys are required for park management. In addition to the baseline soil survey data, a primary product of the soil mapping program is a digital layer for specific park units. The soils data will be automated to provide flexibility in map design and production and to facilitate data management.

Partnerships

The Inventory and Monitoring Program is completing soil maps through national agreements with other federal agencies such as the Natural Resources Conservation Service and with private contractors. In 1997, I&M Program staff continued to assist parks with identifying soil mapping needs so that park objectives could be met through appropriate data collection and scale of maps. For example, special strategies are being developed in cooperation with the Natural Resources Conservation Service to handle the large-area mapping for parks in Alaska, beginning with the Denali National Park and Preserve.

Program Status

The Natural Resources Conservation Service is conducting soil surveys in 36 parks and will continue to support soil mapping until the project is completed. Soil map digitization in Bighorn Canyon National Recreation Area was completed by the conservation service in 1997 at no cost to the National Park Service. Additional mapping was conducted by contractors in

Bighorn Canyon National Recreation Area and Pecos National Historical Park.

Fieldwork and mapping were completed in Acadia, Grand Teton, Hawaii Volcanoes, Theodore Roosevelt, and Yellowstone national parks; Craters of the Moon, Dinosaur, and Hagerman Fossil Beds national monuments; Pecos National Historical Park; and the Southern Arizona Group (Chiricahua, Montezuma Castle, and Tuzigoot national monuments; Coronado National Memorial; and Fort Bowie National Historic Site).

Field mapping continues in Bighorn Canyon, Gateway, Lake Mead, and Santa Monica Mountains national recreation areas; Rocky Mountain and Yosemite national parks; and Saint Croix National Scenic Riverway. Soil mapping was initiated this year in Chaco Culture National Historical Park; Bandelier, Fort Union, Gila Cliff Dwellings, John Day Fossil Beds and Salinas Pueblo Missions national monuments; Carlsbad Caverns, Death Valley, and Joshua Tree national parks; and Denali National Park and Preserve. Field work is planned to begin in 1998 in Crater Lake, Grand Canyon, and Great Smoky Mountains national parks; Apostle Islands National Lakeshore; and Chesapeake and Ohio Canal National Historical Park.

VEGETATION MAPPING

(Fact Sheet 97-23, June 1997)

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 Geo-

graphic Data Committee and other agencies is developing 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 are being 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 (Geographic Information System) 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 US 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 US Bureau of Land Management and the US 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, 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. The acquisition of photographs for Glacier Bay National Park and Preserve and Klondike Gold Rush National Historical Park through partnerships with the US Forest Service, US 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 are being 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 is planned by fall 1997.

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 forthcoming.

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.

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 taking of new photographs is underway as of spring 1997.

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, Isle Royal, Joshua Tree, Voyageurs, 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 acres) of vegetation in the 15 national parks in Alaska is coordinated by the Alaska Regional Office. It is conducted independent of vegetation mapping in parks elsewhere

in the United States, primarily because of the large spatial scale. In national parks in Alaska, vegetation is mapped from satellite imagery, not from aerial photographs. Initially, FirePro field data collected during vegetation mapping over the years in Denali, in Gates of the Arctic, Katmai, Lake Clark, and Wrangell-St. Elias national parks were automated. In Fiscal Year 1996, imagery for vegetation in Denali and Lake Clark national parks and preserves was acquired. Now, vegetation mapping is 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 US Geological Survey is being adapted for Alaska and field tested in one or more of the national parks in Alaska.

Activities in 1997

Priorities for the upcoming field season include:

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

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

Training Opportunity

The US 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 US Bureau of Land Management, Bureau of Reclamation, Department of Defense, Environmental Protection Agency, US Fish and Wildlife Service, and the US

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



COVER: BLACK-TAILED PRAIRIE DOG, *CYNOMYS LUDOVICIANUS*, IN THE GREAT PLAINS PRAIRIE CLUSTER.

MONITORING PROGRAM OVERVIEW

tigations will not provide the needed knowledge and understanding. In the words of Waldo Emerson: *The years teach much which the days will never know.*

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 inves-

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

Water Quality of Rock Creek in Denali National Park and Preserve, Alaska

Water quality and stream morphology provide important information about the health of aquatic ecosystems. Surface water chemistry provides information about local geology, morphology, nutrient status, and biological productivity. Basin characteristics may provide preliminary and direct indications of climate trends or land use, especially in areas that respond quickly to such changes. These areas include arid lands where water is a limiting factor and arctic lands, which may be especially sensitive to climate change. Flow, sediment discharge, and streambank vegetation are the primary independent variables that control the channel morphology in a natural system. Changes in these variables directly affect bank and bed stability and sediment transport characteristics.

In Denali National Park and Preserve, water quality and stream morphology are monitored in two stream channel reference sites in the Rock Creek watershed near park headquarters. The sites were established in 1992 and are about 1.5 km (0.9 mile) apart. Water samples are collected monthly during the ice-free season and are analyzed for major ions, selected nutrients, alkalinity, pH, and total organic carbon. Results indicate a geochemical dominance of the stream water chemistry. In 1997, the mean concentrations were 28 224.8 $\mu\text{eq/L}$ Ca^{++} , 13 179.5 $\mu\text{eq/L}$ Mg^{++} , and 9 158.5 $\mu\text{eq/L}$ SO_4 . Stream water nutrient levels have been low. In 1997, the mean concentration of NO_3^- was 6.65 $\mu\text{eq/L}$, the concentration of PO_4^- was below the minimum detection limit of 1.27 $\mu\text{eq/L}$, and the pH ranged from <7.00 to >8.00 (Table 4, Fig. 1)

In 1997, a study of the relation between soil water chemistry and nutrient levels in Rock Creek was completed. The study was designed to identify factors that control productivity and revealed a lack of nitrates and phosphates. In combination with unstable flows, a high gradient, and a large substrate, the lack of nitrates and phosphates may not only limit primary productivity in Rock Creek but may also account for the low diversity and density of aquatic macroinvertebrates during 1992-1995. Monitoring of benthic invertebrates in Rock Creek was suspended after 1995. If the relation between the abundance and diversity of

the organisms and the productivity of a stream is confirmed from data elsewhere in the park, monitoring of aquatic macroinvertebrates in Rock Creek will be resumed.

In 1997, the US Geological Survey used baseline data of water chemistry from a 1994-96 study of clear and glacial streams by the US Forest Service and the National Park Service to select monitoring sites for the National Water Quality Assessment Program in 1997. The data, which revealed significant differences in water chemistry between streams north and south of the Alaska Range, are expected to be useful for an expansion of water quality monitoring to more and larger ecological communities in the park. The differences in water chemistry of the streams may be caused by geological differences. The softer calcareous sedimentary rocks north of the Alaska Range erode more easily than the hard granitic plutons (bodies of igneous rock that cooled underground) south of the range. The bedrock in the north contributes greater amounts of soluble sediments to north-flowing streams, which raises the pH and alkalinity.

Table 4. Mean values of water chemistry, suspended sediment, and turbidity in 62 streams north and south of the Alaska Range in Denali National Park and Preserve, 1997.

Parameter	North Side	South Side
pH	7.77	7.00
Alkalinity (mg/L)	112.74	22.75
Suspended Sediment ¹ (mg/L)	31.78	19.84
Suspended Sediment ² (mg/L)	670.00	266.26
Turbidity ¹ (NTU)	20.65	14.99
Turbidity ² (NTU)	258.19	79.41

¹Clear-water streams

²Glacier-fed streams

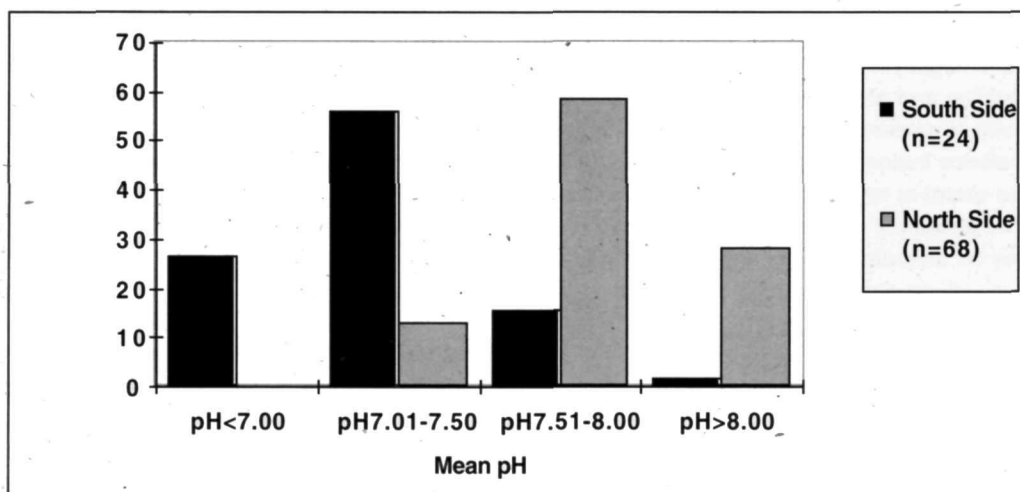


Figure 1. Mean pH of streams on the north and south sides of the Alaska Range, Denali National Park and Preserve, 1994-1996.

Glaciers in Denali National Park and Preserve, Alaska

In 1997, glacial activity throughout Denali National Park and Preserve was monitored to determine the regional effects of climate on the glaciers. Data were collected in two index sites—the Kahiltna Glacier that flows from the southwestern side of Mt. McKinley and the Traleika Glacier that flows from the notherwestern side. Surveys of the Muldrow Glacier will be continued near completion of the study of the glacier's pre-surge condition. Monitoring of glaciers was expanded to include a benchmark site on the glacier at the head of the East Fork Toklat River. Survey monuments and a stake network were installed and their positions mapped to serve as reference points for future measurements of ice flow rates and changes in ice thickness.

Six years of monitoring revealed drastic differences between the Kahiltna and Traleika glaciers. A correlation between the annual mass balance of the two glaciers is negative. Mass balance is the sum of the accumulation and ablation of ice in a glacier and is expressed in meters of equivalent water per year. Mass balance indicates whether a glacier is gaining (positive value) or losing (negative value) mass over time. The amount of ice that is gained or lost through time may be an indicator of changing climate forces

that influence glaciers. When the annual mass balance of the Kahiltna Glacier was positive, that of the Traleika Glacier has consistently been negative, and vice versa. This suggests that snow accumulation or cloud cover concentrate on only one side of Mt. McKinley during any given year, leading to a negative mass balance on one side of the mountain and to a positive mass balance on the other side. The mass balance of the Kahiltna Glacier has not displayed a strong trend, although the glacier has thinned slightly (about 3 m, 9.8 ft) since 1991.

A comparison of mass balance on the Kahiltna Index Site with other glaciers in Alaska revealed a weak correlation with the Gulkana Glacier, 306 km (190 miles) east. Both glaciers are on the south slope of the Alaska Range. Such a correlation suggests that climatic influences on glaciers in southern Alaska may be consistent and that the trend in the mass balance of the Kahiltna Glacier may not be particular to that glacier but may reflect a trend in the region's climate.

Drastic changes have taken place on the Traleika Glacier since 1991. The glacier has thickened by as many as 25 m (82 ft). The rate of surface ice flow has doubled. Because the Traleika Glacier is the major contributor of ice mass to the Muldrow Glacier, this build-up may be the precursor to a surge in this glacier system.

GLACIER SURGING

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

Because the Muldrow Glacier is expected to surge within the next few years, data on the geometry and flow of the glacier have been collected (Fig. 2). Studies of other glaciers suggest that a thickening of the ice and an increase in ice flow velocity may signal a glacier's readiness to surge. The ice thickness of the Muldrow Glacier has increased by as many as 40 m (131 ft) since 1976 but is still 10-45 m (32-147 ft) thinner than prior to its last surge in 1956 (Fig. 3). Annual flow rates, which had decreased steadily since 1982, increased approximately 40% on the Muldrow Glacier during 1996-97 (Fig. 4). This increased flow rate may, however, not be the precursor of a surge. Subsequent measurements will reveal more information and possibly a building trend that may signal the next big advance of the Muldrow Glacier.

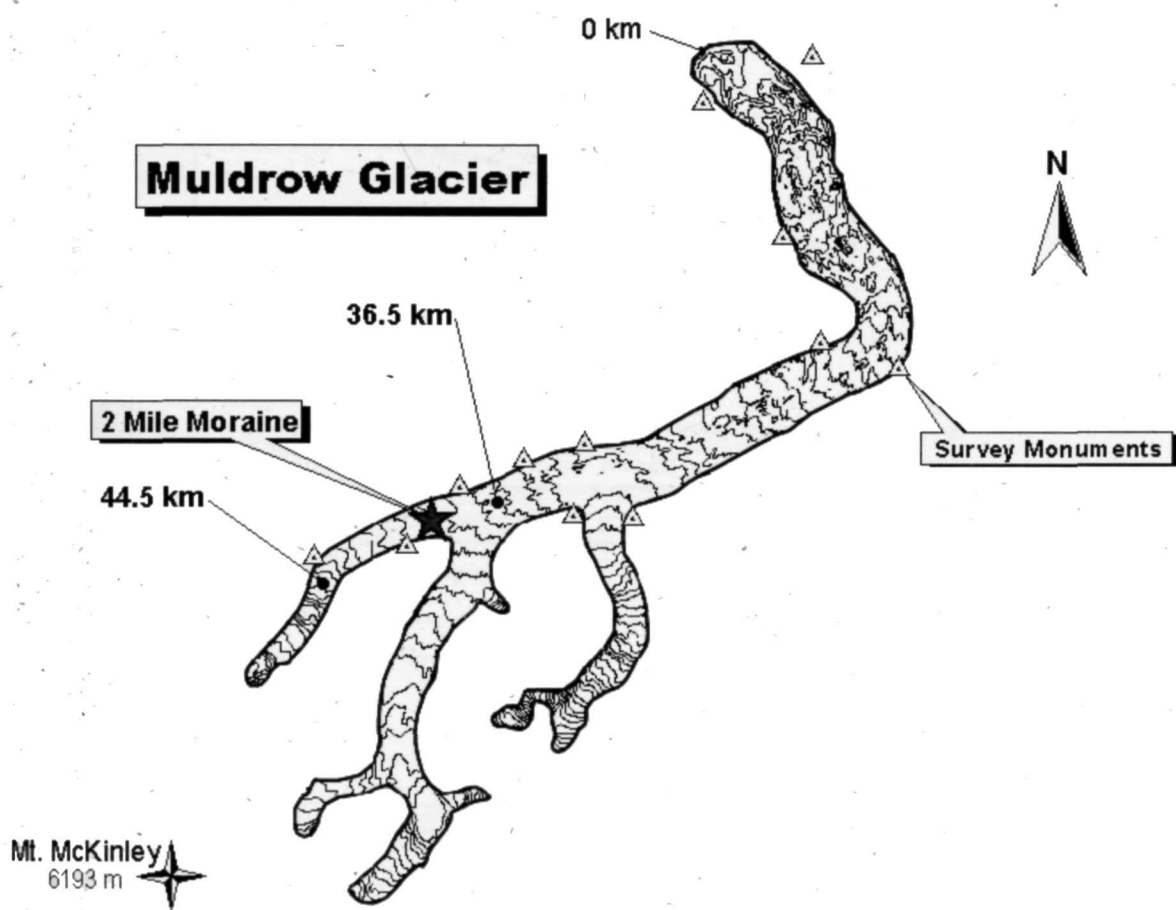


Figure 2. The Muldrow Glacier with the Two-Mile Moraine ice flow target (*) in Denali National Park and Preserve. The center line elevation profile is located between kilometers 36.5 and 44.5 (relative to kilometer 0 at the terminus). Data are collected with geodetic techniques from the survey monuments.

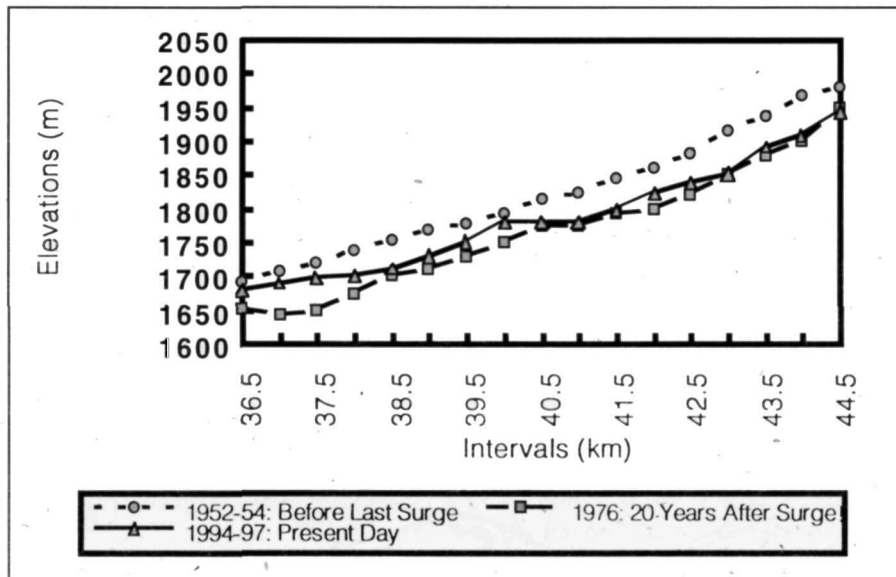


Figure 3. Centerline elevation profiles of the Muldrow Glacier, Denali National Park and Preserve, 1952-1997.

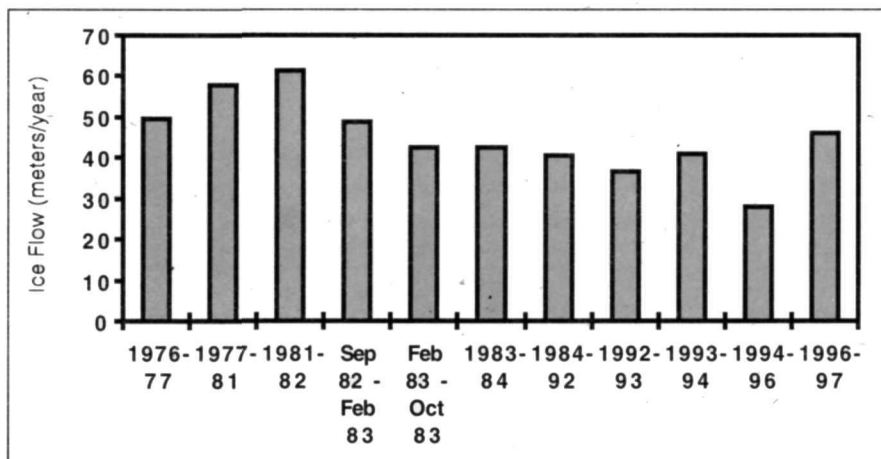


Figure 4. Flow rate of the Muldrow Glacier at the Two-Mile Moraine, Denali National Park and Preserve, 1976-1997.

In August and September 1997, a survey network of 18 index stakes was installed on a comparatively small glacier at the head of the East Fork Toklat River. This is the first glacier in the park that is covered with a comprehensive stake network from top to bottom. This will allow a more detailed understanding of how glaciers and climate interact and will help with characterizing glacier activity on a park-wide scale.

A surge of the small Slippery Creek Glacier that began in 1996 on Peters Dome near the North Face of Mt. McKinley did not continue in 1997. Aerial observations between January and May showed that the glacier did not advance beyond the limit it had reached in late 1996. Thus, the surge seems to have ended during fall 1996, probably when winter freeze-up cut off the supply of melt water on which the glacier had been sliding. A termination at the end of the melting season is consistent with what is known about the behavior of most surging glaciers.

The Shoreline of Cape Cod National Seashore, Massachusetts

Shoreline Processes

Shorelines are dynamic, often violent environments, defined by the shifting of sediments that efficiently diminish the energy of waves and currents. Along the Atlantic and Gulf coasts, a nearly continuous chain of barrier islands and spits has developed over time, protecting the mainland from the direct force of winter storms and hurricanes. Broken periodically by inlets that may open or close in response to major storms, the physical characteristics of the barriers change constantly as sand is redistributed throughout the littoral zone. This movement may be perpendicular to the shore, moving sand onshore or offshore depending on wave steepness, sediment size, and beach slope. Simultaneously, movement may be parallel to the shoreline as sand, stirred up the breaking of waves, is carried along by prevailing longshore current. Under normal conditions, the shoreline at any given point along a beach may be accreting, receding, or stable, although most short-term changes will probably be imperceptible to the untrained observer.

Causes of Shoreline Erosion

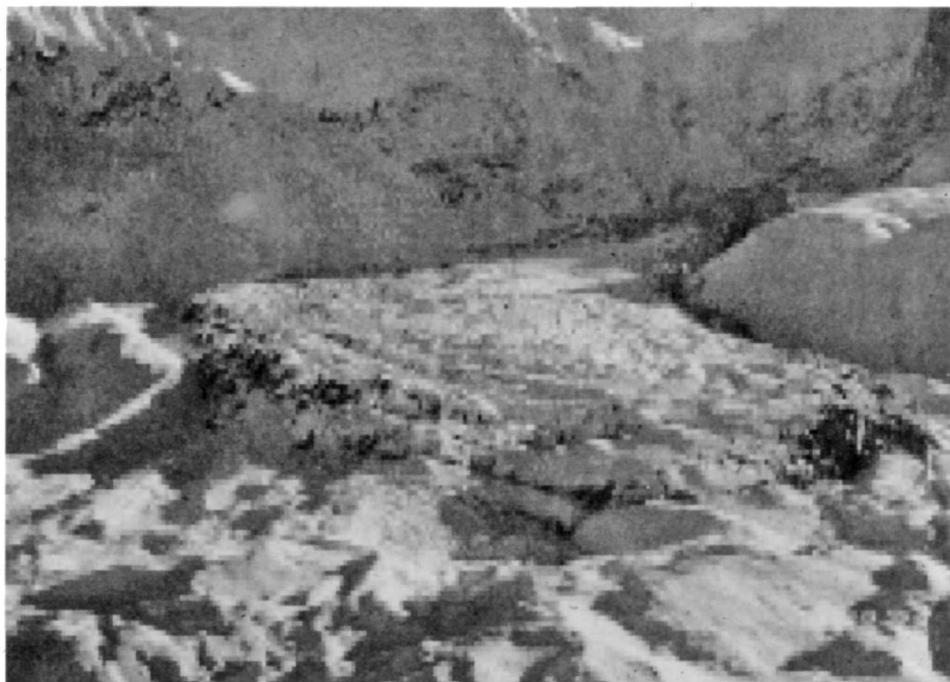
Numerous natural and anthropogenic factors can contribute to erosion of shorelines. Natural factors include sea level rise, storm waves, and longshore sediment transport. Those associated with major storms tend to be the most drastic. The two most frequently cited anthropogenic causes of erosion are the interruption of material in transport and the loss of natural coast protection. Natural coastal defenses are most often lost to coastal development, and condominiums and vacation homes replace existing dunes and increase the potential for overwash erosion and island breaching.

In most cases, however, no one natural or anthropogenic factor is solely responsible for shoreline erosion. Rather, each of several factors—some more obvious than others usually compounds the effects of the others and complicates mitigation of damage. Shoreline erosion may, of course, cause the loss of structures and, more importantly, of natural and cultural resources.

The Cape Cod National Seashore

Most shorelines processes on Cape Cod National Seashore are not impeded by anthropogenic influences. However, long-term monitoring of shoreline processes on the seashore has been initiated because shoreline erosion may threaten other resources. Data from monitoring will be used to:

- ¥ provide resource managers on Cape Cod National Seashore with unambiguous definitions of shoreline dynamics and thereby improve the management of resources in areas that can be threatened by shoreline erosion
- ¥ develop a statistically robust and objective model of shoreline change (directions, trends, and variability) on the seashore and to identify the sites where resources are at risk
- ¥ expand existing spatial databases of shoreline change to better understand the defining patterns of where directions of change (i.e., erosion or accretion) are persistent and where changes are cyclic but about in equilibrium



Slippery Creek Glacier
Denali National Park and Preserve, Alaska



Glaciologists survey the East Toklat Glacier to monitor changes in its ice flow and mass.
Denali National Park and Preserve, Alaska

Photograph by Sousanes

- to account for day-to-day variability in shoreline processes and landform responses—especially the roles of discrete storm events and seasonal variability— to better understand time-scale-dependent variations in trends and variances
- develop protocols for coastal monitoring by staff of the seashore or cooperators during the next 10-15 years that can incorporate technological advances yet provide data consistent with those gathered previously.

In November 1997, copies of all of the survey data on the Marindin monuments and their reoccupance by the Woodshole Oceanographic Institute in the 1950s were obtained. Relocation of the monuments in the field was initiated in fall, and the National Geodetic Survey is determining whether the original site data (latitude and longitude in an unknown coordinate system in 1887) can be transformed into NAD 84 (North American Datum 84).

In 1998, the Marindin monuments will be located with a real-time differential GPS (Global Positioning System) and new benchmarks will be installed. Surveys will be conducted along all Marindin transects of the baseline network to establish an inventory for future monitoring. Remote video cameras will be installed in two locations to quantitatively monitor changes in coastal geomorphology. GPS surveys of shoreline positions will be conducted once per season and immediately after storms during winter-spring.

Status and Trends

Air pollution in National Park System units reduces visibility, injures vegetation, changes lake and stream chemistry, and causes the deterioration of cultural resources. Under the Clean Air Act (Public Law 101-549), the Organic Act, and other legislation, the Department of the Interior must protect resources in the units from these effects.

Background

Since the late 1970s, the National Park Service has monitored visibility and ambient levels of fine particles, ozone, sulfur dioxide, and wet deposition in national parks. Visibility, including photographic, optical, and fine particles, is monitored as part of the Interagency Monitoring of Protected Visual Environments (IMPROVE), which is cooperative national monitoring of visibility by the US Environmental Protection Agency and federal land managing agencies. Wet deposition is monitored as part of the service's participation in the National Atmospheric Deposition Program/National Trends Network (NADP/NTN). The service developed its own network for the monitoring of gaseous pollutants and meteorology, which is supplemented by states in some locations. These networks are essential to the understanding of the effects of air pollutants on ecosystems in parks that previously were presumed to be relatively free of anthropogenic stresses. Before the service's networks were established, monitoring in national parks was scarce because EPA and the states placed priority on health-related monitoring of air quality in urban areas. When the Congress provided additional funding in 1986 and 1987, the National Park Service was able to expand its network and establish a data center to process, validate, and archive data. Ozone, sulfur dioxide, and meteorological data that the service collects are entered into EPA's national database for use by EPA, state agencies, and researchers. Visibility and wet deposition data are available on the Internet (visibility data ftp://alta_vista.cira.colostate.edu; wet deposition <http://nadp.sws.uiuc.edu>.)

Current Status

Fine Particles and Visibility

Until 1988 when IMPROVE became operational, visibility monitoring by the National Park Service was the only source of visibility information in Class I areas in this country. The service has maintained visibility monitoring in many of its parks since 1978. Visibility monitoring includes three types of monitoring (1) photographic (or scene) monitoring, (2) optical monitoring, and, (3) fine particle sampling. Scene monitoring documents the condition of a scene or scenes in a park 3 times a day with a 35-mm camera. Optical monitoring is done with a transmissometer, which measures total atmospheric light extinction, or with a nephelometer, which measures only the scattering fraction of atmospheric light extinction. This monitoring provides a continuous hourly record of visibility in parks. Fine particle sampling allows the identification of the causes, namely, the source types or the source regions responsible for the impaired visibility in parks.

Twenty-four-hour fine particle samples are collected twice weekly in each monitoring location. The fine particulate matter collected in the IMPROVE network is analyzed to determine its chemical composition. The chemical species measured in most IMPROVE sites are of five chemical types: sulfates, nitrates, mass associated with organic carbon, light absorbing carbon, and soil. In the East, sulfate is usually the greatest contributor to visibility impairment and contributes about 50% of the impairment when visibility is best, 60% when visibility is average, and 30% when visibility is worst. In western IMPROVE sites, sulfate contributes about 30% of the impairment when visibility is best, 35% when visibility is average, and 30% when visibility is worst. The next largest chemical contributors to impairment in the East and the West are or-

Class-I Area

A classification established by the US Congress to implement the prevention of significant deterioration of air quality in specific areas, including national parks larger than 2340 ha (6000 acres) and wilderness areas larger than 2025 (5000 acres).

Forty-eight of the 158 nationwide Class-I areas are National Park System units.

ganic carbon and light absorbing carbon. Nitrates contribute more toward visibility impairment in the West than in the East.

Wet Deposition

Wet deposition in parks has been sampled weekly with wet-bucket collectors since 1978. The collectors collect precipitation samples by event. Samples are sent to a central analytical laboratory for chemical analysis of important analytes such as sulfate, nitrate, pH, sodium, calcium, and ammonium. The 29 wet deposition stations in national parks are part of the NADP/NTN network of 200 stations in the United States. A recent study by the service revealed that stations in parks significantly contribute to the characterization by the NADP/NTN network of the spatial trends in precipitation chemistry across the United States.

Gaseous Pollutants

Because of the toxicity of ozone and sulfur dioxide to vegetation and other resources in parks, the National Park Service monitors these pollutants system-wide. Before 1983, the service relied on state agencies to monitor gaseous pollutants in parks. Only few states monitored either ozone or sulfur dioxide in national parks and therefore little or no data were available on the levels of these pollutants in parks. Since 1983, the service has developed a nationwide network of gaseous pollutant and meteorological stations to assess the condition of the air in selected parks. Ozone, and in some parks sulfur dioxide, are continuously monitored with EPA protocols and with sophisticated instrumentation that is kept in temperature controlled shelters. In a few special cases, ozone precursors (nitrogen oxides and volatile organic compounds) are also measured in this fashion. Sulfur dioxide is measured on a time-integrated basis. Samples are collected either every 24-hours twice per week or weekly. Recently, the service experimented with passive samplers to measure ozone, sulfur dioxide, and nitrogen oxides. These samplers provide integrated samples weekly but can also be used for shorter duration. In late 1993, the service formed a partnership with EPA to merge its western portion of the gaseous pollutant network with EPA's National Dry Deposition Network. Although the merger will not increase the number of

monitoring locations, it will provide the measurement of additional pollutants in 18 park areas and additional data analysis.

SPATIAL TRENDS

Fine Particles and Visibility. Fine particulate matter consists of particles with diameters of less than 2.5 micrometers and is referred to as PM-2.5. In the East, the estimated natural background concentrations of fine particles are 3.3 mg/m³, the sulfate concentrations are 0.2 mg/m³, and the natural background visibility is about 9.5 dv (deciviews). In the West, the estimated natural background concentrations of fine particles are 1.5 mg/m³, the sulfate concentrations are 0.1 mg/m³, and the natural background visibility is about 5.0 dv. A value of zero on the deciview scale represents excellent visibility, *i.e.*, visibility unimpaired by anthropogenic or natural particles suspended in the air. The dv scale is a mathematical transform of the traditional visual range and atmospheric indices. For example, 30 dv correspond to a visibility of 19 km (~8 mi) and 10 dv to 144 km (~89 mi).

Fine particle concentrations are typically 3-4 times higher in the East than in the West, but measurements from both regions although well above the natural background estimates are below the annual average EPA National Ambient Air Quality Standard (NAAQS) for particulate matter of 15 mg/m³. This standard and its companion 24-hour standard, if met, should protect the health of people from the adverse effects of fine particulate matter in the air. The fine particle concentrations in all monitored sites seem to comply with the 24-hour NAAQS.

Because of its important relation with visibility impairment and acid deposition, sulfate concentrations are also measured (there is no NAAQS for sulfate). Sulfate concentrations are 6-10 times higher than natural background estimates in the West and 30-40 times higher than natural background estimates in the East.

Visibility displays similar patterns. In the East, visibility must be improved by an average of 20 dv to achieve natural-background conditions. In the West (except in California), an average improvement of about 4 dv is required.

Wet Deposition. Data from the NADP/NTN network for three major constituents (sulfate, nitrate, and pH) show the relatively high concentrations of acidic species in rain and snow in the northeastern United States and in the Ohio River valley. West of the Mississippi River, the sulfate concentrations are generally low and the pattern of nitrate concentrations in rain and snow are variable. In the Northeast, sulfate concentrations exceed nitrate concentrations, but in the West, nitrate concentrations often exceed sulfate. The pH of wet deposition is expressed on a logarithmic scale of hydrogen ion concentrations. The pH of natural rainfall is in the range of 5.2-5.8. A band of low-pH rain is observed in the Northeast. The lowest pH has been recorded in western Pennsylvania, New York, and Ohio. In the western United States, the pH of wet depositions is higher because of fewer acidifying emissions and the presence of buffering materials such as dust in the air that neutralizes acidity. However, in some areas of the West, wet depositions have had a low pH.

Throughout the United States, wet depositions are measured with NADP/NTN wet buckets. However, other methods are needed to estimate total loading of chemicals in sensitive ecosystems in specific parks. For example, many sensitive lakes, streams, ponds, and watershed soils in Class-I parks are located at high elevations, where much of the deposition is in the form of seasonal snow that is released during spring snowmelt. This temporal pattern of chemical depositions to poorly buffered systems is not captured in the annually averaged data, and measurement of the chemical deposition in snow requires different sampling methods and collection intervals.

Ozone. For the National Ambient Air Quality Standard (NAAQS) of ozone, EPA uses a 3-year average of the fourth highest daily maximum 8-hour ozone concentration expressed as parts per billion (ppb) to compare ozone concentrations and to determine attainment of the NAAQS. This measure is an 8-hour concentration that is determined by calculating the highest 8-hour concentration for each day of the year, taking the fourth highest daily values of each year and then averaging this for the highest value over three consecutive years. These calculations smooth some of the shorter-term peak ozone concentrations from

atypical meteorological conditions. Three-year average ozone concentrations that are greater than or equal to 85 ppb exceed the NAAQS. Air pollution levels above the NAAQS can produce adverse effects on human health, particularly of children, the elderly, and people with respiratory diseases.

Monitoring sites of the National Park Service in south-central California, the Northeast, and the east-central United States generally record the highest ozone concentrations in the National Park Service network. Cape Cod National Seashore, Acadia and Great Smoky Mountains national parks, and several NPS units in California have had ozone levels in excess of the NAAQS.

Fine Particles and Visibility in NPS Units that Conduct Prototype Ecological Monitoring

Prototype ecological monitoring in Denali National Park and Preserve, Great Smoky Mountains National Park, and Shenandoah National Park includes monitoring visibility. The three units, which are part of the IMPROVE visibility network, monitor particulate matter and the optical properties of the atmosphere that are important for understanding the effect that air pollutants have on visual air quality.

Average PM-2.5 concentrations of fine particulate matter in Great Smoky Mountains and Shenandoah national parks are approximately 5 mg/m³ when visibility is best, 10 mg/m³ when visibility is average, and 20 mg/m³ when visibility is worst. The PM-2.5 concentrations of worst visibility (2-4 µg/m³) in Denali National Park and Preserve are less than the concentrations when visibility is best in Great Smoky Mountains and Shenandoah national parks in the East. The fine particle concentrations in Denali National Park and Preserve are generally the lowest of all measured in the IMPROVE network (Fig. 5a-c).

The fine particulate matter concentrations in Great Smoky Mountains and Shenandoah national parks follow a seasonal trend that has been observed in most continental IMPROVE monitoring sites. Sulfate (and total fine particulate) concentrations are several times greater in summer than in winter. Sulfate concentra-

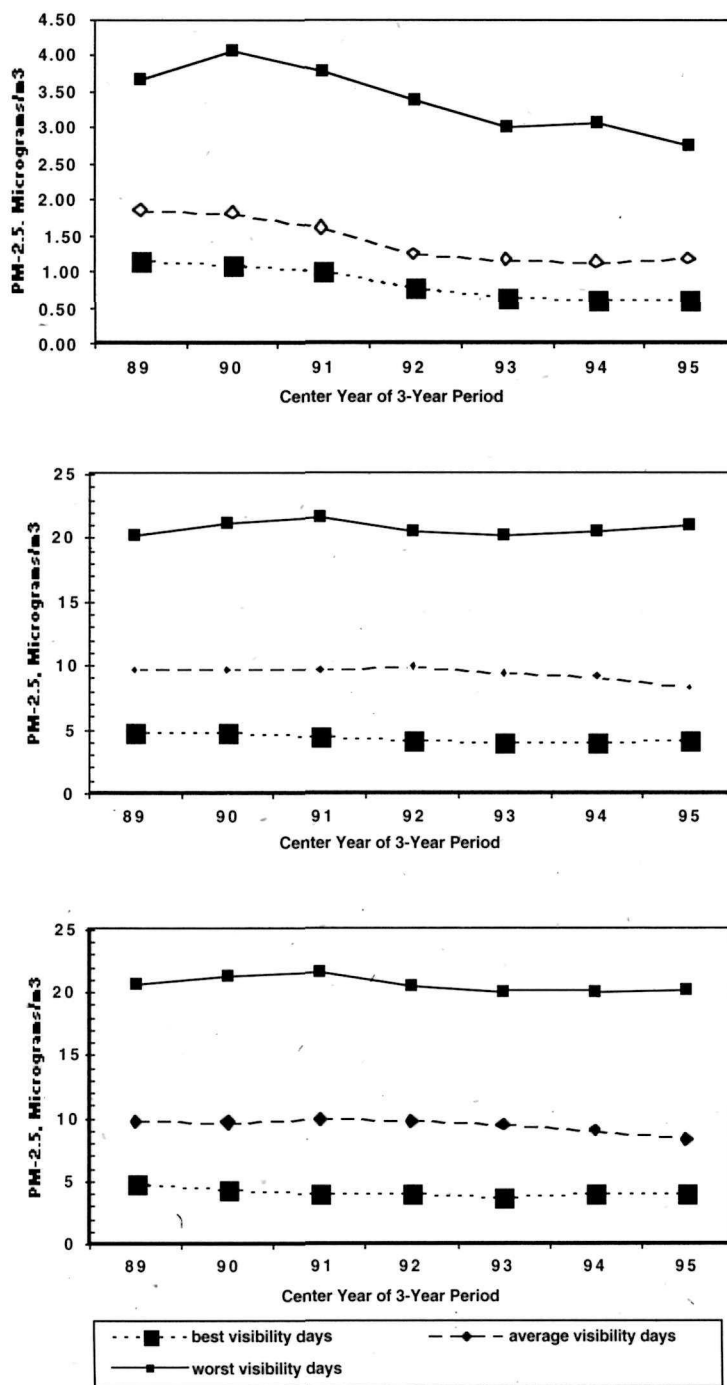


Figure 5 a-c. Three-year average PM-2.5 particulate matter concentrations in (top to bottom) Denali, Great Smoky Mountains, and Shenandoah national parks, 1989-1995.

tions in Denali National Park and Preserve are greater in winter than in summer but are very low in both seasons. Sulfate concentrations in summer are more than 20 times greater in the eastern parks than in Denali National Park and Preserve and more than 10 times greater than concentrations in western continental IMPROVE monitoring sites (Fig. 6a-c).

On days with the worst visibility during 1988-96, insignificant or no change occurred in the 3-year average deciduous forest visibility in Shenandoah National Park, but visibility improved by about 0.2-0.4 dv/year in Denali National Park and Preserve. Data from Great Smoky Mountains National Park were statistically inconclusive. The average visibility days improved by an estimated 0.3-0.5 dv/year in Denali National Park and Preserve, by 0.02-0.1 dv/yr in Great Smoky Mountains National Park, and by 0.1-0.2 dv/year in Shenandoah National Park. The best visibility in the parks improved by about 0.3-0.4 dv/yr in Denali National Park and Preserve, by 0.1-0.2 dv/yr in Great Smoky Mountains National Park, and by 0.1-0.2 dv/yr in Shenandoah National Park (Fig. 7a-c).

Wet Deposition in NPS Units that Conduct Prototype Ecological Monitoring

Wet Sulfate

Sulfate depositions are elevated in Cape Cod National Seashore, Great Smoky Mountains National Park, and Shenandoah National Park. The concentrations are about half of the highest concentrations in western New York and Pennsylvania. The maximum sulfate concentrations in these parks were 2-3 mg/L during 1980-96. The concentrations were highest in the 1980s. The sulfate concentrations on Cape Cod National Seashore and in Shenandoah National Park are about equal. The concentrations are lower at low elevations in Great Smoky Mountains National Park. Sulfate concentrations in Denali National Park and Preserve were as high as 0.52 mg/L but were generally in the range of 0.1-0.25 mg/L, which is comparable to other low depositions in the western United States. During 1985-93, sulfate depositions declined significantly only in Shenandoah National Park.

Wet Nitrate

Nitrate concentrations in rain and snow on Cape Cod National Seashore and in Great Smoky Mountains and Shenandoah national parks were 0.6-1.2 mg/l. The concentrations were highest on Cape Cod National Seashore. Sulfate in these sites was always higher than nitrate. The nitrate concentrations in these parks were about half of the maximum concentrations in monitoring sites in Michigan, New York, and Pennsylvania. The low nitrate concentrations in Denali National Park and Preserve were in the range of 0.06-0.26 mg/l, which is comparable to concentrations in the western United States. However, the nitrate to sulfate ratio in Denali National Park and Preserve approaches 1, and in 1991 the nitrate concentration was greater than the sulfate concentration. No significant patterns of nitrate concentrations were observed in the eastern parks during 1985-93. However, nitrate concentrations in Denali National Park and Preserve increased significantly (Fig. 8a-d).

Hydrogen Ion

Hydrogen ion or acidity of wet deposition is expressed as pH, which is the negative log of the hydrogen ion concentration. The pH values on Cape Cod National Seashore and in Great Smoky Mountains and Shenandoah national parks are acidic in a range of 4.36-4.75. Lower pH values have been measured only in Pennsylvania and New York. In Denali National Park and Preserve, pH values are 5.15-5.60, approaching the 5.6 pH of theoretical unpolluted rain and are comparable to values in the western United States. Temporal trends in pH values during 1985-93 were not detected in these parks.

Ozone in NPS Units that Conduct Prototype Ecological Monitoring

In the ozone monitoring network of the National Park Service, the AVERAGE ANNUAL fourth highest 8-hour concentration during 1994-96 varied from 46 ppb (parts per billion) in Olympic National Park, Washington, to 105 ppb in Sequoia National Park, California. Five of the seven NPS units that conduct prototype ecological monitoring monitor ozone. Among them, the highest average ozone concentrations during

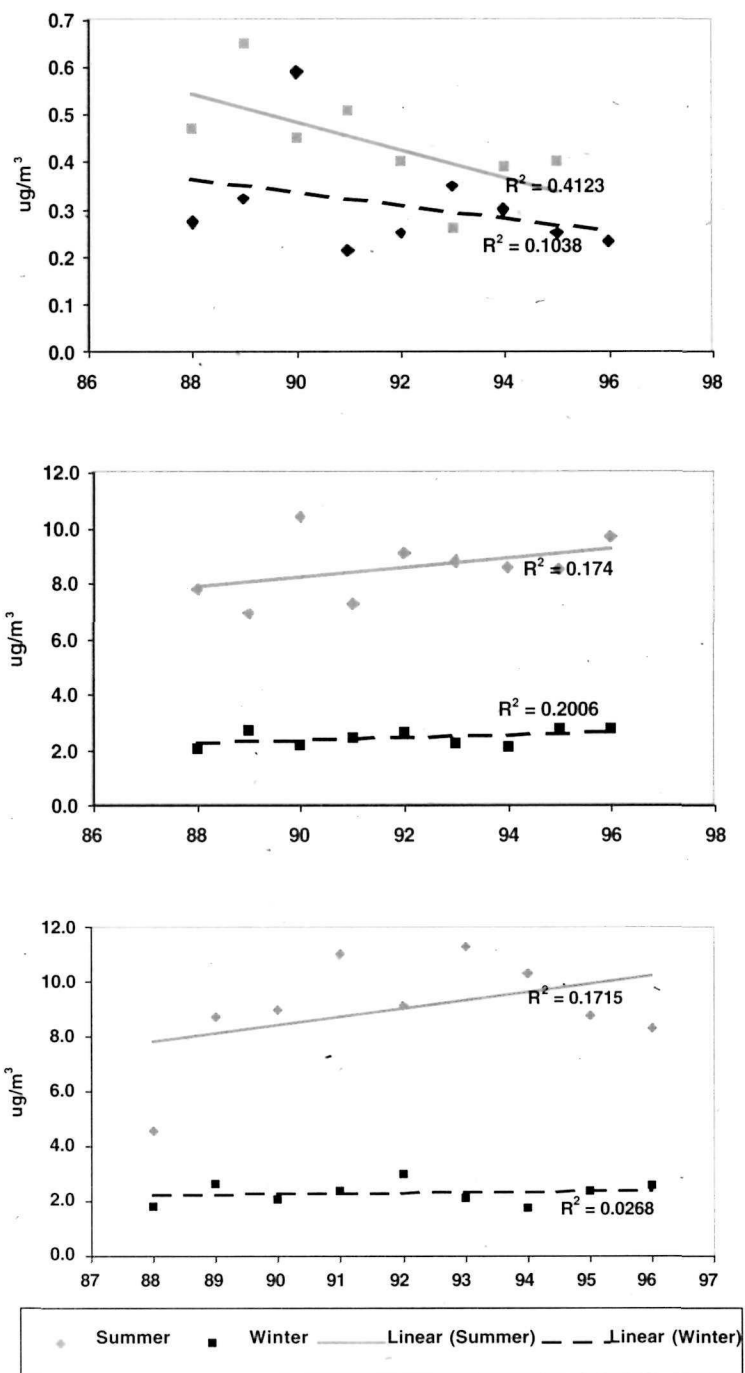


Figure 6 a-c. Seasonal mean sulfate concentrations in (top to bottom) Denali, Great Smoky Mountains, and Shenandoah national parks, 1987-1996.

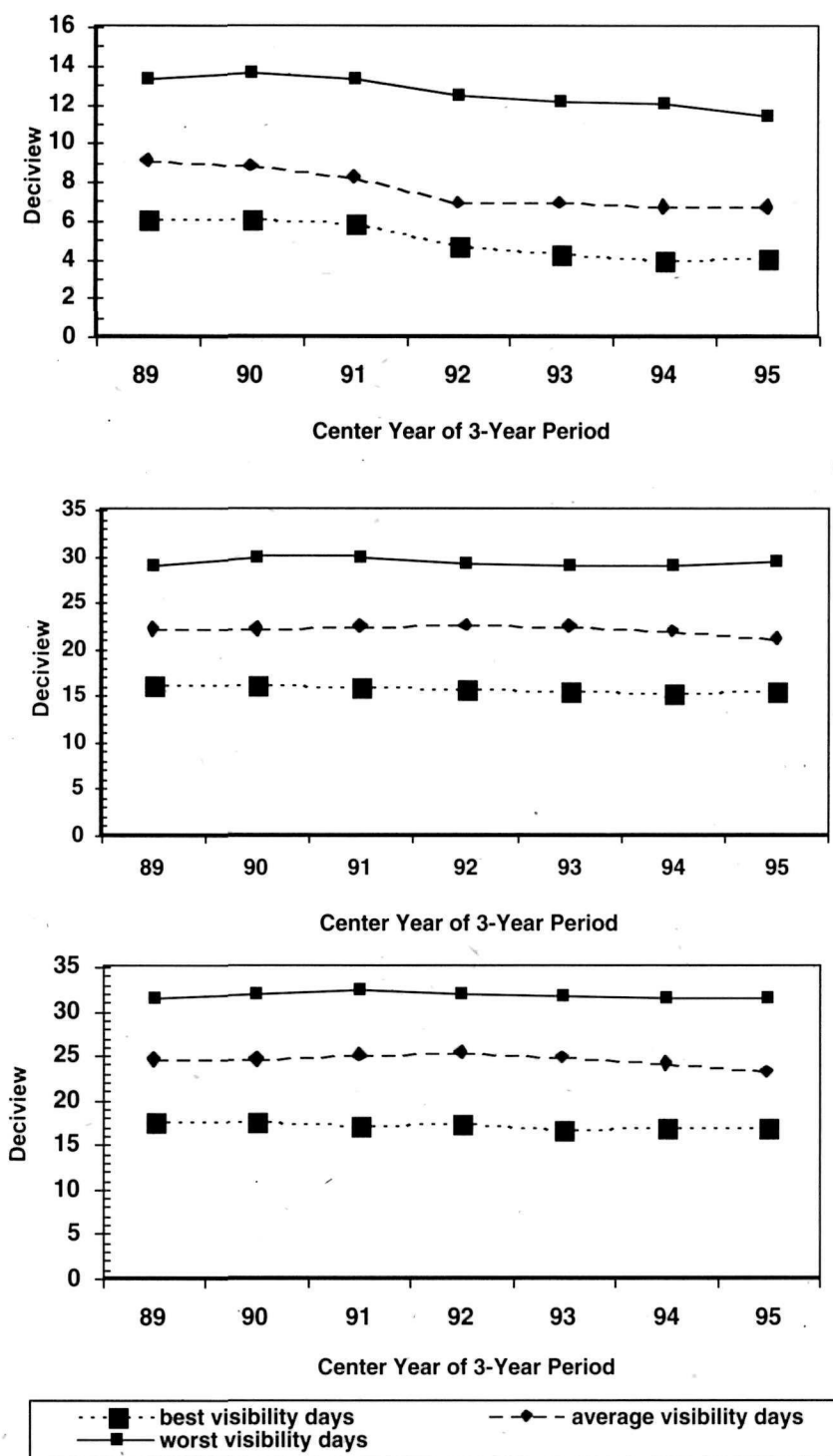


Figure 7 a-c. Three-year average visibility in deciview in (top to bottom) Denali, Great Smoky Mountains, and Shenandoah national parks, 1989-1995.

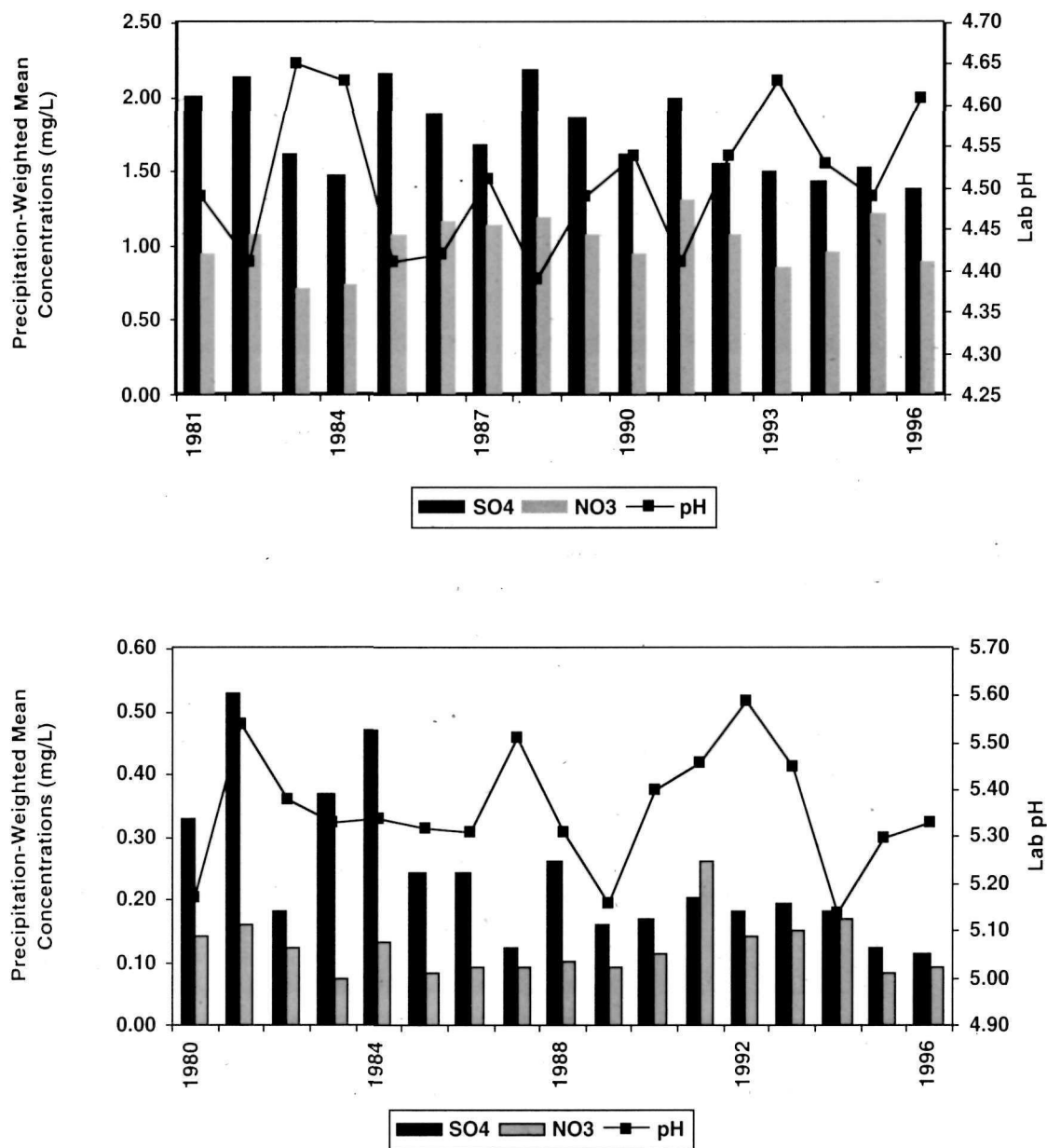


Figure 8 a-b. Annual average pH and precipitation-weighted mean sulfate and nitrate concentrations (mg/L) on Cape Cod National Seashore 1981-1996 (top) and in Denali National Park and Preserve 1980-1996 (National Atmospheric Deposition Program-National Trends Network).

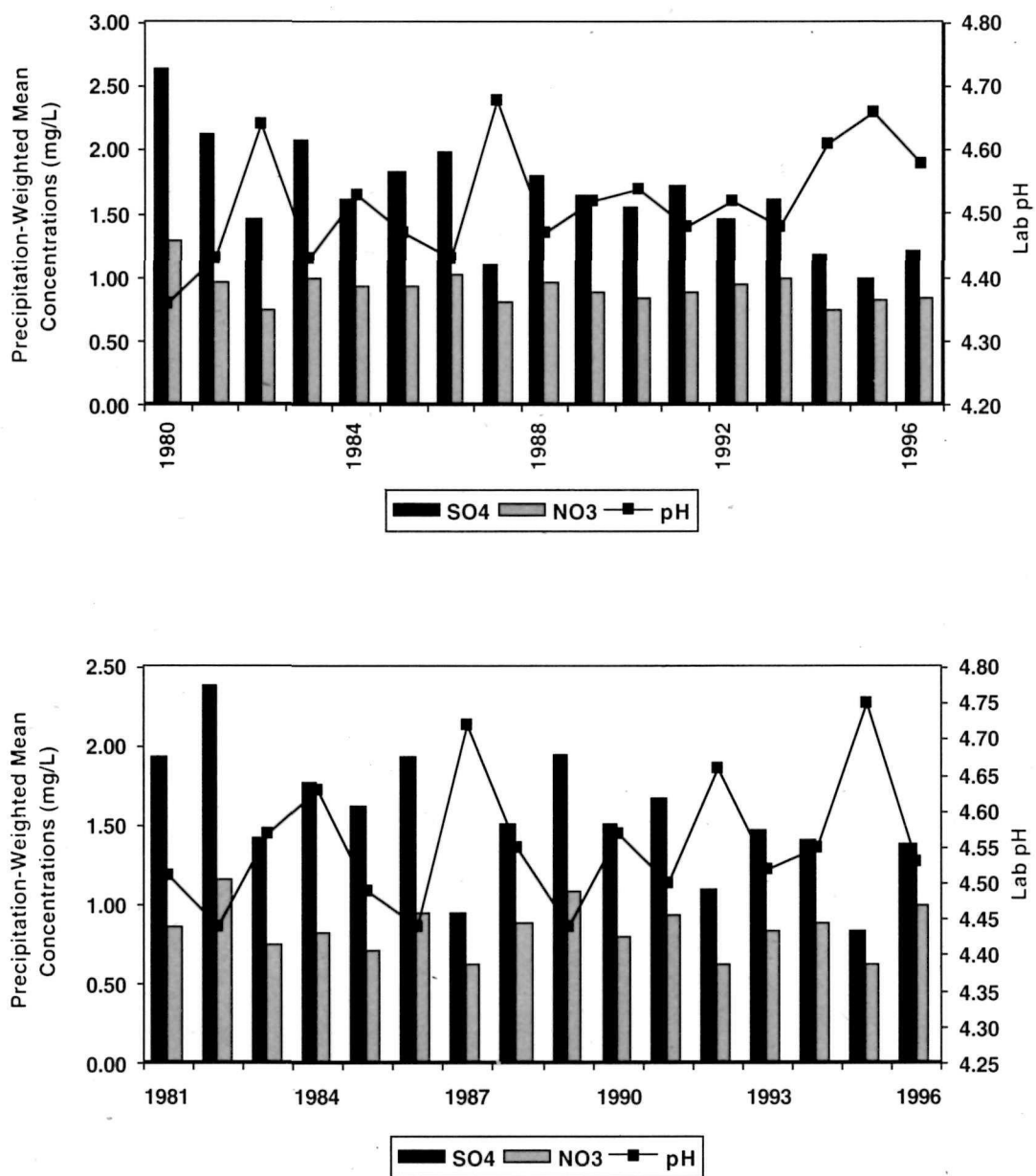


Figure 8 c-d. Annual average pH and precipitation-weighted mean sulfate and nitrate concentrations (mg/L) in Great Smoky Mountains National Park 1980-1996 (top) and in Shenandoah National Park 1981-1996 (National Atmospheric Deposition Program-National Trends Network).

1994-96 were on Cape Cod National Seashore and in Great Smoky Mountains and Shenandoah national parks. Ozone levels on Cape Cod National Seashore and in Great Smoky Mountains National Park (Look Rock site) exceeded the NAAQS standard. The 84 ppb in Shenandoah National Park approached the 85 ppb NAAQS standard. Concentrations in Channel Islands and Denali national parks were below the ozone standard. The average ozone concentration of 52 ppb in Denali National Park and Preserve during 1994-1996 was the second lowest such concentration in the NPS network and well below the national standard. The highest concentrations in the NPS network have consistently been recorded in southern California and in the East and the lowest in the Northwest and Alaska and on the northern plains and the Colorado Plateau (Fig. 9a-e).

Analysis of statistically significant long-term trends in ozone concentrations is in progress and is not available at this time. A qualitative inspection of the ozone charts suggests that 3-year average ozone concentrations on Cape Cod declined between 1989 and 1996, increased in Great Smoky Mountains National Park (Look Rock site) between 1990 and 1996, and varied little in Shenandoah and Denali national parks between 1989 and 1996. (Ozone monitoring in Channel Islands National Park ended in 1992 and commenced again in a new site in 1996. No ozone data were collected during 1993-95.) The 3-year average ozone concentrations of 1989 and 1990 in many sites in the eastern United States reflect the influence of unusually high ozone levels created by a long, hot, and dry summer in 1988.

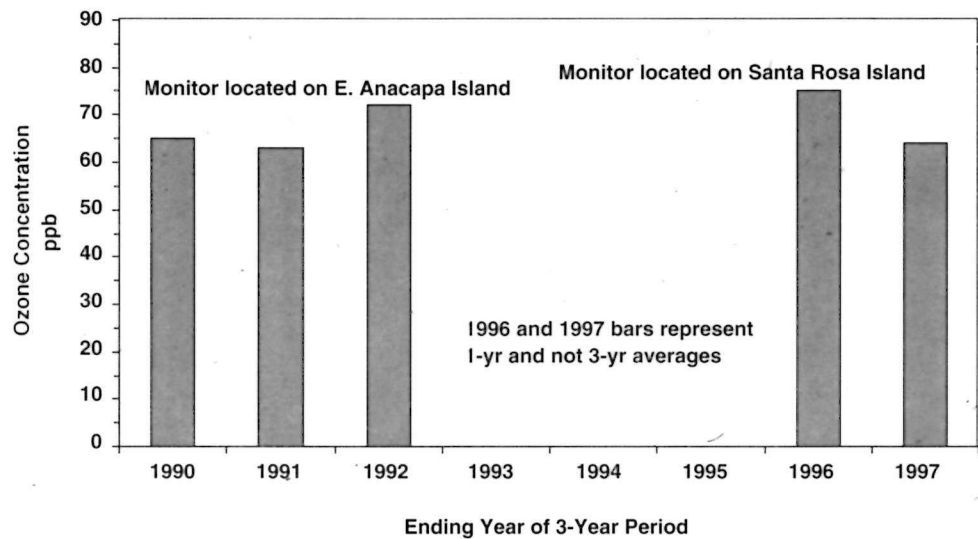
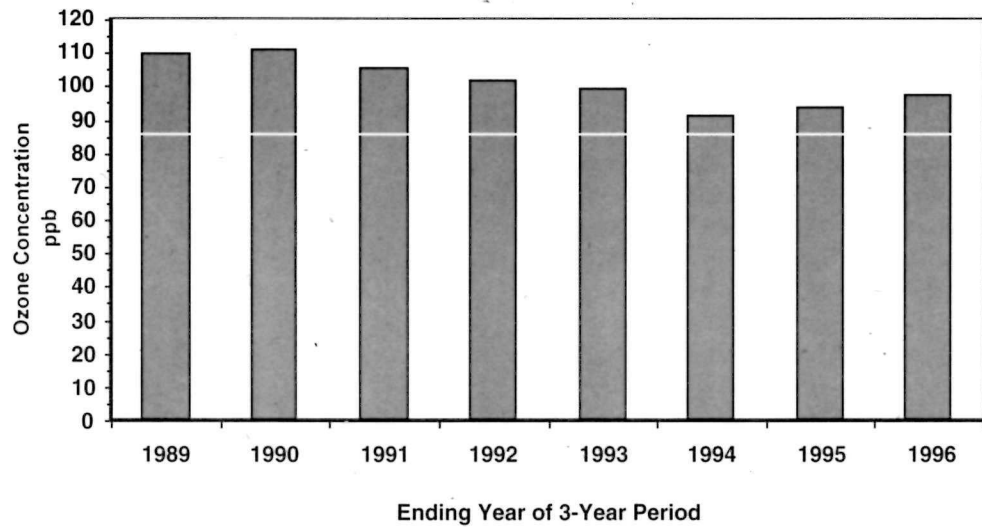


Figure 9 a-b. Three-year averages of the fourth highest daily maximum 8-hour ozone concentrations (parts per billion) on Cape Cod National Seashore 1989-1996 (top) and in Channel Islands National Park 1990-1997 (NPS Gaseous Pollutant Monitoring Network). 85 ppb=lowest ozone concentration that exceeds the National Ambient Air Quality Standard.

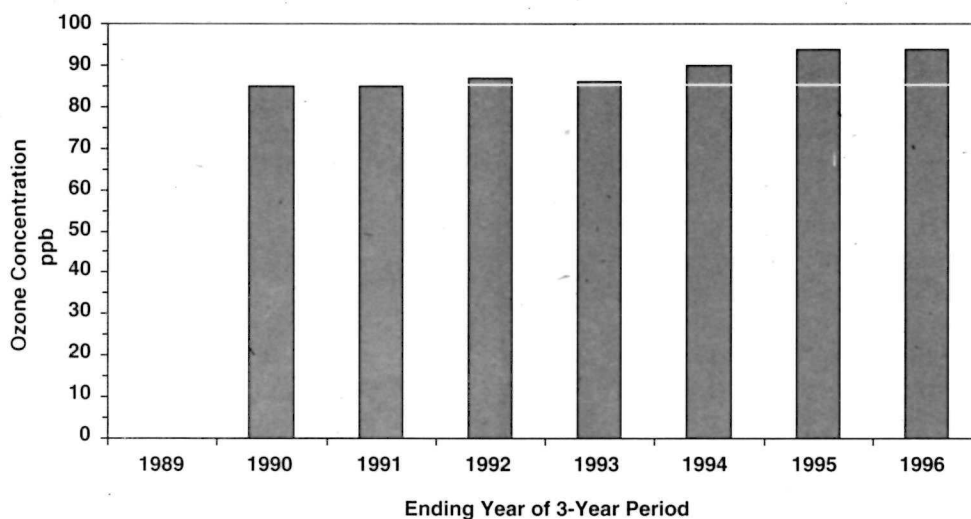
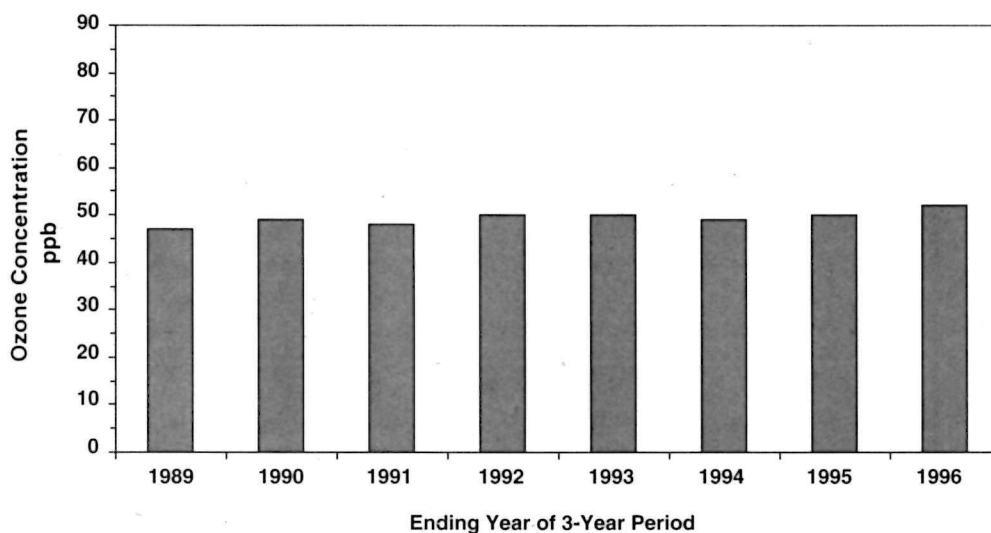


Figure 9 c-d. Three-year average of the fourth highest daily maximum 8-hour ozone concentrations (parts per billion) in Denali (top) and Great Smoky Mountains national parks 1989-1996 (NPS Gaseous Pollutant Monitoring Network). 85 ppb=lowest ozone concentration that exceeds the National Ambient Air Quality Standard.

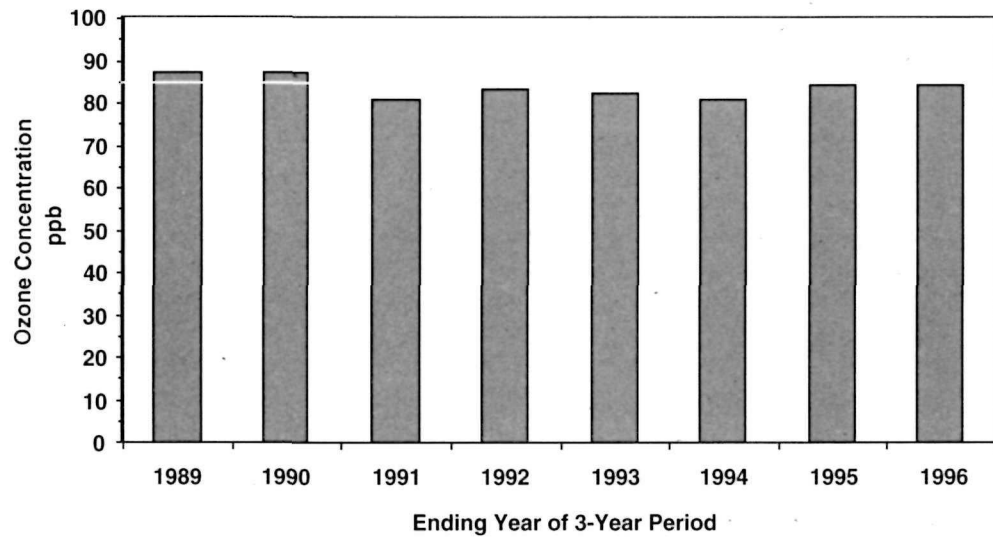


Figure 9 e. Three-year averages of the fourth highest daily maximum 8-hour ozone concentrations (parts per billion) in Shenandoah National Park 1989-1996 (NPS Gaseous Pollutant Monitoring Network). 85 ppb=lowest ozone concentration that exceeds the National Ambient Air Quality Standard.

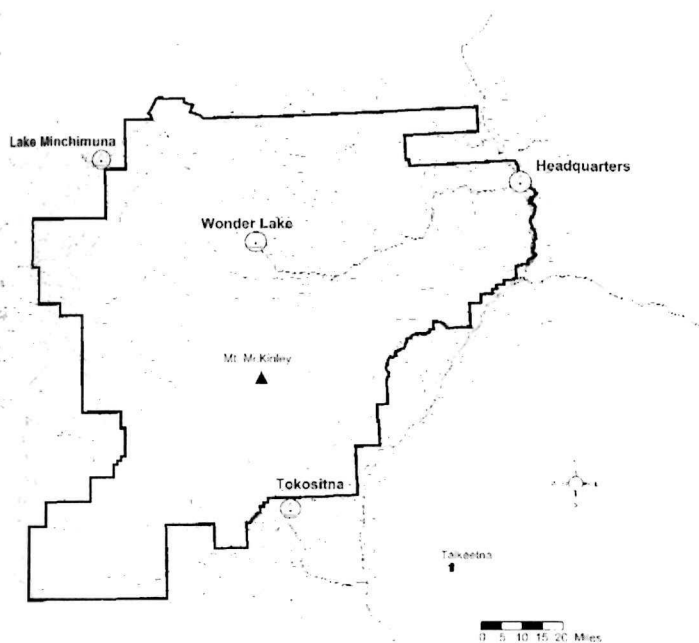
Weather in Denali National Park and Preserve, Alaska

Weather in Denali National Park has been monitored since 1922. This extended record in the northeast corner of the park has been invaluable for researchers of long-term changes in the region's natural resources and climate. Recognizing the need for evaluating the health of the Denali ecosystem, the National Park Service expanded monitoring of weather with the Inventory and Monitoring Program.

Initially, long-term monitoring was focused on ecosystem studies in the Rock Creek drainage, a headwater stream in the northeast of the park. Multiple weather stations were installed to gather data in support of various ecological research. Six automated stations at elevations of 700-1400 m (2300-4500ft) in the Rock Creek drainage are now in operation. Stations consist of electronic data loggers and various sensors that record basic parameters such as air temperature, relative humidity, precipitation, barometric pressure, wind speed, wind direction, and solar radiation. Four of the

Rock Creek stations are in intensive study plots where data on soil and snow conditions are also collected.

Weather monitoring, however, has not been limited to Rock Creek. In 1993, monitoring weather in more remote locations was initiated to gather data on the climate of the entire Denali region. With remote automated weather stations, installed with the assistance of the National Interagency Fire Center, weather information is gathered in two locations in the northwestern section of the park—McKinley River and Lake Minchumina. The network of the remote automated weather stations was expanded in 1995 to include a station at Wonder Lake and again in 1996 with the installation of a station on the south slope of the Alaska Range near the Tokositna River. The stations have been subjected to a range of typical problems in remote areas in Alaska. The problems include damage by bears and extended downtime because of difficult access for maintenance. Nevertheless, the stations have functioned well and have generated useful data for comparing the differences in climate throughout the region.



Weather stations at Headquarters, Lake Minchumina, Tokositna, and Wonder Lake help with characterizing park-wide weather patterns in Denali National Park and Preserve, Alaska.

Weather data from throughout the park reflect the typical climates of south-central and interior Alaska. To the south, the climate around Cook Inlet and the Gulf of Alaska is maritime. The southern slope of the Alaska Range is heavily influenced by that climate, and the range of temperature there is therefore more moderate than elsewhere in the park (Fig. 10). It receives more rainfall than any location in the northern half of the park. For example, in one month in summer 1997, the Tokositna Station received as much as three times more precipitation than the Lake Minchumina or Park Headquarters stations (Fig. 11).

In contrast to the maritime influences on the southern slope of the Alaska Range, the greater temperature extremes and lesser precipitation north of the range reflect a continental climate, the intensity of which varies from west to east along the north slope of the Alaska Range. The variation is in part a function of proximity to the crest of the range. Park Headquarters is on the lee side of the warmer climate to the south within

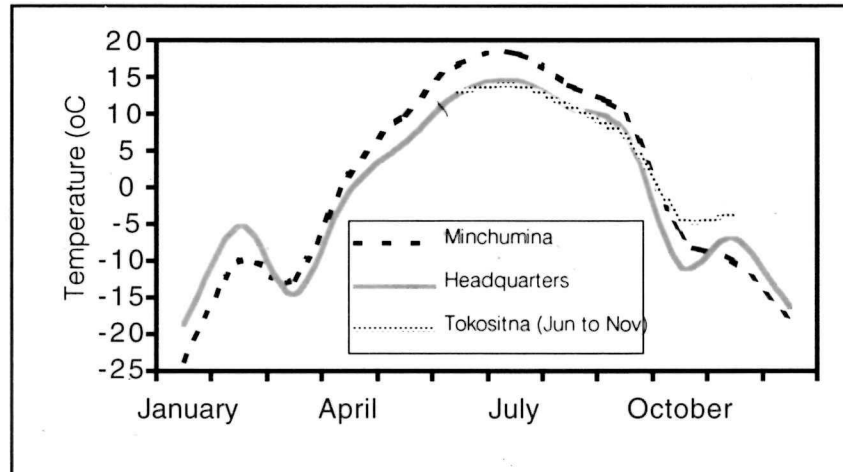


Figure 10. Monthly average temperature at three weather stations in Denali National Park and Preserve, 1997.

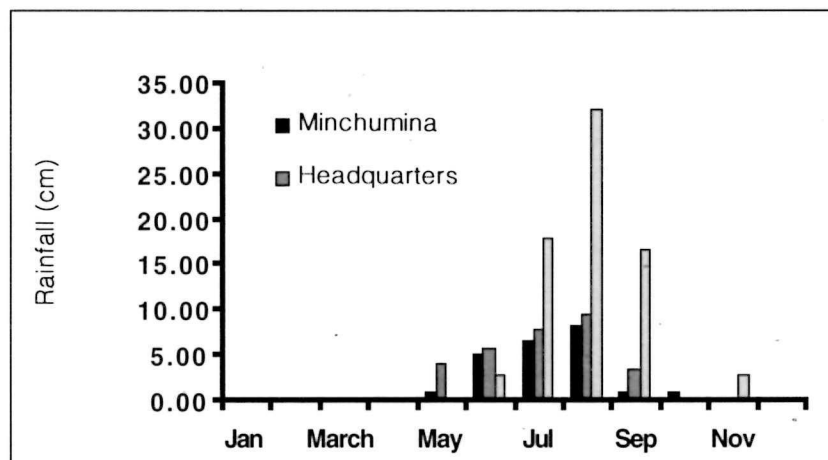


Figure 11. Monthly total rainfall at three weather stations in Denali National Park and Preserve, 1997.

25 km (15.5 mi) of the crest of the Alaska Range. It is affected by a down slope wind that causes higher average temperatures than in areas farther to the north. Lake Minchumina, located more than 100 km (62 miles) north of the crest, does not experience these lee side effects. The proximity to the crest of the Alaska Range has a similar effect on precipitation in the north. The park headquarters area receives slightly more rainfall than Lake Minchumina.

The pattern of regional weather flow along the north slope of the Alaska Range also influences the degree of the continental climate. The western half of the park receives weather that flows from the southwest along the range front. The southwesterly flow originates in the Bering Sea and is colder than the air masses from Cook Inlet on the south slope and comparatively dry by the time it reaches the park. This effect dominates the climate at Lake Minchumina. In contrast, the park headquarters area is sometimes influenced by weather that moves from the south through passes over the Alaska Range or over the relatively low crest of the range east of Mt. McKinley. The park headquarters area is, therefore, in a mixing zone between the southwesterly flows that parallel the northern slope of the range and the occasional maritime influences of the climate to the south. This is another reason why the climate at headquarters is somewhat warmer and wetter than the climate at Lake Minchumina and in the western half of the park.

The wide range of climatic conditions contributes to a diversity of ecosystems in Denali National Park and Preserve. Information from the Inventory and Monitoring Program supports research into resources beyond the boundaries of Rock Creek.

Salt Marsh Restoration on Cape Cod National Seashore, Massachusetts

The coastal salt marshes of the outer Cape Cod developed when the rising Atlantic Ocean flooded glacial outwash valleys during the past 2000-4000 years. The salt marshes are a vital component of the Cape Cod coastal ecosystem. Organic material from the marshes is responsible for the high productivity of fishes and shellfishes in the ocean and in adjacent estuaries. Salt marshes also provide rich feeding areas for migratory birds.

Most of the salt marshes in the Cape Cod Bay on Cape Cod National Seashore and in many other parts of the cape have been partially altered by dikes, railroad grades, and other structures. The structures have restricted or eliminated tidal flow into the marshes. In addition, many marshes have been drained for mosquito control. The altered conditions from the reduced tidal exchange effected the replacement of natural salt marsh vegetation like smooth cordgrass (*Spartina alterniflora* Loisel.) with common reed (*Phragmites australis* (Cav.) Trin. ex Steud.) that is characteristic of degraded and disturbed salt marshes.

Restoration of a 36.5-ha (90-acre) salt marsh in Hatches Harbor is planned in 1998. The restoration requires the installation of new concrete box culverts in the earthen dike to increase tidal water exchange. Flooding depth, pore water salinity, sulfides, and biomass of smooth cordgrass in the marsh were determined in 1997 for an evaluation of recovery after restoration. For further evaluation of changes after restoration of normal tidal flow, comparisons of the same variables were made between the salt marsh in Hatches Harbor (experimental site) and a marsh immediately outside the Hatches Harbor dike (control site). The comparison in 1997 revealed that as expected most of the control site de-watered at every low tide, whereas 10-20 cm (~4-8 inches) of water remained on the experimental site during low spring tides throughout the 7-day tidal cycle. Total sulfite concentrations in pore water were below detection (<10mM) in the control site and in most of the experimental site. However, it exceeded 100 mM in one area of the experimental site where flooding was most prolonged. Salinity did not exceed 34 ppt in either the

control or the experimental site. Salinity ranged from 29 to 33 ppt in the control site and from 0 to 32 ppt in the experimental site where saltwater inflow is restricted. In 1998, monitoring of water levels, salinity, and sulfide will be continued. Observations will begin 2 hours before predicted low water levels in Cape Cod Bay.

Kelp Forests in Channel Island National Park, California

Brown algae consist of about 1500 species of multicellular protists that occur almost exclusively in the sea. In many northern regions, they are the most conspicuous seaweeds and dominate rocky shores almost everywhere in temperate North America. Photosynthesis by the larger brown algae, particularly a group known as the kelps (Order Laminariales) is responsible for most of the food production where these plants are abundant. Kelps have variously shaped parts: flattened blades, stalks, and grasping basal portions that anchor the plants to the rocks. Kelps of the genus *Macrocystis* can reach lengths of 100 m. The flattened blades of these species float on the surface of the water. Some of the larger kelps form extensive beds sometimes called forests that are harvested commercially for sodium and potassium salts, iodine, and alginates that are used in the formation of gels. The organic matter that kelps produce supports fishes and invertebrates and some marine mammals and birds that live among the seaweeds and feed on them or on other animals that live there.

Majestic kelp forests are precious natural resources in Channel Islands National Park and have been monitored there since 1982. Exceptionally ferocious storms in 1982-83 that were attributed to a strong El Nino current severely damaged kelp forests throughout southern California and the Channel Islands. Because El Nino infused nutrient-poor warm water into the area, new kelp plants starved in the following summer. A succession of storms in subsequent years and feeding on the plants by sea urchins (*Strongylocentrotus franciscanus*, *S. purpuratus*) also impeded the recovery of the kelps.



Salt marsh in Hatches Harbor on Cape Cod National Seashore, Massachusetts.
Normal tidal flow and typical salt marsh vegetation will be restored in 1998.

Sea urchins feed on kelp—particularly drift kelp that has broken off the living plant—and reproduced abundantly in response to the wealth of drift kelp after the storms. Seastars (*Asterina miniata*, *Pisaster giganteus*), fishes, and lobsters (*Panulius interruptus*) usually prey on young sea urchins. However, the abundance of fishes and lobsters was depressed from excessive harvests. The seastars either moved into deeper, colder water or succumbed to a wasting disease from unknown bacteria that seemed to have arrived in the warm water of El Niño. The demise of kelp forests in many areas was caused by the exceptionally large populations of sea urchins in subsequent years. Where strong storms in the 1980s reduced the abundance of sea urchins, seastars returned and kelps recovered, at least until the occurrence of another strong El Niño in 1997 (Figs 12-14).

When in 1997 El Niño again caused severe storms and brought exceptionally warm water into the area, the kelp forests in the park had not yet recovered. In early summer, the remaining kelps already were pale and tattered, which is an indication of poor growth. By the end of the year, after storms in fall and winter, most kelp forests in the park had been destroyed.

Coral Reefs in Virgin Islands National Park

Most coral reefs around the islands of St. Croix, St. John, and St. Thomas in the US Virgin Islands are shal-

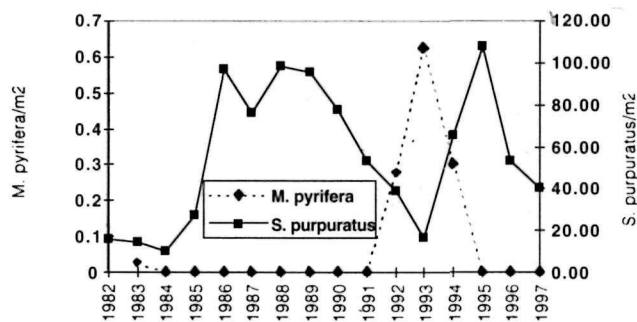


Figure 12. Densities of kelp, *Macrocystis pyrifera*, and sea urchins, *Strongylocentrotus franciscanus*, at the sea lion rookery, Channel Islands National Park, 1982-1997. When the density of the urchins increased, the density of the kelp decreased.

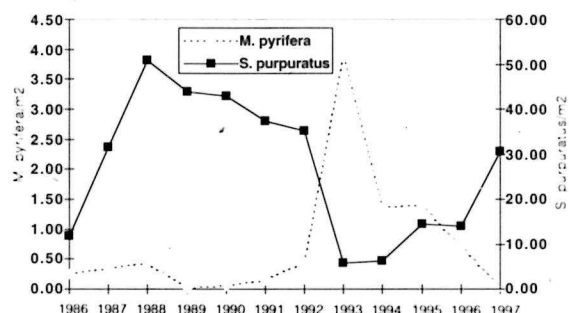


Figure 13. Densities of kelp, *Macrocystis pyrifera*, and sea urchins, *Strongylocentrotus franciscanus*, at Cat Canyon, Channel Islands National Park, 1986-1997. When the density of the urchins increased, the density of the kelp decreased.

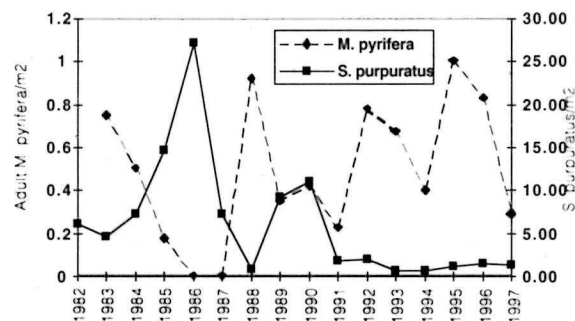


Figure 14. Densities of kelp, *Mycrocystis pyrifera*, and sea urchins, *Strongylocentrotus purpuratus*, at Johnson's Lee South, Channel Islands National Park, 1982-1997. When the density of the urchins increased, the density of the kelp decreased.

low fringing reefs that parallel the islands' coastlines. Many are true coral reefs on frameworks of coral skeletons that have been deposited over thousands of years. Elsewhere, coral reef organisms grow on submerged boulders and rock ridges near shore. Submerged bank reefs—some with spur and groove formations—also occur in deeper water. Reefs grow on the walls of the Salt River Canyon, a drowned river valley (i.e., an estuary) on the northern shore of the St. Croix island. Extensive barrier reefs with well-de-

lined lagoons do not occur around St. John and St. Thomas. In some locations, fringing reefs extend from rocky headlands at bay entrances. They cut off back-reef areas and may lead to the formation of salt ponds. More than 40 species of scleractinian corals have been found on reefs of the US Virgin Islands. The total cover of living coral on the reefs is typically less than 40% but more in some reef zones.

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

Monitoring of reefs in the Lameshur and Newfound bays in 1996-97 indicated little change in the amount of living coral in either site. The coral cover in Lameshur Bay is still only about 10%, reflecting the lack of recovery since Hurricane Hugo damaged this reef in 1989. Live coral in Newfound Bay is about 20%. The amount of macroalgae (seaweed), which often is a good indicator of overall reef condition, fluctuates widely in Lameshur Bay where it sometimes reaches mean values of more than 30% but remains consistently low (less than 10%) in Newfound Bay.

Data from study sites in the Lameshur and Newfound bays and from other permanent study sites around St. John are supplemented with underwater videography. Videography is used on reefs in Florida and elsewhere to monitor corals and other benthic organisms. The protocols for videography are being modified for Virgin Islands National Park, Buck Island Reef National Monument, and Dry Tortugas National Park. The videotapes from analog and digital video cameras are compared, and tapes from a variety of reefs are quantitatively analyzed. Underwater videography permits efficient use of a diver's time underwater and provides visual records that can be archived and compared with subsequent images. The optimum number of transects

per site, the number of frames per transect, and the number of identification points per frame that adequately characterize and reveal changes in the coral reef will be determined.

Since July 1997, new coral diseases around St. John have been recorded. Some are similar to diseases or conditions that have been reported from Florida and from other Caribbean islands. Colonies of the dominant coral (*Montastraea annularis*) around St. John and to a lesser degree colonies of other species lost pigment or tissue. Bright white areas of exposed skeleton are rapidly colonized by algae. The disease is appearing on numerous reefs around St. John, including on some that are least disturbed by human activities. The affected coral species, the depth of occurrence, the water temperatures, and the degree of recovery by the corals are documented with videography and still photography. A potential pathogen (a bacterium) has been isolated by a microbiologist of the Florida International University. Samples of diseased and healthy coral mucus and tissue from St. John have been collected and sent to microbiologists of the University of South Carolina for culturing, isolation, and identification. Presently, pathogens have been identified for only two coral diseases. The fungus *Aspergillus sydowii* causes disease in sea fans (*Gorgonia ventalina*), and a suite of bacteria and fungi are associated with black band disease. The fungus was isolated and identified from an air sample during an African dust storm on St. John in July 1997. Because the fungus cannot reproduce in seawater but was viable in the air sample, the source of the fungus is of great interest. Monthly air samples are now taken in areas off St. John.

Coral Reefs in Buck Island Reef National Monument, Virgin Islands

Coral reefs in Buck Island Reef National Monument have been monitored since the late 1970s. Information about coral, fishes, and underlying marine geology has been collected in all major habitats of the eastern barrier reef of the monument. In September 1989, Hurricane Hugo devastated Buck Island with sustained winds of 5.2 m/min (140 mph) and gusts of 7.5 m/min (200 mph). It was the most severe hurri-

cane in more than 50 years and severely damaged the reefs. Damages of the coral reef by Hurricanes Luis and Marilyn in December 1995 were patchy and not as severe.

Comprehensive monitoring in 1996 revealed obvious signs of recovery from hurricane damage. Most whole coral heads of star coral (*Montastrea annularis*) and brain coral (*Diploria strigosa*) survived the effects of the hurricanes, although many sustained heavy partial mortality. Mortality of mustard hill coral (*Porites astreoides*) was more extensive but caused in part by a higher rate of natural mortality from chronic factors, and the population levels seem to have been maintained by successful recruitment. Monitoring in 1996 also revealed that populations of star coral (*M. annularis*) are maintained by the persistence of colonies over extremely long time without little if any recruitment. Brain coral (*Diploria strigosa*) is maintained by colony persistence and sporadically good recruitment, whereas Mustard hill coral (*P. astreoides*) has low persistence but high recruitment. Despite severe localized damage from the storms, these processes have remained essentially unchanged during the unusually high frequency of hurricanes since 1989.

Sampling of coral was continued in 1997. Several surveys of the reef system were made to determine the presence of coral diseases. In November, less than 1% of the coral was affected. Upgrading of the stake system for monitoring and development of a protocol for monitoring with videography were initiated. A level of monitoring that resource managers of the National Park Service can maintain must be determined.



Elkhorn coral, *Acropora palmata*, barrier reef in Buck Island Reef National Monument, US Virginia Islands

Prairie, Glade, and Woodland Plant Communities, Great Plains Prairie Cluster

The prairies of North America developed from the interaction of climate, grazing, and fire. Fire was caused by lightning and set by native people. Since European settlement, most of the tallgrass prairie and a significant portion of the mixed grass prairie have been lost to intensive agriculture and urban development. Fire and grazing, which greatly influence species diversity, have been eliminated or altered by human control. Fragmentation of the prairie and concomitant local extinction and fewer neighboring populations for re-colonization have led to a loss of species diversity.

The six historic or cultural parks of the Great Plains Prairie Cluster are small but include some of the last remnants of the prairies that once blanketed the region. Because of the loss of pre-settlement disturbance regimes and landscape fragmentation, management is needed to preserve and restore the native plant communities of these parks. The goals of monitoring prairie plant communities in the six prairie cluster parks are the detection and assessment of changes over time. Park managers are interested in learning how native prairie remnants are influenced by landscape fragmentation, exotic plants, and prescribed fire. They also want to know whether the restoration of a diverse array of native prairie species in former agricultural and disturbed areas was successful.

During the 1996 field season, trials of plant community sampling methods were conducted in three of the prairie cluster parks. In 1997, nine plant communities in four parks (Effigy Mounds National Monument, Iowa; Pipestone National Monument, Minnesota; Scotts Bluff National Monument, Nebraska; and Wilson's Creek National Battlefield, Missouri) were monitored. Two

hundred and twenty 10-m² plots were established, and species composition in each plot was sampled twice during the growing season.

Preliminary results indicate that species richness and diversity were highest in the goat prairies in Effigy Mounds National Monument and in the limestone glades and oak woodland of Wilson's Creek National Battlefield (Table 5). The richness and diversity of the goat prairies and limestone glades are high although woody invasion after fire suppression reduced the size of these communities. Species richness may be higher in these naturally fragmented communities because of small-scale heterogeneity. However, the position of some plots in transition areas between prairie and adjacent savanna and woodland may have affected the results.

Table 5. Number of plots, species richness, species diversity, and relative cover of native and exotic plant species by community type. Great Plains Prairie Cluster, 1997.

Park	Community Type	Plots	Species Richness (Native Species)	Shannon Diversity Index	Relative Cover (%)	
					Native	Exotic
Scotts Bluff National Monument	Mixed grass prairie	33	51 (45)	1.64	96	4
	Degraded mixed grass prairie	35	39 (33)	1.85	67	33
	Ponderosa pine woodland	20	54 (50)	2.37	94	6
Pipestone National Monument	Sioux quartzite prairie	10	63 (54)	2.70	75	25
	Restored tallgrass prairie	30	76 (59)	2.68	50	50
Effigy Mounds National Monument	Goat prairie	46	163 (145)	3.66	93	7
	Restored tallgrass prairie	30	92 (81)	2.80	84	16
Wilson's Creek National Battlefield	Limestone glade	30	123 (102)	3.57	80	20
	Oak woodland	30	102 (94)	3.31	99	1

An examination of the relative cover of native and exotic plants indicated that three of the remnant communities (limestone glades in Wilson's Creek National Battlefield, Sioux quartzite prairie in Pipestone National Monument, and degraded mixed grass prairie in Scotts Bluff National Monument) are threatened by the invasion of exotic species (Table 5). The cover of exotic species in these communities ranges from 20% in the limestone glades to 33% in the degraded mixed grass prairie. By contrast, the invasion by exotic species of the goat prairies in Effigy Mounds National Monument and the oak woodland in Wilson's Creek National Battlefield is low.



Sampling prairie vegetation in Scotts Bluff National Monument, Nebraska



Goat prairie at the Mississippi River in Effigy Mounds National Monument, Iowa

Monitoring also revealed that the restoration of prairie communities is at different stages. Species richness and diversity are high and the level of exotic cover is low in the restored tallgrass prairie of Effigy Mounds National Monument. In the restored tallgrass prairie of Pipestone National Monument, however, the cover of exotic plant species is still 50% and the number of native species is not as high. Clearly, restoration of the tallgrass prairie of Pipestone National Monument must be continued.

In 1998, vegetation sampled in 1997 will again be sampled. New plots will be established for vegetation sampling in Agate Fossil Beds National Monument and Homestead National Monument of America in Nebraska. Data from 1997 and 1998 will be used as a baseline for future monitoring.

Effects of Climate Change on Vegetation at Tree Line in the Rock Creek Watershed, Denali National Park and Preserve, Alaska

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

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

Vegetation monitoring in the initial phase of long-term ecological monitoring in Denali National Park and Preserve in 1992 was designed to detect responses to global warming in the boreal forest-upland tundra ecotone against the background of natural variation. Specific objectives were:

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

Study design is based on and compatible with the Bonanza Creek Long-Term Ecological Research site near Fairbanks, where boreal forest communities at a

lower elevation are monitored. In the Rock Creek watershed, monitoring is focused on four major vegetation types along a gradient from about 830 m to 1260 m (2723-4134 ft) above sea level. The plant communities range from riparian broad-leaved forest and conifer forested slopes through tree line to alpine tundra. Elevation at the tree line is about 1200 m (3937 ft).

The early snowfall in 1992 damaged and killed trees region-wide in the park and at Bonanza Creek. Although the annual growth of diameter in white spruce was similar in the forest and at tree line, it was less in a comparably aged stand at low elevation at Bonanza Creek. Crops of white spruce cones have been small to moderate, and only few viable seeds dispersed each year. Data from several more years are needed to evaluate the relation between climatic measurements and white spruce growth and reproduction.

In 1997, National Park Service personnel collected data on the condition, growth, cone production, and seed viability of white spruce and on the phenology and berry crops in four plant communities in the Rock Creek watershed. The berry productivity in the tundra and forests was substantially higher in 1997 than in previous years (Figs 15-16). Crowberries (*Empetrum nigrum*) were 57% of the total crop. However, blueberry (*Vaccinium uliginosum*) has been the dominant producer at tree line. For example, blueberries were 90% of the berry crop at tree line in 1995.

The number of white spruce cones in the forests and at tree line was significantly higher in 1997 than in 1996 (Fig. 17). However, the viability of white spruce seeds remained low. As in past years, the mean growth rate of white spruce was higher in forests than at tree line (Fig. 18). No major changes in tree condition (mortality and structural damage) were noted either in riparian forests or at tree line.

In 1998, the integration of vegetation data with data about other resources—for example, climate and soils—in the Rock Creek watershed will be a major focus to determine changes in vegetation since 1992. Subsequent comparisons with similar data from other boreal forests are expected to reveal region-wide trends on a landscape scale.

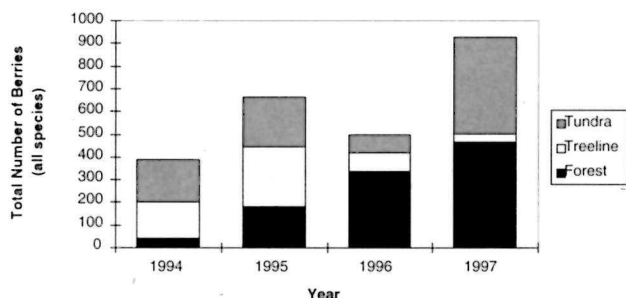


Figure 15. Annual berry crop in three types of plant communities in the Rock Creek watershed, Denali National Park and Preserve, 1994-1997.

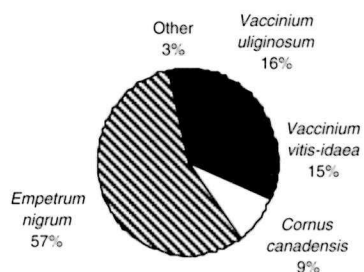


Figure 16. Percent composition of berry crops by species in three types of plant communities in the Rock Creek watershed, Denali National Park and Preserve, 1997.

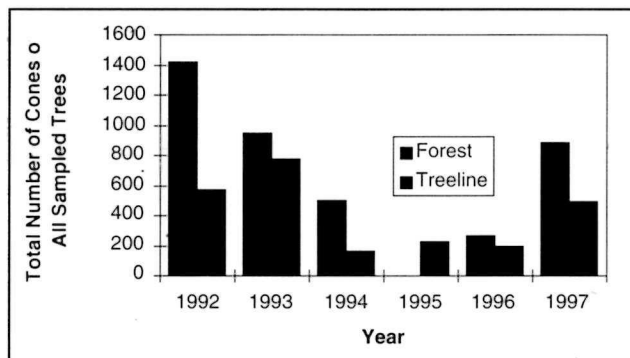


Figure 17. Annual cone production of white spruce, *Picea glauca*, in two types of plant communities in the Rock Creek watershed, Denali National Park and Preserve, 1992-1997.

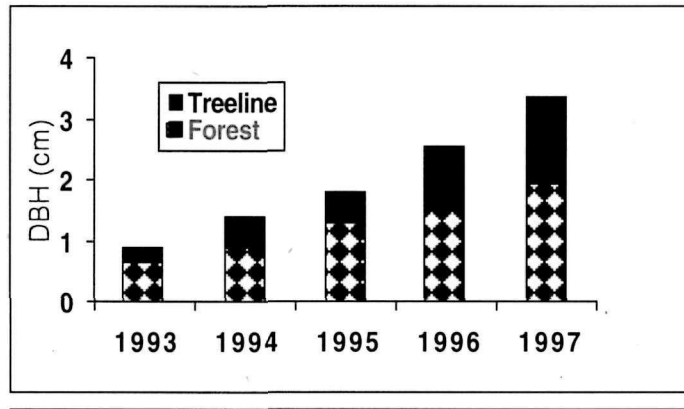


Figure 18. Cumulative growth of white spruce, *Picea glauca*, in two types of plant communities in the Rock Creek watershed, Denali National Park and Preserve. Growth is expressed in diameter at breast height (DBH).

Long Term Vegetation Monitoring in Great Smoky Mountains National Park, Tennessee and North Carolina

The goals of vegetation monitoring in Great Smoky Mountains National Park are the detection, assessment, and quantification of change particularly anthropogenic change—in vegetation over time. When completed, a park-wide network of permanently marked plots will be sampled, and the information will be used for management of vegetation or for the design of specific studies of vegetation.

Information from long-term vegetation monitoring will be used for the management of vegetation with prescribed fire. Whereas fire has been suppressed since the establishment of the park more than 60 years ago, current management includes letting natural fires burn and setting prescribed fires. Fire will be used to promote vegetation that requires fire for regeneration and to restore fire-dependent habitat for specific fauna such as the federally listed endangered Red-cockaded Woodpecker (*Picoides borealis*). In 1997, eight plots were made in two areas where the Red-cockaded Woodpecker nested in the past. These areas will be treated with prescribed fire to restore habitat for the woodpecker. Vegetation and forest litter in the plots were sampled according to standard protocols of the National Park Service, which were modified slightly.

The modified protocols are compatible with the protocols for long-term monitoring of other vegetation plots in the park and with the protocols of the North Carolina Vegetation Survey. The modified protocols provide the collection of data in a format that permits easy comparison with data from other areas of the Southern Appalachians and from many other National Park System units.

The Red-cockaded Woodpecker last nested in the park in the 1980s. The bird seeks nesting cavities in older live pines that are surrounded by hardwoods. Such habitat has become rare in the park because of the long history of fire suppression. Restoration of such habitat may take many years and requires fire.

One of the habitats was burned to lower the hardwood species component, enhance the reproduction of pines (*Pinus* spp.), and lower accumulated forest litter that could fuel catastrophic crown fires. The fire decreased the accumulated duff and litter from more than 11 t/ha (>30 t/acre) to less than 5.5 t/ha (<15 t/acre). Monitoring and further treatment with fire will be continued to prevent the accumulation of litter and to further the restoration of the favored habitat of the Red-cockaded Woodpecker.

American Columbo in Cades Cove, Great Smoky Mountains National Park, North Carolina and Tennessee

Browsing of American columbo (*Frasera caroliniensis* Walt.) by white-tailed deer (*Odocoileus virginianus*) has been evident since 1987 when the plant was first discovered in the Great Smoky Mountains National Park. American columbo is a long-lived perennial herb in the Gentian family that has been monitored in Cades Cove in the park since 1988. The species is not federally listed as rare but is considered rare in the park. All three populations in the park are in Cades Cove, the eastern edge of the species' range. The populations receive significant pressure from browsing by deer.

The stability of the American columbo populations is not known. The plants may take advantage of disturbances in canopies of early-succession trees. The largest population is on a limestone outcrop with a southwestern exposure that was used for grazing livestock prior to the establishment of the park. Because the canopies in the three sites are increasing, tracking American columbo has become a priority in natural resource management. The smallest population has lost about 30 plants since 1988 and has shown no signs of reproduction. Because the plants reproduce only by seed, the species may be vulnerable to extirpation from heavy browsing by white-tailed deer, which prevents flowering. The plants in one population have periodically flowered. As many as 103 flowering plants were observed in 1994. Only one plant of the second population flowered in 1994.

The number of browsed American columbo has, however, decreased since 1992. This may be attributable to a decline of the density of white-tailed deer in Cades Cove. The abomasal parasite count, which correlates with deer density, suggests the size of the deer herd in Cades Cove is at its lowest since monitoring of the parasite began in 1989 (Fig. 19). Much of the sampling was done before the monitoring program was approved as operational, and inter-component sampling was therefore not coordinated. Still, the data suggest heavy browsing by deer on American columbo during approximately 2 years before high internal parasite loads were seen in the deer. If this finding is confirmed, American columbo may prove to be a useful

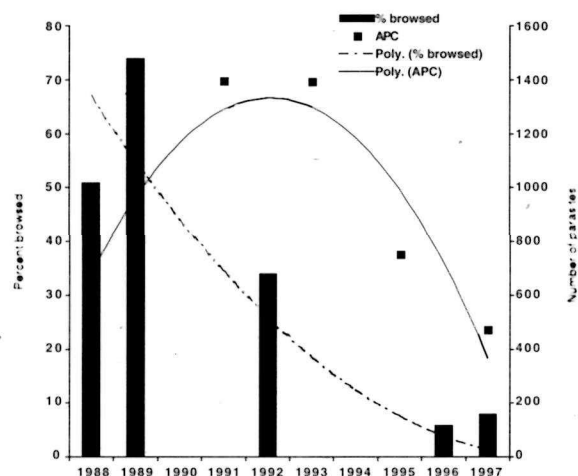


Figure 19. Browsed (%) American columbo, *Frasera caroliniensis* Walt., and number of abomasal parasites in Cades Cove, Great Smoky Mountains National Park, 1989-1997.

example of a rare, palatable plant as an indicator of deer herd health. Yearly monitoring of American columbo will be continued. (However, yearly monitoring of the abomasal parasite, which requires sacrificing deer, is not desirable and will not be done.)

White Mandarin and Sword-leaved Phlox in Shenandoah National Park, Virginia

Monitoring of two rare plant species was continued during 1997. White mandarin (*Streptopus amplexifolius*), an extremely rare species in Virginia, is found in two locations in Shenandoah National Park. One of these populations has been monitored since its discovery in 1990. Until 1997, the population consisted of 10-20 individuals. In 1997, none was seen. This abrupt decline is tentatively attributed to an unusually dry spring that delayed the development of many species. Monitoring will continue in 1998.

Sword-leaved phlox (*Phlox buckleyi*) is rare world-wide. Two populations have occurred along Skyline Drive in the park. The species prefers sunny roadside

embankments that are usually well within the seasonal mowing zone of the drive. The sizes of both populations have drastically fluctuated since their discovery in 1990. In a single year, the number of flowering plants in a population increased to 533% or decreased to only 3%. No plants were found in the site of either population in 1996. Changes in the mowing schedule along Skyline Drive and shading from encroaching roadside shrubs may be responsible for the declines. The 1997 surveys revealed two flowering stems in one site, indicating a possible recovery. In 1998, the mowing schedule will be adjusted and shading from roadside shrubs will be reduced to promote recovery of the sword-leaved phlox.

RARE, THREATENED, AND ENDANGERED PLANTS

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 a wet prairie-sedge meadow in Pipestone National Monument, Minnesota. The management unit where the orchid occurs was burned (prescribed) in late May 1997, about 2 weeks later than in previous years. Park managers use fire in late spring to control the cool-season exotic grass, smooth brome (*Bromus inermis* Leyss), which has invaded the prairie. Previously, the unit had been burned in early May 1994.

In July 1997, flowering western prairie fringed orchids were counted for the fifth 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 1997, only three flowering orchids were found, which is the lowest number of flowering orchids in the 5-year record (Table 6). The low number of flowering plants

Table 6. Number of flowering western prairie fringed orchids (*Platanthera praeclara* Sheviak & Bowles) by year and by date of previous fires. Pipestone National Monument, Minnesota, 1992-1997.

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

is consistent with observations in other studies, which revealed that late spring fires reduce flowering in the orchids. Although flowering seems to have been affected by the late spring fire, survival of the marked plants was not. The number of the orchids marked in 1994 and 1995 gradually declined. However, the survival of orchids was greater in Pipestone National Monument than in Sheyenne National Grassland, North Dakota (Table 7).

Flowering orchids and the orchids marked in 1994 and 1995 will again be monitored in July 1998. Monitoring

will reveal the response of the western prairie fringed orchid 1 year after a late spring burn. In 1998, the locations of all flowering plants will be marked for future demographic monitoring.

Table 7. Number and percent of flowering western prairie fringed orchids (*Platanthera praeclara* Sheviak & Bowles) that were relocated after permanent marking in 1994 and 1995 in Pipestone National Monument and in 1987 in Sheyenne National Grassland.

Year	Site/No. Flowering Plants	No. (%) Plants Relocated 1 Year	No. (%) Plants Relocated 2 Year	No. (%) Plants Relocated 3 Year
1994	Pipestone/18	13 (72)	9 (50)	7 (39)
1995	Pipestone/34	27 (79)	13 (38)	
1997	Sheyenne/160	88 (55)	44 (28)	25 (16)

Missouri Bladderpod in Wilson's Creek National Battlefield, Missouri

The Missouri bladderpod (*Lesquerella filiformis* Rollins) is a federally listed endangered plant that occurs in a narrow range of southwestern Missouri and northern Arkansas. The plant is restricted to limestone glades, which are sparsely vegetated grasslands with shallow soils and exposed bedrock. Among the 60 populations in its range, one of the largest protected populations is in Wilson's Creek National Battlefield. Three smaller populations of the plant occur elsewhere in the park.

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

Fluctuations in the sizes of the Missouri bladderpod populations have been drastic (Fig. 20). Such fluctu-



Western prairie fringed orchid
Platanthera praeclara Sheviak & Bowles
Pipestone National Monument, Minnesota



Missouri bladderpod
Lesquerella filiformis Rollins
Wilson's Creek National Battlefield, Missouri -

tuations are typical of winter annuals and complicate recognition of long-term trends in population dynamics and assessment of habitat management.

The density of one Missouri bladderpod population in the park has been monitored since 1988. Each spring, the plants are counted in 30 or more 3 m x 3 m plots that are placed at regular intervals along permanently marked transects. The transects are evenly spaced throughout the glade. The mean density of the Missouri bladderpod has ranged from 0 to 22 plants/m² (average=4 plants/m²) during the 10 years of monitoring. The estimated population size in the 1.38 ha area occupied by the population has ranged from 0 to 303,400 (average=55,900 plants; Table 8).

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.

Climate and the Population Dynamics of the Missouri Bladderpod, Wilson's Creek National Battlefield, Missouri

Limestone glades in Missouri are characterized by xeric conditions during much of the growing season and by a unique flora adapted to extremes of temperature and moisture. The Missouri bladderpod (*Lesquerella filiformis* Rollins) is a federally listed endangered plant species restricted to limestone glades in a narrow range of southwestern Missouri and northern Arkansas. Four populations of the Missouri bladderpod occur on limestone glades in Wilson's Creek National Battlefield.

One of the largest Missouri bladderpod populations has been monitored since 1988, and its size has fluctuated drastically from year to year. Plant survivorship has also varied from year to year and among microhabitats in the glade. Changes in the population size may be related to variable weather and to the interaction of weather with physical site conditions, including soil depth and litter depth.

In 1995, an automated weather station was installed 0.44 km north of the site of this population of the Mis-

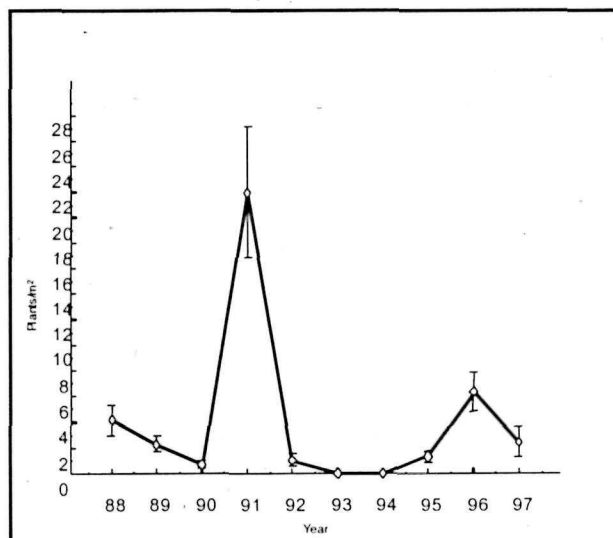


Figure 20. Mean density (standard error) of the Missouri bladderpod, *Lesquerella filiformis* Rollins, in Wilson's Creek Battlefield, 1986-1997.

Table 8. Mean density and estimated population size of the Missouri bladderpod (*Lesquerella filiformis* Rollins); Wilson's Creek National Battlefield, 1988-1997.

Year	Number of Plots	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

souri bladderpod. The site is ideal for the weather station because it also supports a small Missouri bladderpod population but is isolated from park trails. One objective of climate monitoring in this location is the generation of potential predictors of Missouri bladderpod population dynamics from monthly and annual summaries of weather, soil temperature, and moisture data in different glade microhabitats (Table 9).

Monitoring in 1996 and 1997 revealed extreme temperatures on the glade. In every month of both years, the mean maximum temperatures were higher and the mean minimum temperatures were lower than the maximum and minimum mean temperatures recorded by the National Weather Service 16 km (~10 mi) north of the park in Springfield, Missouri. In 1997, 25 more days with temperatures at or above 32°C (90°F) and 36 more days with temperatures at or below freezing were recorded on the site than at the Springfield weather station. Soil temperatures and moisture levels also varied among the four glade microhabitats. Differences in germination and survival of the Missouri bladderpod may be partially attributable to the climatic differences among the glade microhabitats.

A preliminary analysis of climate variables indicates that precipitation in May of the previous year may be a significant predictor of Missouri bladderpod population size.

Table 9. Climate variables tested for correlation with the size of the Missouri bladderpod (*Lesquerella filiformes* Rollins) population.

Number of days $\geq 33^{\circ}\text{C}$	Degree days in August
Number of days with snow cover	Degree days in September
Number of freeze-thaw cycles	Monthly precipitation indices ¹
Number of days soil temperature $\leq 0^{\circ}\text{C}$	Spring precipitation index ¹
	Fall precipitation index ²

¹Indices are quotients of the actual precipitation on site and the normal precipitation reported from the nearest National Weather Service Reporting Station.

RARE, THREATENED, AND ENDANGERED ANIMALS

Hawksbill Sea Turtles in Buck Island Reef National Monument, US Virgin Islands

The hawksbill sea turtle (*Eretmochelys imbricata*) occurs in tropical and subtropical waters of the Atlantic, Pacific, and Indian oceans. These attractive reptiles have an elongated, oval shell and overlapping scutes on the carapace (shell). The scientific name *imbricata* refers to these overlapping scutes. The carapace is brown and has numerous yellow, orange, or reddish brown splashes. The plastron (breast plate) is yellowish with some small black spots. The head of the hawksbill sea turtle is small, the jaw is beak-like, and each flipper has two claws. The turtle's common name is derived from the bird-like or hawk-like shape of its beak or upper jaw. The length of the adults ranges from 76 to 89 cm (30-35 in) and the weight from 43 to 75 kg (95-165 lb). The mean curve-carapace length (89.8 cm nuchal notch-to-tip) and the mean weight (69.8 kg) of nesting hawksbill sea turtles on Buck Island in the Greater Antilles were within these ranges during 1994-97.

Hawksbill sea turtles are omnivorous. They feed on a variety of organisms such as algae, mangroves, fish, barnacles, mollusks, sponges, and sea urchins. The turtles like shallow coastal waters around reefs and quiet bays where they forage on the bottom or in floating vegetation beds. All post-pelagic age classes favor coral reefs for feeding on sponges and for resting on ledges and in caves. The turtles also frequent rocky outcrops and shoals, which likewise are good habitat for sponges.

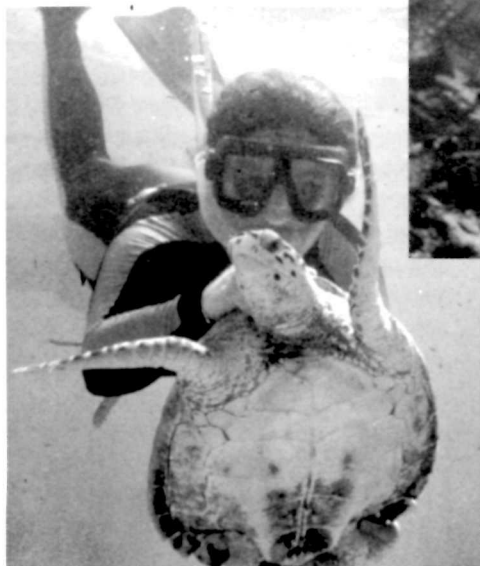
Hawksbill sea turtles may reach adult size in 15-20 years but may take 30 or more years to reach sexual maturity. Adult females reproduce every 2-3 years. In the Caribbean, the nesting season begins in May, peaks during July-September, and continues through December. The females lay several clutches in 2-week intervals. They bury their eggs in the sand under vegetation on beaches where hatchlings emerge after about 60 days. The hatchlings usually emerge at night. To reach the open water, the hatchlings emerge from the nest and head for the lighter horizon, which is over the sea.

The hawksbill sea turtle has been a federally listed endangered species since 1970. The major cause of the exploitation of the species has been the demand for the tortoiseshell. Other causes are human consumption of the eggs, use of the skin for leather, destruction of nesting habitat by development and other anthropogenic uses of beaches, spearing of the turtles for sport and profit by scuba divers and snorklers, pollution, and loss of eggs and hatchlings to non-human predators.

One of the most significant nesting areas of the hawksbill sea turtle under the jurisdiction of the United States is in Buck Island Reef National Monument, US Virgin Islands. The nesting population in the monument has been monitored since the early 1980s and includes the tagging of adults and juveniles. The species is monitored throughout the year, but monitoring is intensified during the nesting season. From July to October, research staff and volunteers patrol the nesting beaches each night and record the activities of the turtles. Recorded data include site selection and fidelity, migration intervals, fecundity (clutch and egg size), carapace size, weight and growth of individuals, nesting and hatching success, and recruitment. Threats from predation, poaching, anthropogenic recreation, inundation by sea water, and desiccation are recorded. Every effort is made to prevent harm to the eggs, and threatened clutches are relocated.

In 1991, radio and acoustic telemetry and satellite tracking were added to visual monitoring to determine the movements of the hawksbill sea turtles. Telemetry revealed that the turtles remain close to the island during the nesting period but depart immediately after laying their final clutches of the season. Satellite tracking revealed that the turtles travel hundreds to thousands of kilometers from Buck Island to their foraging grounds. In 1997, five females that nested on Buck Island were fitted with satellite transmitters. The signals are currently being monitored to map the migration route and destination of the individuals.

Since 1992, staff of the Buck Island Reef Sea Turtle Research Program has participated in a study by the National Marine Fisheries Service and the University of Florida, Gainesville, to identify the genetic composition of the regional hawksbill populations. Dead



Hawksbill sea turtle, *Eretmochelys imbricata*,
in Buck Island Reef National Monument
US Virginia Islands

hatchlings and blood samples from nesting females were analyzed. To date, more than 50% of the hawksbill sea turtles that nest on Buck Island have been sampled. Analyses indicated that hawksbill sea turtles that nest on Buck Island are not a segment of a larger population but a genetically distinct population that is isolated from the hawksbill sea turtles that nest in Puerto Rico, Antigua, and Barbados. The hawksbill sea turtles that nest on Buck Island are closely related to the hawksbill sea turtle haplotype that nests on Belize in Central America. The only recovered tag of a hawksbill sea turtle that nested on Buck Island was from the Miskito Cays, Nicaragua, just north of Belize. The recovery confirmed the genetic connection and supported the hypothesis that hawksbill sea turtles migrate long distances between their nesting and foraging grounds.

In 1994, a study to determine a non-lethal method of sexing sea turtle hatchlings was initiated in the monument. Incubation temperatures determine the sex of sea turtles. To identify a baseline of the hatchling sex ratio on Buck Island, ambient beach temperatures in each nesting habitat were recorded at a depth of 30 cm (~12 in) in the center of the clutch. More than 450 dead embryos were collected for gonad analysis. The high number of dead, full-term embryos was directly related to an increased incubation temperature from the destruction of vegetative cover by hurricanes. Because of the unusually warm nesting sites, a significantly high portion of hatchlings was female. The non-lethal method of sexing hawksbill sea turtle hatchlings is applicable to nesting populations throughout the world.

Usually, the hawksbill sea turtles on Buck Island do more than 80 percent of their nesting activities on forested beaches. During 1991-97, damages from several hurricanes substantially reduced the vegetative cover in nesting areas. Temperatures are about 2°C higher in exposed nests than in shaded nests. The exposure of nests seems to have reduced the hatch success of 83-88% from before the damage to 65-70% since the hurricanes.

The number of nesting females was lower in 1997 than in 1996 (Table 10), but the proportions of first-time nesters (recruits) on the island and females who had

nested on the island previously (returning migrants or r'migrants) were the same (Fig. 21). After 4 years of comprehensive tagging, all tagged adult females

Table 10. Information about hawksbill sea turtles *Eretmochelys imbricata* that nested on Buck Island Reef National Monument, 1996-1997.

	1996	1997
Number of nesting females	30	21
Average carapace length (cm)	88.9	88.9
Average carapace width (cm)	78.7	78.9
Average weight (kg)	68.6	65.7
Average absence from Buck Island (yr)	2.5	2.0
Average number of clutches per female	2.2	3.3
Range of number of clutches per female	1-4	1-5
Average number of eggs per clutch	150.5	149.0
Number of relocated nests	46	24
Hatch success of in situ clutches(%)	78.4	70.8
Hatch success of moved clutches (%)	59.9	61.7
Hatch success of in situ and moved clutches (%)	69.2	67.5
Total number of nesting females tagged for identification to date	96	105

should have been encountered at least once on the nesting beach. Nesting turtles without tags are considered new recruits or first-time nesters who just reached reproductive maturity. The increased number of recruits to the nesting population is significant and possibly the result of the protection of the beach and conservation of the turtle in Buck Island Reef National Monument that began in the mid-1970s. The increased number also suggests that these recruits

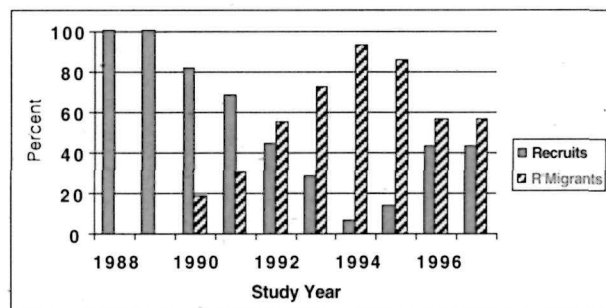


Figure 21. Female hawksbill sea turtles, *Eretmochelys imbricata*, nesting for the first time (recruits) or again (r'migrants) on Buck Island, 1988-1997. R'migrants denotes returning migrants, i.e., females who previously nested on the island.

were hatched in the mid-1970s and took about 25 years to reach reproductive maturity. The large number of recruits may offset the absence and possible demise of many long-term nesters in 1996 and 1997.

Also in 1994, the National Park Service began a study of juvenile hawksbill sea turtles in the near-shore waters of Buck Island Reef National Monument. The study complies with the 1993 recovery plan for the hawksbill sea turtle in the Caribbean by the US Fish and Wildlife Service and the National Marine Fisheries Service. The plan stipulates the protection and management of developmental habitat including Buck Island Reef National Monument where sea turtles spend 20-30 years until they become sexually mature. The plan also stipulates the identification of the abundance, spatial distribution, and temporal distribution of the turtle in the marine environment and the identification of the genetic relationships among Caribbean populations. Accordingly, the study in the monument is of habitat utilization and behavior, size and age class distribution, population size, gender composition, length of residency, food sources, and genetic lineage of juvenile hawksbill turtles.

In 1997, 45 of 80 sighted juveniles were tagged. Sixteen of the 45 were new to the study and raised the number of tagged juveniles to 57. Most (61.5%) observed turtles were swimming, many (30.4%) were resting in the reef, some (5.9%) were feeding, and some (2.2%) were coming to the surface to breathe. Testosterone analysis of 36 samples to date revealed 24 females and 11 males. The average weight of the juveniles ranged from 2.2 kg in the smallest size class to 25.5 kg in the largest size class (Table 11, Fig. 22). The most growth of a juvenile was from 29.0 cm ccl (curved carapace length), 26.1 cm ccw (curved carapace width), and 3.5 kg at first capture to 42.4 cm ccl, 38.4 cm ccw, and 9 kg within 20 months. The longest recorded residency was 37 months in 1997 by a

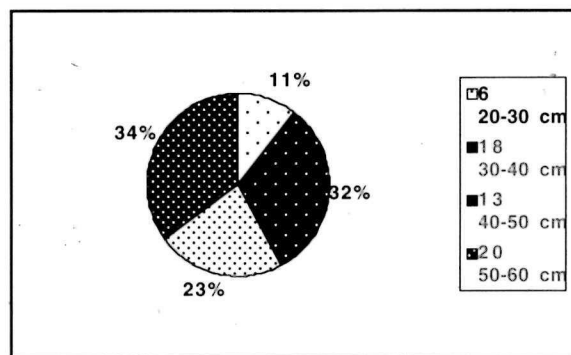


Figure 22. Size class distribution of juvenile hawksbill sea turtles, *Eretmochyles imbricata*, in Buck Island Reef National Monument, 1994-1997.

juvenile who was first tagged on 23 November 1994. Genetic analysis of 38 juveniles revealed that 8 are of the same haplotype as the females that nest on Buck Island. The remaining individuals are related to populations in Mexico, Puerto Rico, Cuba, and Antigua. The relation of 5 individuals was not determined. The diversity of the haplotypes of the juveniles identifies Buck Island Reef National Monument as a developmental habitat that supports juvenile hawksbill sea turtles from all over the Caribbean.

Piping Plovers on Cape Cod National Seashore, Massachusetts

Cape Cod National Seashore consists of about 87 km (54 miles) of beaches on the outermost portion of the arm of Cape Cod, a glacial outwash plain that juts about 97 km (60 miles) seaward from mainland Massachusetts. Seventy-one kilometers (44 miles) of the beaches are managed by the National Park Service; 16 km (10 miles) are owned and managed by towns. Recreational developments on these beaches include public parking and off-road vehicle trails on nearly all town-owned beaches and on 14 km (8.5 miles) of the beaches that are managed by the National Park Service. Beach nourishment and erosion control are minimal on outer Cape Cod. Shoreline development includes small groins at Herring Cove Beach, a break-

Table 11. Size class distribution of juvenile hawksbill sea turtles (*Eretmochyles imbricata*) in Buck Island Reef National Monument, 1994-1997.

Size Class	Number of Juveniles	Average Weight (kg)	Minimum Weight (kg)	Maximum Weight (kg)
20-30 cm	6 (11%)	2.2	1.0	3.0
30-40 cm	18 (32%)	5.4	3.5	8.0
40-50 cm	13 (23%)	11.5	6.0	16.0
50-60 cm	20 (34%)	25.5	13.5	49.5

water inside Wood End, and a small dredging project at Aunt Lydia's Cove in Chatham. Sixteen kilometers (10 miles) of town-owned sand spits exist on Nauset Beach in Orleans and Chatham. Sand spits on the Coast Guard Beach in Eastham, Jeremy Point in Wellfleet, and Race Point, Wood End, and Long Point in Provincetown are in the care of the service. The remainder of the beach is backed by high bluffs or dunes that do not provide access to bays or harbors. Cape Cod National Seashore receives about 5 million visitors annually, and during the 15 April-15 November season, the National Park Service issues 2500 permits for off-road vehicles.

On the Atlantic Coast, the piping plover (*Charadrius melodus*) breeds on coastal beaches from Newfoundland to North Carolina. Since 1986, the species has been federally listed as threatened. The beaches of Cape Cod National Seashore support as many as 10% of the 1350 pairs in the population. Piping plovers are threatened by the cumulative effects of habitat loss, human disturbance, and predation. Annual surveys of breeding plovers, nesting success, and productivity have been conducted on Cape Cod National Seashore since 1985 (Table 12).

Protection of the Piping Plover on Cape Cod National Seashore consists of temporal and spatial restrictions of off-road vehicles, seasonal restricted access by visitors of areas where the plovers nest, control of avian and mammalian predators by surrounding nests with mesh-topped or string-topped welded wire structures, and raising of public awareness of the status and the management of the plover. In 1997, the North Beach remained open to off-road vehicles for the second consecutive year. The South Beach, except for 0.8 km (0.5 mile) at the extreme southern end of the route, was closed. About 1.6 km (1 mile) at the extreme northern end of the route remained closed for approximately 1 month. By 13 August, the entire off-road vehicle corridor was reopened to vehicles.

In 1997, nesting and brood rearing of piping plovers was monitored on eight beaches of Cape Cod National Seashore from Provincetown to Orleans. Sixty-seven pairs of plovers were observed, and the habitat of 107 nests was categorized. The first clutches were initiated during early May. Many (41%)

Table 12. Population size and reproductive rate (number of fledglings per breeding pair) of Piping Plovers, *Charadrius melodus*, on Cape Cod National Seashore, 1985-1997.

Year	Number of Pairs	Reproductive Rate
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

nests were on berms, and equal portions were on fore dunes (23%) and in areas that occasionally are washed over by high waves (23%). The remaining nests (13%) were in various habitats. Protective structures were erected around 72 nests (protected nests) to keep out mammalian and avian predators, notably red foxes (*Vulpes vulpes*) and American crows (*Corvus brachyrhynchos*).



Nests of Piping Plovers, *Charadrius melodus*, are protected from predators with welded wire structures. Cape Cod National Seashore, Massachusetts

Nesting peaked during the first week of June. Hatching peaked in the second week of June and again in the second week of July after high waves had destroyed nests in areas that occasionally are washed over by high waves in late June. The hatching success was 47%, the fledging success 61%, and the reproductive rate (number of fledglings per breeding pair) was 1.5 (12). Eighteen of 27 clutches were destroyed by high waves. High waves were the leading cause of nesting failure. Nine clutches (33%) were abandoned by the hens, and 3 (11%) clutches were infertile. Forty-five (63%) of the 72 clutches in protected nests hatched, and 25 (71%) of the unprotected clutches did not hatch. The causes were abandonment by the hen (7, 28%), predation by crows (5, 20%), and unknown causes (13, 52%).

Annual productivity of piping plovers fluctuates widely. An estimated mean annual reproductive rate of 0.8-0.9 is necessary to sustain a local population with typical survivorship. Simulations based on reproductive rates of less than 0.7 or more than 1.0 project rapidly declining or increasing populations. On Cape Cod National Seashore, the reproductive rate of the Piping Plover began to increase in 1988, when nests were first protected with wire enclosures. Now, Piping Plovers nest on beaches—including the 13.7-km (8.5-mile) off-road vehicle corridor, where they did not nest before 1990.

Piping plovers on Cape Cod National Seashore will be monitored indefinitely or at least until the Species can be removed from the federal list of endangered and threatened animals. Improvements in the reporting procedures of data, notably uniformity, will be initiated in 1998.

Peregrine Falcons in Channel Islands National Park, California

The restoration of Peregrine Falcons (*Falco peregrinus anatum*) in California has been primarily conducted by the Santa Cruz Predatory Bird Research Group. The National Park Service has worked closely with the group by monitoring falcons in Channel Islands National Park. Because of compliance with the National Park Service mandate to conserve the scenery and the wild life of the National Park System units, little that may affect the availability of the falcons' prey, habitat, and nesting ecology in Channel Islands National Park has changed since 1950.

In the early 1900s, Peregrine Falcons were relatively common throughout California. In the 1950s, however, nesting territories on the Channel Islands and in other parts of California seemed to be abandoned. By the 1960s, Peregrine Falcons were considered rare, and by the early 1970s, the American Peregrine Falcon was nearly extirpated in California. During the 1970s, the first state-wide survey was conducted, and only two occupied territories were found. During this period, DDT was identified as the cause of eggshell thinning in the falcons and in other piscivorous and carnivorous birds. Although the use of DDT has been banned since then, the restoration of Peregrine Falcons in Channel Islands National Park is still enhanced by fostering and hacking.

Hacking was conducted in the park during 1985-86 and in 1997

and will be continued in 1998. In the 1980s, Peregrine Falcons began to re-occupy historic territories when a released male remained near the release site and attracted a mate. By 1997, the annual number of occupied territories by Peregrine Falcon pairs in the park was slightly above 10 or at roughly 50% of the estimated carrying capacity.

Throughout the restoration, territory occupancy, productivity, and behavior of the falcons have been monitored. The contents of eggs, eggshells, blood, and prey remains have been collected for analyses. The monitoring and the analyses provide information for the evaluation of the recovery and for improving the protection and restoration of the falcons in the park.

Fostering and Hacking

Fostering is the transfer of eggs from nests of wild birds to incubators in a laboratory and the subsequent transfer of the hatchlings from the laboratory to the nests of the wild parents. The removed eggs are replaced with artificial eggs to keep the parent bird at the nest. Hacking is used to expand the range of a remnant population of birds into areas from which the birds were extirpated. The young birds are held in a hack-box until they strengthen their wings and get used to the environment into which they will be released. One side of a hack-box permits the young birds a view of their surroundings. The birds are surreptitiously fed by their keepers. Young Peregrine Falcons are usually released from a hack-box after 1-2 weeks. Hacking allows young falcons to gain independence and to establish a region of natal origin where no adults are present. The falcons later disperse and seek nesting territories within roughly 16-80 km (10-50 miles) of their natal origin.

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

Many species of insects and diseases affect the forest trees of Great Smoky Mountains National Park. Some insects and diseases are from other continents and relatively new to North American hosts. The forests have adapted to many pests, but the recently introduced species can severely injure or kill populations of a particular species. In the park, Fraser's fir (*Abies fraseri*) has been severely damaged by the balsam woolly adelgid (*Adelges piceae*), American beech (*Fagus grandifolia*) by beech bark disease (*Cryptococcus fagisuga* and *Nectria* spp.), flowering dogwood (*Cornus florida*) by dogwood anthracnose (*Discula destructiva*), and great laurel (*Rhododendron maximum* L.) by environmental stress such as drought and by the non-specialized fungal pathogen *Botryosphaeria* spp. Environmental stress was the probable cause of the vulnerability of great laurel to the pathogen. Some tree species are affected by pests that cause localized mortality but do not threaten the survival of a particular host. Monitoring reveals information that can be used to protect and manage affected species in the park and in the surrounding region. American beeches are monitored every other year and will be monitored again in 1998.

Balsam Woolly Adelgid

Populations of the balsam woolly adelgid (*Adelges piceae*) on Fraser's fir were larger in 1997 than in 1996 on only one of four monitored peaks. The population density on the remaining peaks had not significantly changed since 1996 (Fig. 23). In one area where the balsam woolly adelgid is controlled, firs had to be

The restoration of Peregrine Falcons (*Falco peregrinus anatum*) in California has been primarily conducted by the Santa Cruz Predatory Bird Research Group. The National Park Service has worked closely with the group by monitoring falcons in Chan

treated a second time because of re-infestation. The extent of infestation differs among areas and even between adjacent trees.

Botryosphaeria

Great laurel—sometimes called rosebay rhododendron—is a common long-lived shrub in the Appalachians. In the Smoky Mountains, great laurel is a characteristic shrub in all forest types except in spruce-fir (*Picea-Abies*) communities. Multiple stems can arise from one root crown, and exclusive thickets of great laurel are not unusual. The shrubs bloom in June, and the display of showy flowers in the park is well known.

Since 1988, areas of dead or dying great laurel stems were noticed in several areas throughout the park. Initial attempts to identify the disease were frustrating. No cankers were apparent on the branches, and no decay was found in the stem heartwood. In cooperation with the US Forest Service, samples of root tissue were cultured, but no recognizable pathogen was identified. A cooperative agreement was initiated in 1993 with the Department of Entomology and Plant Pathology of the University of Tennessee to identify the disease and to establish monitoring of the shrub. Attempts were made to isolate the causal pathogen from live and dead stem tissue and from the live-dead

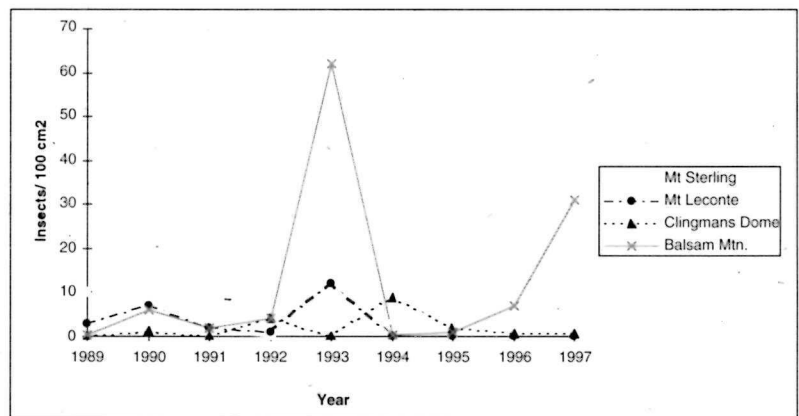


Figure 23. Mean density of balsam woolly adelgids, *Adelges piceae*, in four locations in Great Smoky Mountains National Park, 1989-1997.

transition zone on the stem tissue. Isolations from the transition zone tissue delivered the best results. A species of the non-specialized fungal pathogen *Botryosphaeria* spp. was the only consistently isolated pathogen. The difficulty with isolating a single causal pathogen suggested that the disease is part of a decline complex. The affected plants are mature 20-70 year old specimens and, therefore, could be affected by stress such as prolonged drought. Under prolonged stress, the stems become susceptible to pests and pathogens that would normally not cause a severe decline of health.

In 1993, 12 plots for monitoring great laurel were established in one location. More than 700 stems were tagged and evaluated annually for symptoms of twig die back, leaf chlorosis, and number of leaf whorls per stem. The latter is an indicator of plant vigor. These parameters are assigned a numerical value and the values are combined into an overall health value (R) in a range from 1 (healthy) to 7 (long dead). The R values of all stems in each plot and of all stems in all plots are averaged. Old and newly dead stems are included in the overall values.

Between 1996 and 1997, ten stems died. The health of the shrubs in all plots combined increased slightly since inception of the study in 1993 (Fig. 24). On a plot by plot basis, the health of the shrubs decreased slightly in some plots and increased in others.

Unidentified Casual Agent

In response to defoliation and mortality of American holly (*Ilex opaca* Ait.), monitoring of the species was initiated in 1993 with assistance from the US Forest Service. No single casual agent was identified. Trees in 5 plots are evaluated with methods of the US Forest Service. Certified evaluators record visual measurements of crown characteristics as indicators of tree vigor. Percent transparency, which is a measure of foliage integrity, increased in 3 of the 5 plots since 1993. Percent mortality of fine twigs and percent defoliation decreased in all plots. Annual mortality has been minimal since 1993. Some of the trees that survived defoliation seem to be recovering and are producing new shoots and leaves. Comprehensive moni-

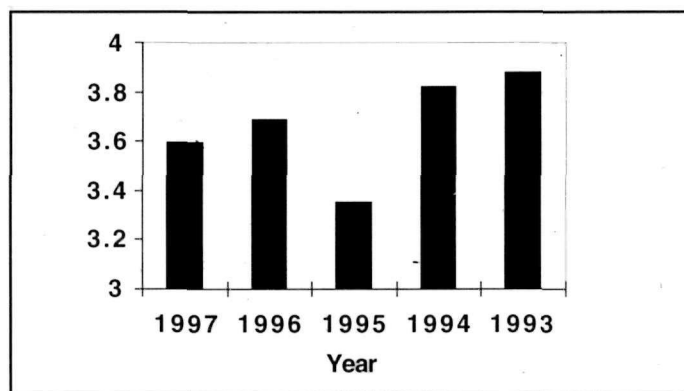


Figure 24. Health status of great laurel, *Rhododendron maximum* L., in Great Smoky Mountains National Park, 1993-1997.

toring of the trees is now limited to every other year. Yearly inspections are only cursory.

Forest Pests and Diseases in Shenandoah National Park, Virginia

Forests in Shenandoah National Park have been monitored since 1987 to determine changes in species composition, structure, and growth and the influence of natural and anthropogenic factors over time. Vegetation is sampled in 129 permanent sites that represent the eight major vegetation types in the park, three different elevation ranges, two distinct aspects, and the three major administrative districts.

The hemlock woolly adelgid (*Adelges tsugae*), an introduced insect, was first identified in Shenandoah National Park in early 1988 along the Thornton and Frazier Hollow drainages. To determine the distribution of the woolly adelgid and the damage by the pest, hemlocks (*Tsuga canadensis*) in permanent and in randomly selected plots have been sampled yearly since 1990-91. All stands were infested by 1993; 91% were infested in 1997. Infestations are now greatest at the lower elevations.

Abalone in Channel Islands National Park, California

Seven species of abalone (Table 13) occur off the coast of southern California. The threaded and flat abalone (*Haliotis assimilis*, *H. walelensis*) are uncommon and little known. The remaining species used to support a multi-million dollar fishery until excessive harvest and a bacterial disease, withering syndrome, severely depleted their populations.

Table 13. Abalone, *Haliotis* spp., species that occur off the coast of southern California.

threaded abalone	<i>Haliotis assimilis</i>
pink abalone	<i>H. corrugata</i>
black abalone	<i>H. cracherodii</i>
green abalone	<i>H. fulgens</i>
red abalone	<i>H. rufescens</i>
white abalone	<i>H. sorenseni</i>
flat abalone	<i>H. walelensis</i>

After World War II, the abalone fishery in California grew rapidly. Soon, easily accessible abalone populations along the mainland shorelines were exhausted. However, modern equipment permitted the exploitation of abalone on offshore reefs. When the abundance of pink and red abalone (*H. corrugata*, *H. rufescens*) declined in the 1970s, the fishery shifted to green abalone (*H. fulgens*) in shallow water and to white abalone (*H. sorenseni*) in deep water. When white and green abalone populations collapsed, the harvest shifted to intertidal black abalone (*H. cracherodii*). When the remnants of the black abalone population succumbed to disease, the fishery shifted to red sea urchins (*Strongylocentrotus franciscanus*). Careful examination of what seemed to have been a sustained harvest over 25 years revealed serial depletion. The exploitation of the abalone was compounded by the withering syndrome. The disease was discovered in abalone at the Channel Islands in 1985.

Monitoring of the intertidal ecosystem of Channel Islands National Park began in 1982 and has included monitoring of abalone twice yearly in 15 permanent sites. Relict populations of seemingly disease-resis-

tant abalone survive on the islands at less than one percent of their former abundance (in the early 1980s, the densities of black abalone at the Channel Islands often exceeded 100/m²). In 1997, abalone were rare in all sites. The abundance of all species was so low that the monitoring protocol had to be severely changed to determine the presence of the animals. A research submersible was used in 1997 to search for white abalone in deep water. Only four white abalone were found during an 11-hour search in about 4 ha (~10 acres) of suitable habitat. Black abalone were present only in waters of San Miguel Island where the density is about 1/m² (~1/11 ft²; Fig. 25). The only remaining large populations of red abalone are at San Miguel Island. However, even there a highly

Two biogeographic regions converge at the Channel Islands. The Oregonian Province (San Miguel and Santa Rosa Islands) is characterized by cold nutrient rich water and the community includes many northern species. The Californian Province (Anacapa and Santa Barbara Islands) is characterized by warmer waters with species more common to areas to the south.

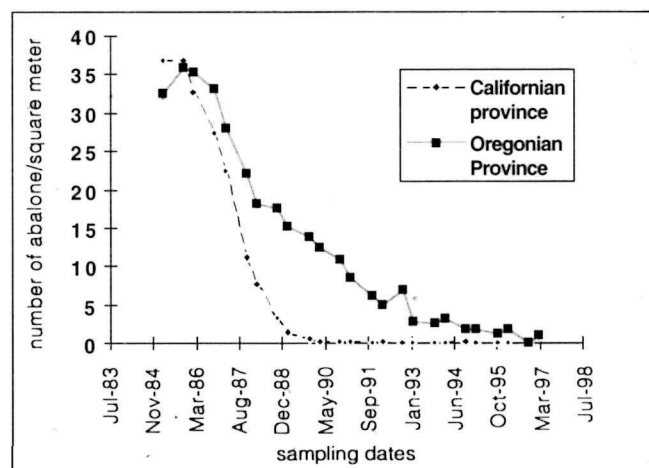


Figure 25. Density of black abalone, *Haliotis cracherodii*, in Channel Islands National Park, 1983-1997.

skewed sex ratio of 20 females to 1 male further threatens the productivity of the species. Further grave threats to the persistence of abalone are para-

sitic sabellid worms that were introduced into California. So far, none has been detected in abalone in the park.

Data from monitoring abalone in Channel Islands National Park became decisive for the state's suspension of abalone harvests in southern California in 1997. In the park, the most threatened species is the white abalone. Its status has been monitored, and attempts have been made to locate potential brood stock. In cooperation with an ad hoc group of representatives of governmental and nongovernmental agencies, park staff are developing a plan for captive breeding of white abalone. A small experiment to enhance natural production of pink abalone by concentrating them in a small area at Anacapa Island is underway.

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

Tallgrass prairies are among the most highly fragmented natural areas in North America. Only about 1% of the original area still exists. One of the most visible components of the prairie is the butterfly community. Because of their host specificity and range requirements, butterflies seem to be affected by landscape patchiness. Consequently, butterflies may be useful for examining the effects of prairie fragmentation. Larger prairie remnants and remnants that are managed to promote plant diversity should support a larger number of butterfly species than isolated smaller prairies.

During summer 1997, inventories of butterflies were made in ten plant communities in four parks (Effigy Mounds National Monument, Iowa; Homestead National Monument of America, Nebraska; Pipestone National Monument, Minnesota; and Wilson's Creek National Battlefield, Missouri). Butterfly diversity in relation to prairie size, degree of isolation, and type of management is being examined in these and other prairie remnants.

Preliminary results indicate little relation between patch size and butterfly species richness (Table 14). The two community types with the highest richness—goat prairies in Effigy Mounds National Monument and

Table 14. Butterfly species richness and size of prairie, glade, and woodland communities in four units of the Great Plains Prairie Cluster, 1997.

National Park System Unit	Community Type	Area (ha)	Species Richness
Effigy Mounds National Monument, Iowa	Goat prairies	0.45	16
	Restored prairie-north	20.00	9
Homestead National Monument, Nebraska	Tallgrass prairie	0.30	10
	Restored prairie	40.00	10
Pipestone National Monument, Minnesota	Tallgrass prairie	75.20	12
	Sioux quartzite prairie	2.00	5
	Restored prairie	12.40	7
Wilson's Creek National Battlefield, Missouri	Limestone glade	7.40	28
	Oak woodland	30.20	9
	Restored prairie	0.20	10

limestone glades in Wilson's Creek National Battlefield—are among the smallest in area. This result illustrates that small but intact remnant populations may contribute disproportionately to local or regional diversity (Table 15). After additional sampling in summer 1998, species per area relations and the effects of management will be examined statistically.



Great-spangled fritillary, *Speyeria cybele*, on butterfly milkweed, *Asclepias tuberosa*, in the Great Plains Prairie Cluster

Table 15. Species, common names, and occurrence of butterflies, Lepidoptera, in remnant and restored prairies, glades, and woodland communities of the Great Plains Prairie Cluster, 1997.

Species	Common Name	EM			H		P		WC		
		1	2	3	2	3	4	2	5	2	6
<i>Amblyscirtes vialis</i>	roadside skipper								x		
<i>Anaea andria</i>	goatweed butterfly								x		x
<i>Asterocampa celtis</i>	hackberry butterfly								x	x	x
<i>Atalopedes campestris</i>	sachem								x	x	
<i>Battus philenor</i>	blue swallowtail								x		
<i>Callophrys gryneus</i>	cedar hairstreak	x							x		
<i>Calycopis cecrops</i>	red-banded hairstreak										x
<i>Celastrina argiolus</i>	spring azure	x							x		
<i>Ceononympha tullia</i>	ringlelet					x					
<i>Cercyonis pegala</i>	wood nymph			x	x	x		x	x	x	x
<i>C. eurytheme</i>	alfalfa butterfly		x	x	x	x	x	x	x	x	
<i>C. philodice</i>	clouded sulphur	x		x		x			x	x	
<i>Danaus plexippus</i>	monarch	x	x	x	x	x	x	x	x		
<i>Epargyreus clarus</i>	silver-spotted skipper	x									
<i>Erynnis horatius</i>	Horace's dusky wing								x		
<i>Euptoieta claudia</i>	variegated fritillary			x		x			x		
<i>Everes comyntas</i>	eastern-tailed blue	x	x	x	x	x		x		x	
<i>Harkenclenus titus</i>	coral hairstreak								x		x
<i>Lethe anthea</i>	pearly eye	x									
<i>Libytheana carinenta</i>	snout butterfly								x		
<i>Limenitis arthemis</i>	white admiral										x
<i>Lycaena hyllus</i>	copper			x							x
<i>Megisto cymela</i>	little wood satyr	x							x	x	
<i>Nymphalis antiopa</i>	mourning cloak	x									x
<i>Papilio cresphontes</i>	giant swallowtail		x						x	x	
<i>P. glaucus</i>	tiger swallowtail	x			x			x	x		
<i>P. polyxenes</i>	black swallowtail					x					
<i>Pholisora cattulus</i>	common sooty wing			x	x						
<i>Phyciodes morpheus</i>	crescent		x								
<i>P. tharos</i>	pearl crescent	x	x		x	x	x		x		
<i>Pieris rapae</i>	European cabbage butterfly					x	x	x			
<i>Poanes hobomok</i>	Hobomok skipper								x		
<i>P. zabulon</i>	Zabulon skipper								x		
<i>Polites mystic</i>	long dash					x					
<i>P. themistocles</i>	tawny edged skipper				x				x	x	
<i>Polygonia interrogationis</i>	question mark								x		
<i>P. progne</i>	gray comma	x									x
<i>Satyrium calanus</i>	banded hairstreak		x								
<i>Satyrium caryaevorum</i>	hickory hairstreak	x									
<i>Speyeria cybele</i>	great spangled fritillary	x	x		x				x		
<i>Speyeria idalia</i>	regal fritillary	x		x	x	x	x	x			x
<i>Thorybes pylades</i>	northern cloudy wing								x		
<i>Vanessa cardui</i>	painted lady			x							
<i>V. atalanta</i>	red admiral	x	x						x		
<i>Wallengrenia egereme</i>	northern broken dash		x						x		

EM=Effigy Mounds National Monument

HM=Homestead National Monument of America

P=Pipestone National Monument

WC=Wilson's Creek National Battlefield

1=goat prairie

2=restored prairie

3=tallgrass prairie

4=quartzite prairie

5=limestone glade

6=oak woodland

Conchs and Lobsters in Virgin Islands National Park, US Virgin Islands

In 1996, scientists of the Biological Resources Division of the US Geological Survey and visiting investigators of the University of Hawaii and the Jacksonville University sampled queen conchs (*Strombus gigas*) around St. John. They took samples along transects that had been surveyed in 1981, 1985, and 1990. The abundance of adult conchs has declined since 1981 despite a 5-year moratorium, park regulations that prohibit the taking of more than 2 conchs/person/day, and other restrictions. Conchs were found almost exclusively in seagrass beds. The areal coverage of seagrasses was substantially reduced in recent years, primarily from damage by hurricanes and anchors. The abundance of adult and juvenile conchs in Fish Bay on the southwestern boundary of the park is much lower now than in 1985. Hurricane Hugo in 1989 turned almost all of a large seagrass bed in Fish Bay into sand bottom. Conch density is moderately high (38-75/ha) in a few bays of St. John. These densities are higher than those reported from the Florida Keys, Bahamas, and Puerto Rico but substantially lower than densities in other locations such as Cuba, Turks and Caicos, and Los Roques, Venezuela. The abundance of conchs did not differ between area in and outside waters of Virgin Islands National Park, indicating that the park is not a refuge for queen conchs. Continued harvest could eliminate conchs from park waters.

During August 1996, the abundance and size distribution of lobsters (*Panulirus argus*) were sampled by SCUBA divers in Fish Bay, Reef Bay, Yawzi, and Tektite. Lobsters were previously sampled in Fish Bay and Reef Bay in 1985 and in Yawzi and Tektite in 1970.

In 1996, lobster densities (lobsters/hectare) in Fish Bay (6.7/ha) and Reef Bay (2.7/ha) were nearly the same as in 1985 (5.6/ha, 3.1/ha). The estimated densities at Yawzi (7.7/ha) in 1996 were similar to densities in 1970 (2.5-9.4/ha). However, the densities at Tektite (3.0/ha) markedly decreased since 1970 (6.7-9.0/ha). Whereas the mean density of lobsters was 19.4 (± 28.7 SD)/ha in 89 randomly sampled reef sites around St. John in 1970, the mean density in four sampled reef sites in 1996 was only 5.0 (± 2.5 SD)/ha.

Even more alarming than changes in density were the changes in size distribution. The mean carapace length of lobsters on reefs was 11.1 (± 30.3) cm in 1970 but only 8.0 (± 29.4) cm in 1996. Whereas nearly 80% of the lobsters exceeded the legal size in 1970, less than 29% exceeded the legal size in 1996. In 1970, only 12% of the lobsters were less than 7 cm, but in 1996, 63% were 7 cm or smaller. The data suggest St. John's lobsters are highly exploited. Because adult spiny lobsters periodically migrate into deeper water, a determination of whether the excessive harvest is from offshore commercial trapping or from near-shore recreational harvest is difficult. Continued monitoring of the lobster status at St. John is imperative to the management of this resource.

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

Brook trout (*Salvelinus fontinalis*) were surveyed in 22 first order and third order streams at elevations of 616-1502 m (2020-4925 ft). In some reaches, brook trout populations coexist with rainbow trout (*Oncorhynchus mykiss*). The water temperature was 8.0-18.3°C (46.4-~64.4°F), and the stream discharge was 1.4-217.7 L/sec (0.05-7.69 ft³/sec). The pH in the streams was 4.8-6.8, the conductivity was between 2 and 18 Mhos/cm, and the stream gradient was between 1.3 and 14.3 %. The density of the brook trout was 0.05-0.607/m² (0.005-0.007/ft²). The young-of-the-year comprised 10-42% of the brook trout populations that did not coexist with rainbow trout, indicating a relatively strong 1997 year class.

The number of brook trout per 1.6 km (1 mile) of stream ranged from 25/km to 906/km (40-1,450/mile), however, in most streams the average was 250-312/km (400-500/mile; Table 16). Adult brook trout in the park rarely live beyond 4 years of age and seldom exceed 200 mm (8 inches) in length. In any given year, fewer than 10% of all brook trout are greater than 275 mm (7 inches).

In general, the conditions and densities of trout are not significantly different from 1996. In fact, the density of sympatric brook trout and rainbow trout populations have not changed significantly in the last 5-10

The abundance of brook trout significantly declines only after major storms between November and March, and the abundance of rainbow trout declines only after major storms between February and May.

Fishes in Large Streams in Great Smoky Mountains National Park, Tennessee and North Carolina

Fishes in four of the large stream systems in Great Smoky Mountains National Park were sampled in 1997: Abrams Creek, Cataloochee Creek, Hazel Creek, and Little River. Some of the most species-rich reaches are in the large streams of the park, and the species composition in these streams has not significantly changed since the early 1970s (Fig. 26). The species richness indicates excellent habitat and water quality in the large streams but tends to decline upstream throughout the watersheds of the park. The abundance of sensitive species such as salmonids (Salmonidae) and dace (Cyprinidae) did not change

between 1996 and 1997. The densities of smallmouth bass (*Micropterus dolomieu*) in Abrams Creek increased 300% from 0.01/m² (<0.01/ft²) in 1996 to 0.03/m² (0.003/ft²) in 1997. More than 85% were young-of-year, indicating excellent reproductive success of reproductive success. Low reproduction in previous years may have been attributable to poor spawning habitat because of sedimentation from Cades Cove. From 1988 to 1996, the densities of smallmouth bass and rock bass (*Ambloplites rupestris*) had steadily declined in Abrams Creek (Fig. 27). The increases may be evidence of the successful stabilization of stream banks and reduction of sediment loading in Cades Cove.

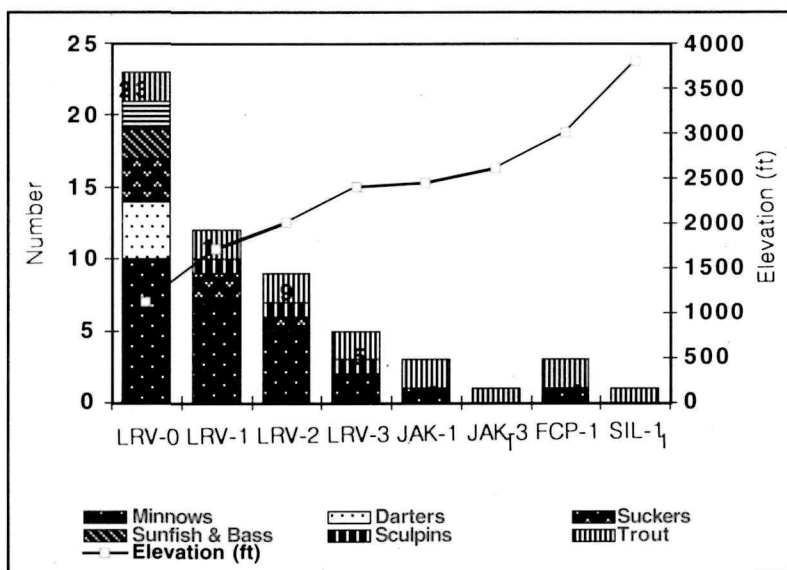


Figure 26. Diversity of fish species in the Little River watershed, Great Smoky Mountains National Park, 1997.

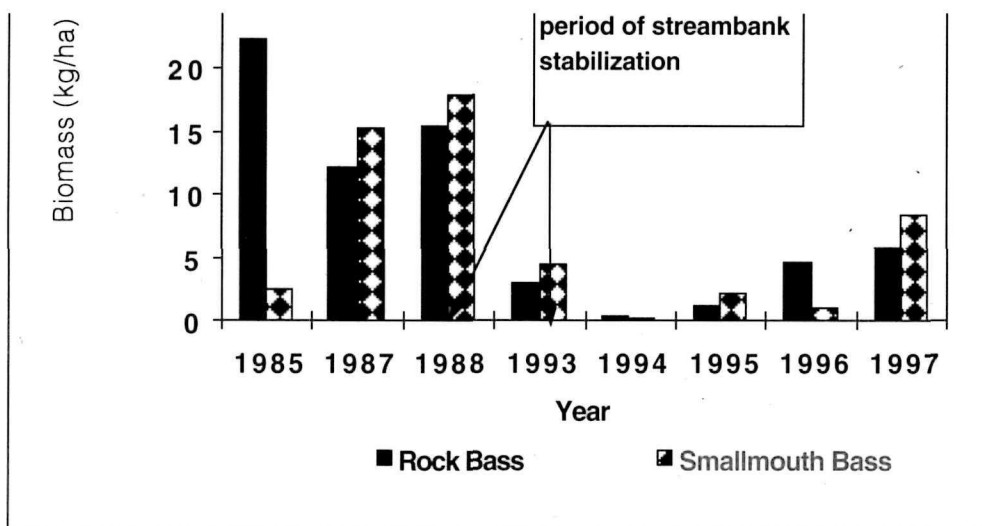
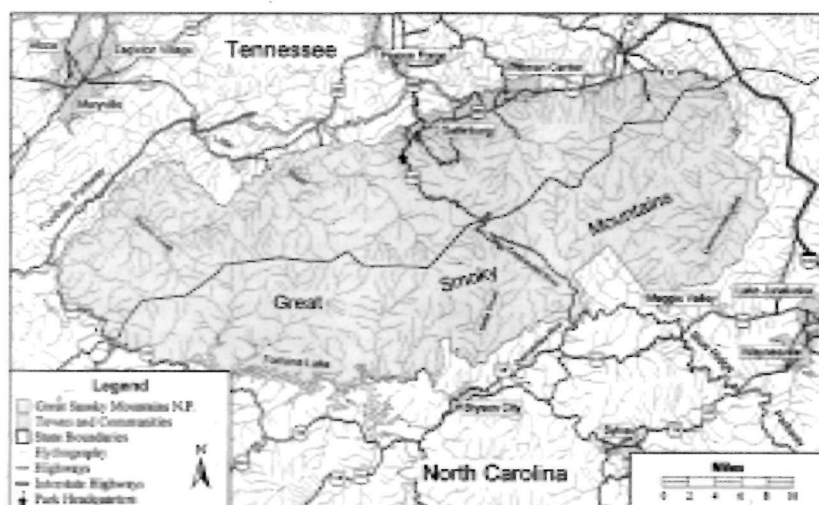


Figure 27. Biomass of game fishes in Abrams Creek, Great Smoky Mountains National Park, 1997.



Large streams in Great Smoky Mountains National Park
Tennessee and North Carolina

Brook Trout in Shenandoah National Park, Virginia

Torrential rains caused localized major floods in June 1995. Heavy snow falls and subsequent sudden melting caused widespread floods in January 1996. Rains from Tropical Storm Fran caused widespread floods in September 1996. During winter 1996-97, the streams recovered from flooding because the temperatures and the amount of precipitation were moderate. The survival of the eggs and hatchlings of brook trout (*Salvelinus fontinalis*) over winter under such favorable conditions was excellent as evidenced by the large number of juvenile brook trout in summer. From 1996 to 1997, the number of brook trout per hectare increased by 54% in the Staunton River, by 20% in the Rapidan River, and by 243% in the Moorman River (Table 16). Recolonization by brook trout in the middle sections of the Staunton and Moorman rivers improved substantially. The inventory and monitoring fisheries crew captured a record number of 8911 brook trout in 1997. Eighty-five percent of the captured trout were juveniles. However, the lowermost reaches of the Staunton River remain devoid of fishes. In 1998, information about the status of fishes in the park will be improved with recent data about acidification of streams.

Table 16. Number of brook trout, *Salvelinus fontinalis* by reach and mean number per hectare in the Moorman's, Staunton, and Rapidan rivers in Shenandoah National Park, Virginia, 1997.

River and Reach	1996	1997
Moorman's River		
Lower reach	49	231
Middle reach	254	1761
Upper reach	2135	6377
mean/ha	813	2789
Staunton River		
Lower reach	0	0
Middle reach	1723	1151
Upper reach	2802	5822
mean/ha	1508	2324
Rapidan River		
Lower reach	0	0
Middle reach	924	1959
Upper reach	1917	1464
mean/ha	947	1141

Status of Reef Fishes in Virgin Islands National Park

The declines and shifts in the relative abundance of reef fishes around St. John have been substantial. In summer 1997, the average density of groupers (*Serranidae*) and snappers (*Lutjanidae*) on four coral reefs was alarmingly low. The density of groupers was 0.006-0.015/m² (0.0006-0.0010/ft²) and that of snappers 0.003/m²-0.050/m² (0.0003-0.005/ft²) of reef. The density of these commercially important species is often a good indicator of fishing pressure on a reef.

Fishermen set traps in five different habitats: algal plain, coral reef, gorgonian hard-bottom, seagrass beds, and non-living substrate. Most traps were set in the algal plain and gorgonian habitat, suggesting increased exploitation of deeper, non-coral habitats. Most fishes were trapped on the algal plain (mean=5.7, SE=0.6) and the fewest fishes were trapped on the seagrass beds (mean=3.4, SE=1.0). The greatest number of species (41) was trapped in coral habitat and the least (22) on seagrass.

The trophic structure of trapped fishes differed among habitats. Species feeding on mobile invertebrates were trapped in greatest numbers on algal plain, seagrass, and non-living substrates. Herbivores were the most abundant feeding guild trapped on coral and gorgonian substrates. The number of piscivores was low and varied from 0.00/trap on gorgonian hard-bottom to 0.13/trap (mean=0.08, SE=0.03), in algal plain. Acanthurids (tang) dominated the trap contents on gorgonian hard-bottom and on non-living substrates, whereas scarids (parrotfishes) and acanthurids equally dominated coral habitat. Of the few trapped serranids (groupers; 57), more were captured per trap in algal plain habitat (mean 0.14, SE=0.1) than in other habitats, although the frequency of occurrence of serranids was highest in coral habitat. Of the 59 identified species, only 9 were trapped in all habitats. Six of these species were more than 50% of all censused fishes. The most abundant species, the blue tang (*Acanthurus coeruleus*), is a small, fast-growing herbivore. This type of fish may dominate the catch when a fishery has been severely overfished.

Land Birds in Denali National Park and Preserve, Alaska

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

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

The survey of land birds by the Alaska Bird Observatory in 1997 revealed that the total number (69) of species during all surveys was lower in 1997 than in previous years, probably because fewer days were spent in the field (17 total days). Eighty-six taxa were detected in 44 days in 1996, 80 taxa in 70 days in 1995, and 86 taxa in 30 days in 1994. As in past years, the species richness was greatest on the western end of the park road where a wide variety of habitat types includes ponds and lakes. An average of 35 species (minimum=33, maximum=38) was seen on each of the first three eastern segments of the road and 44 species on the westernmost road. Several species, including the Alder Flycatcher (*Empidonax alnorum*) and the Gray-cheeked Thrush (*Catharus minimus*), were more common on the western end of the road.

Since 1992, 45 species have been detected on off-road routes. The annual species richness has ranged from 26 to 32 species. More species (32) were de-

tected in 1997 than during the previous 4 years. The relative abundance of most species was similar between years.

The inter-annual variation in population-size trends was similar between estimates from on-road and off-road surveys. The abundance of rare species (occurring at fewer than 2% of all counting stations) tended to fluctuate widely between years because rare species were not detected in some years. In contrast, the annual variations of population sizes of common species were small.

Off-road and on-road surveys will be continued in 1998. Frequency (proportion of stations where birds were seen) has been the primary variable. However, total counts (total number of individuals seen at each station) will be continued because inter-annual variation in bird abundance is estimated from total counts in virtually all monitoring programs.

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

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

Since 1989, the Institute for Bird Populations has coordinated the cooperative monitoring of avian productivity and survivorship (MAPS) by public and private agencies and bird banders who maintain a North American network of stations where birds are captured with mist nets and banded. The objectives are estimates of adult survival and recruitment into the adult population and the determination of indices of popu-

lation size and post-fledging productivity in land bird species. The estimates and indices can be used to investigate temporal, spatial, and between-species patterns in primary demographic parameters to identify proximal causes of population changes, to identify management for reversing declines, and to evaluate the effectiveness of management.

The Institute for Bird Populations (IBP) operated six constant-effort mist-netting and banding stations in 1997. Four of them were in the same locations as during 1992-96. Two new stations were established in 1997 and replaced a non-productive station at Rock Creek.

- During 1997, 857 birds (29 species) of 1175 captured birds were banded. 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. The percentage of captured young, however, was higher in the more forested stations and inversely correlated with adult population size.

- Adult population sizes decreased slightly from 1996 to 1997. The pooled number of captured adults of all species decreased by 7.1%. The number of captured adults of three species—Alder Flycatcher (*Empidonax alnorum*), Yellow-rumped Warbler (*Dendroica coronata*), and Wilson's Warbler (*Wilsonia pusilla*)—decreased significantly ($P < 0.10$).

- Six-year trends suggest that the adult population size of two species—Swainson's Thrush (*Catharus ustulatus*) and Common Redpoll (*Carduelis flamea*)—substantially declined since 1992. During the same time, the adult population of the Yellow-rumped Warbler (*Dendroica coronata*) increased. The adult population size of the Boreal Chickadee (*Parus hudsonicus*), Orange-crowned Warbler (*Vermivora celata*), and American Tree Sparrow (*Spizella arborea*) varied erratically from year to year.

- Productivity was relatively constant during 1992-97 despite pronounced differences in the timing of the initiation of breeding. Productivity in 1994 was



The Wilson's Warbler, *Wilsonia pusilla*, population declined in Denali National Park and Preserve, Alaska.

Photograph by P. Knuckles

low, seemingly because of heavy rains during the latter half of June. Productivity and survival remained fairly constant from 1995 to 1997.

(Productivity and survivorship information about target species in Denali National Park and Preserve suggest that adult survivorship may have been the primary demographic parameter that affected population size during the 6 years. Low productivity, especially in 1993 and 1994, may be causing the continuing population decline of the Swainson's Thrush. High productivity in 1993-95 may be responsible for the increased population levels of the Yellow-rumped Warbler.

Golden Eagles in Denali National Park and Preserve, Alaska

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

The National Park Service has been monitoring Golden Eagles in Denali National Park and Preserve since 1987. Currently, this study is the only long-term study of migratory Golden Eagles in the northern latitudes of North America. During the past decade, long-term studies in the western

United States revealed yearly declines in the number of Golden Eagles in fall migration. Because most Golden Eagles that nest in the park are residents of more southern locations, results from the study in the park have broad-scale implications for the conservation of Golden Eagles throughout the western United States.

During extensive surveys from 1987 to 1996, biologists discovered that the largest known breeding population of Golden Eagles in Alaska is in the park. Since 1988, the occupancy and reproductive success by Golden Eagles in 75 nesting territories have been monitored each year. The data are used to make inferences about the population status of Golden Eagles in the park and to compare the reproductive success of this Golden Eagle population with the reproductive success of eagles elsewhere in the world. In 1997, 72 nesting areas of Golden Eagles were monitored. Territorial pairs occupied 63 nesting areas. The occupancy rate in 1997 (88%) was the highest recorded during the past 10 years. Seventy-one percent of the territorial pairs laid eggs in 1997. This is a 29% increase over 1996 and the highest recorded laying rate since 1990. The success rate of 80% in 1997 was somewhat lower than the rate of 88% in 1996. Thirty-six successful pairs produced a total of 57 fledglings. Overall population productivity was 0.90 fledglings/territorial pair, and the mean brood size was 1.58. The overall population productivity and the mean brood size were higher in 1997 than in the last 6 years.

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

Overall productivity of the population (measured as the number of fledglings per monitored nesting area) has drastically varied during the study period (Fig. 28). The proportion of pairs that laid eggs decreased steadily each year from 90% in 1989 to 33% in 1994. However, incubating rates began to increase in 1995 and 1996. The hatching rate also varied greatly, rang-

ing from 42% to 83%. Overall population productivity varied from a low of 0.13 fledglings/nest in 1994 to a high of 0.88 fledglings/nest in 1989. Despite changes in hatch rate and overall population productivity, median brood sizes of 1.13-1.68/nest remained stable during the study period.

Without anthropogenic factors, much of the variation in the reproductive success of birds of prey can be related directly to food supply. The number of nests and the number of eggs highly correlate with observed highs and lows in the population cycles of snowshoe hares (*Lepus americanus*) and willow ptarmigans (*Lagopus lagopus*) in the study area. The correlation suggests that prey availability before egg-laying plays a major role in determining how many eagles lay eggs each year. When eagles return to the park in late winter (March), the diversity of available prey species is low. Based on observations, snowshoe hares and willow ptarmigans are the two most common available prey species of eagles during March. At that time, other common prey species of Golden Eagles in sum-

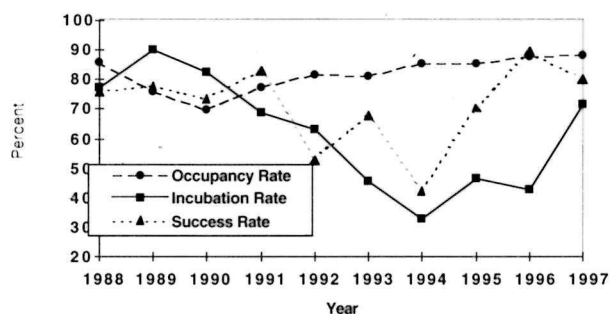


Figure 28. Reproductive success of Golden Eagles, *Aquila chrysaetos*, in a sampling area, Denali National Park and Preserve, 1988-1997.

mer such as the hoary marmot (*Marmota caligata*) and the arctic ground squirrel (*Spermophilus parryi*) are hibernating.

Research in Denali National Park and Preserve has only begun to uncover some factors that regulate the reproduction of Golden Eagles. So far, biologists have not detected direct relations between weather condi-

tions and reproductive success. The relation between weather and prey availability has not yet been examined.

Research during 1997-99 is concentrated on environmental factors that may affect the population productivity of the Golden Eagle. The role of habitat quality (including prey availability) in relation to occupancy of the nesting territory and reproduction and the role of wintering habitat and its relation to future reproductive efforts will be examined. Researchers determined that prey availability and weather during winter can influence reproduction in Golden Eagles. Because Golden Eagles in the park spend nearly 4 months on

their wintering grounds annually, locating and assessing these areas in relation to reproductive success is important information about the ecology of the birds. Satellite radio telemetry will be used to determine the annual movements of adult eagles. The studies will be conducted cooperatively by the Alaska Support Office of the National Park Service and the Forest and Rangeland Ecosystem Science Center of the Biological Resources Division, US Geological Survey. The studies will be funded by the Natural Resource Protection and Preservation program of the National Park Service.

Land Birds in Shenandoah National Park, Virginia

The abundance of land birds—notably that of the migratory neotropical species—has declined during the past 30 years. The decline is attributed to human activities that cause loss or degradation of habitat and widespread environmental contamination. In eastern North America where large parks, refuges, or other protected lands are rare, birds are particularly harmed by forest fragmentation. The large (79,380 ha, 196,000 acre) Shenandoah National Park is therefore particularly valuable to land birds in the eastern United States. The forested upland of the park on 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. More than one third of the 205 bird species in the park are neotropical migrants. Each year, data on adult land birds in the park are collected to estimate the population structure and size, post-fledging productivity, and survivorship. The estimates are examined for trends.

General data on bird populations in the park have been collected in breeding bird surveys since 1990 and by the Monitoring Avian Productivity and Survivorship (MAPS) Program since 1992. The ten most frequently encountered birds in the breeding bird surveys since 1990 in descending order are the Rufous-sided 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 virens*), Scarlet Tanager



Golden Eagle, *Aquila chrysaetos*, nestlings are banded during the annual nest survey in Denali National Park and Preserve, Alaska.

(*Piranga olivacea*), and Chipping Sparrow (*Spizella passerina*). Since 1992, productivity indices of 14 species have been determined and survivorship of 20 species has been estimated.

To date, 5711 birds of 66 species were banded by MAPS. The most abundant species in decreasing order were the American Redstart, Veery, Ovenbird, Hooded Warbler (*Wilsonia citrina*), Wood Thrush, Gray Catbird (*Dumetella carolinensis*), and Eastern Towhee. In contrast to the range-wide declining abundance of the neotropical migrants, the populations of the Veery, Wood Thrush, Solitary Vireo, American Redstart, Worm-eating Warbler (*Helminthos vermivorus*), Ovenbird, Hooded Warbler, and Canada Warbler (*Wilsonia canadensis*) in the park increased substantially (>20%/year) during 1992-97. The productivity of most of these species was high during several years after defoliation of the canopy by the gypsy moth (*Lymantria dispar*) created optimal nesting habitats in heavy shrubs and in herbaceous plant and grass communities.

In contrast, the abundance of the Downy Woodpecker (*Dendrocopos pubescens*), Scarlet Tanager, Rose-breasted Grosbeak (*Pheucticus ludovicianus*), and Indigo Bunting declined substantially. Indigo buntings are not a forest species. However, defoliation may have created near optimal habitat for 1-2 years, particularly before shrubs began to dominate the understory. Consequently, the abundance of this bird was higher than expected during several years but then declined to its more common level when the forest canopy recovered. The remaining three species are either cavity or tree nesting forest species. Defoliation may have made their nests more than usually susceptible to predation or parasitism from Brown-headed Cowbirds (*Molothrus ater*).

Small Mammals in Denali National Park and Preserve, Alaska

In 1997, the area in which small mammals are sampled was extended beyond the boundaries of the Rock Creek drainage to three surrounding watersheds. The objective was to learn whether the dynamics of small mammal populations that have been tracked in Rock Creek for the past 6 years are indicative of the dynamics of populations in similar watersheds along the park road. The knowledge will assist with determining whether the environment of Rock Creek is representative of demographic patterns of small mammals throughout the front country of Denali National Park.

Study plots were established in two watersheds immediately west of Rock Creek and in the Hines Creek watershed into which Rock Creek drains. In these four study areas, 1959 small mammals or approximately 1 mammal/20 traps were captured in 38,400 traps during summer. Small mammals in a study plot at McKinley Bar, located 2 km (1.2 mi) off the park road and about 100 km (62 mi) southwest of Rock Creek, were also sampled. Sampling in the McKinley Bar plot has been conducted annually since 1994 but on a less frequent schedule than in the plots at Rock Creek.

During 1992-96, the abundance of northern red-backed voles (*Clethrionomys rutilus*) was erratic but consistently higher than those of the tundra voles (*Microtus oeconomus*) and singing voles (*Microtus miurus*; Fig. 29). In 1997, however, the abundance of the red-backed vole declined precipitously in Rock Creek and McKinley Bar and were lowest at McKinley Bar. A similarly sharp decline in abundance was not observed of the tundra and singing voles whose abundance exceeded that of the red-backed voles in all watersheds.

The mechanism that governs population dynamics seems to differ between the red-backed vole and the other sampled vole species. For example, one explanation for the variation in abundance may be the difference in diet. Red-backed voles eat fruits and seeds, whereas tundra and singing voles eat primarily herbs. A berry crop failure could cause low over-winter survival of red-backed voles but would not af-

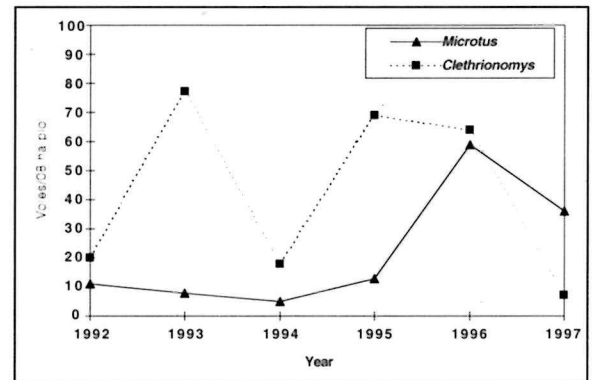


Figure 29. Estimated abundance of voles, *Clethrionomys* spp. and *Microtus* spp., in the Rock Creek watershed, Denali National Park and Preserve, 1992-1997.

fect tundra and singing voles who rely on different foods.

Although the abundance of red-backed voles was low in all watersheds, information from a year when the abundance was high is needed to determine whether the population dynamics of small mammals in the Rock Creek watershed is representative of the dynamics of small mammals over a larger spatial scale.

The spatial sampling regime in the 1997 field season revealed one incident of long-distance dispersal. A juvenile male tundra vole, tagged in the Rock Creek watershed on 9 July was subsequently recaptured on 14 July at a distance of 3 km (1.9 mi) in a different watershed.

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

Management of gray wolves (*Canis lupus*) and their prey in interior Alaska has been controversial during the last three decades. The control of wolves to bolster two populations of caribou (*Rangifer tarandus*) adjacent to Denali National Park and Preserve has again gained attention. Research in the park provides information about the declines of caribou populations and some of the possible causes. The fluctuating populations of both species illustrate the complexity

of managing these species to meet an array of public interests.

Wolves and caribou are two of the large mammalian species in Denali National Park and Preserve. The relation between these large mammals in the park is the only one of its kind that is virtually unaffected by human harvest. Therefore, the park provides a unique opportunity for the study of the natural interactions of these species. The findings may provide basic information for the management of wildlife elsewhere.

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

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

The Denali caribou herd increased from about 1000 animals in 1975 to almost 2500 in 1986 during the decade of mostly below-average snowfalls and increased at about 7%/year in 1986 when the research began. Approximately 46 wolves inhabited the 10,000 km² (3900 mi²) range of the caribou herd in the early years of the study. The number of wolves was lower than expected from the abundance of large prey species in the park. Light snowfalls were favorable to caribou, and few died. Wolves preyed primarily on moose (*Alces alces*) and preyed on only a few very young and very old caribou. The reproduction of

wolves was low, and the dispersal of young wolves was high. Several wolves died in fights between packs.

When winters became more severe again in 1988-89, the number of wolves increased rapidly to 74 within only 2 years. Reproduction increased, and the dispersal of young wolves decreased. In the deep snow, caribou were vulnerable to predation and replaced moose as the most important prey species for wolves. Losses of adult female caribou increased eight-fold to nearly 20%/year. Between 1990 and 1991, nearly half the adult males (about 500 animals) died. The caribou herd stopped growing at about 3300 in 1990 and plummeted to 1700 by 1993—a 50% decline in only 3 years (Fig. 30). At the same time, the number of wolves in the range of the caribou herd also declined to about 60 individuals—a 23% reduction between March 1990 and March 1993.

Subsequent to the reduced availability of forage on the alpine ridges and the increased energy costs of getting to forage under deep snow, the production of calves decreased. Coincident with the increased snowfall, the age at which adult females first reproduced increased from 2 years to 3 years, fewer adult females were pregnant, the birth weight of young was 28% lighter, and stillbirths were noted for the first time in the study. Survival of 4-month-old young substantially declined from nearly 56% in the early years to about 9% in the later years. When young were born

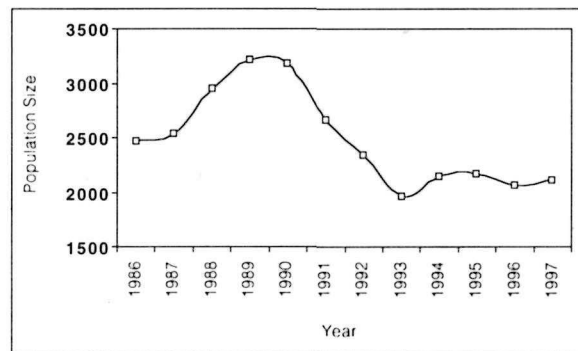


Figure 30. Estimated population size of caribou, *Rangifer tarandus*, in Denali National Park and Preserve, 1986-1997.



Caribou, *Rangifer tarandus*, in Denali National Park and Preserve.

Photograph by P. Knuckles.

large, the few that died were killed by predators primarily within the first 10 days of their lives. The smaller young that were born later in the year died in greater numbers during the early 10 day period but also continued to be killed throughout the year, indicating that they were more vulnerable to predation than the larger young.

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

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

In 1997, the Biological Resources Division of the US Geological Survey and the National Park Service monitored the population dynamics of 11 wolf (*Canis lupus*) packs and the Denali caribou (*Rangifer tarandus*) herd.

- Collars were replaced or added to 28 wolves of monitored packs. Five wolves were also outfitted with experimental data-logging GPS collars. The technology was tested to evaluate the movement of wolves during the caribou calving season.
- The estimated population size of the wolves was 100 in March 1997 or 5.9 wolves/1000 km². This density is comparable to densities in March 1994 and 1996. During the past 12 years, wolf densities ranged from about 3.5 wolves/1000 km² to 7.8 wolves/1000 km² (Fig. 31).
- The estimated population size of 104 wolves in fall had declined from 140 in fall 1996. The three largest packs in the park declined by about 50% during the past year. The fecundity in 1997 of 0.44 pups/

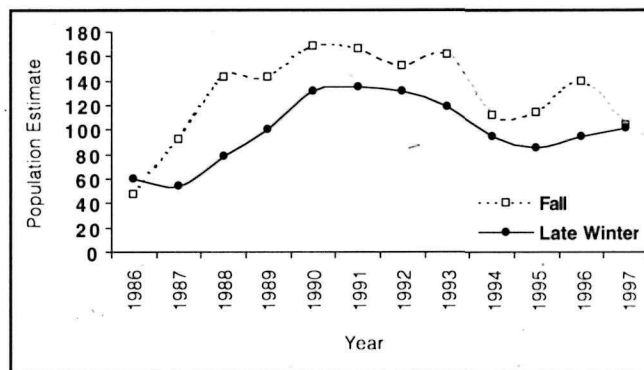


Figure 31. Estimated population size of the gray wolf, *Canis lupus*, in Denali National Park and Preserve, 1986-1997

older wolf was substantially lower than the average fecundity of 0.62 pups/older wolf during the previous 11 years of the study.

⌘ Six radio-collared wolves died during 1997. The causes of death were trapping (4), other wolves (1) and unknown natural causes (1). In 1997, subsistence trappers harvested about 8 wolves (none of them radio-collared) in the section of the park that was added in 1980. An estimated equal number of wolves from packs that range-primarily in the study area was killed by hunters or trappers outside park boundaries. During 1 May 1986 through 30 April 1997, 17 radio-collared wolves were harvested from the study area at an average annual harvest rate of 6%.

⌘ Areas surrounding 5 historically active den sites were closed to visitors during summer to prevent human disturbance.

⌘ During May 1997, 83 adult female caribou were monitored and their 74 calves were radio collared. The fertility of caribou declined; only 79% of the females calved. None of seven 2-year-olds in the radio-collared sample calved. However, 97% of the older cows calved.

⌘ The deaths of 40 calves during May were attributable to wolves (16), bears (14), undetermined perinatal causes (8 within 24 hours of birth), a wolverine (1), and an unknown predator (1). Only 15 calves survived to 1 October 1997.

⌘ Winter snowfalls have been normal since 1993, and the Denali Caribou Herd has stabilized at about 2000 animals. The estimated population size was 2100 caribou in fall. In late September 1997, the sex ratio of the herd was 16 calves:29 adult males:100 adult females.

⌘ Game management units of the state of Alaska that the Denali Caribou Herd uses remained closed to caribou hunting in 1997. Fifty local hunters were issued federal subsistence permits for hunting in portions of the sections added to

the park in 1980, which caribou from other herds occasionally use. However, no caribou were taken. The Denali caribou herd remains unaffected by hunting.

Dall Sheep in Denali National Park and Preserve, Alaska

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

Dall sheep are easily visible from the park road and are a major attraction of visitors. They are also a vital component of the Alaskan Range. During the past 62 years, biologists conducted surveys to estimate the sizes and the sex and age compositions of Dall sheep populations throughout the park. Adolf Murie began a study of the relation between the timber wolf (*Canis lupus*) and Dall sheep in 1939. He accumulated ex-

The abundance of Dall sheep, *Ovis dalli*, is estimated annually in Denali National Park and Preserve, Alaska.

Photograph by P. Knuckles.



tensive data on each species, including age and sex compositions, from ground surveys during 3 years. On 4 August 1934, park personnel conducted the first aerial census of wildlife in the park and counted 2280 Dall sheep during a 4-hr flight. The second aerial census of sheep was conducted in 1947. Thereafter through 1968, aerial surveys were conducted approximately every 2-3 years.

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

Now, aerial surveys are conducted yearly over a smaller section of sheep habitat in the eastern area of the park and on the southern side of the Alaska Range, which was not included in previous surveys. In 1996, a significant portion of sheep habitat in the park was surveyed during winter and summer as part of a study of seasonal migration in sheep. During the survey in summer, 1873 sheep were counted in areas over which previous surveys had been conducted, and 379 sheep were counted inside park boundaries on the southern side of the Alaska Range.

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

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

In 1997, Dall sheep were counted on the ground and from the air during the week of 30 June (the sheep have been counted on the ground in the park-road corridor since 1974):

Table 17. Number of Dall sheep, *Ovis dalli*, lambs and yearlings per 100 ewes and 23-year mean along Park Road, Denali National Park and Preserve, 1996-1997.

Year	Lambs/100 Ewes	Yearlings/100 Ewes
1996	51	17
1997	54	24
23-year mean	48	21

- 200 sheep were classified during counts on the ground: 109 ewes, 26 yearlings, and 59 lambs or 54 lambs/100 ewes and 24 yearlings/100 ewes.
- The number of lambs was similar in 1996 (56) and 1997 (59) and slightly higher than the mean lamb:ewe ratio (48) during the past 23 years. The number of yearlings was greater in 1997 (26) than in 1996 (18) and slightly higher (21) than the 23-year mean yearling:ewe ratio (Table 17).
- The sixth annual aerial count of the sheep was conducted over the Upper Savage, Upper Sanctuary, and Upper Teklanika areas. Unsuitable weather conditions and unavailability of aircraft prevented completion of the aerial survey over the Outer Range. A total of 242 sheep was

counted. Of this total, 157 were unclassified ewe-like animals, 38 lambs, and 47 rams.

- Staff of the National Park Service and the Biological Resources Division of the US Geological Survey continued to monitor the effects of vehicles on Dall sheep crossing the park road, particularly during seasonal migrations. Observations suggested that vehicles and visitors may deter or delay some sheep from traveling between their summer and winter foraging areas.
- Wildlife biologists are evaluating the effectiveness of the survey methods. Changes will be made in 1998 based on the results of this review.

Black-tailed Prairie Dogs in Scotts Bluff National Monument, Nebraska

Prairie dogs (*Cynomys sp.*) once inhabited about 10-20% of the short- and mixed-grass prairies of the United States—now they inhabit a mere 2% of their historic range. The proximate causes of this decline include disease, agricultural practices, and urban development. Although the number of black-tailed prairie dogs (*C. ludovicianus*) may have increased after heavy cattle grazing in the late 1800s, it has since been greatly reduced. Additionally, sylvatic plague (*Yersinia pestis*) was introduced into North America in the late 1800s and is presumed to have caused massive prairie dog die-offs.

Twelve National Park System units have been historically populated by black-tailed prairie dogs. During the past 20-40 years, prairie dogs have been extirpated from five units south of the Colorado-Kansas border. These populations seemingly were small relics of larger external populations that were intensively controlled. Stochastic effects on the resulting small populations may have played a role in their eventual demise.

During summer 1995, monitoring protocols and digital mapping technologies were developed to determine the distribution and abundance of black-tailed prairie dogs in seven parks in the Great Plains, including Scotts Bluff National Monument, Nebraska. Continued

monitoring in Scotts Bluff National Monument in 1996 and 1997 indicates a 86% increase in colony size and a 137% increase in prairie dog density since 1995 (Table 18).

Table 18. Distribution and abundance of the black-tailed prairie dogs, *Cynomys ludovicianus*, in Scotts Bluff National Monument, 1995-1997.

Year	Colony Size (ha)	Density (prairie dogs/ha)	Population Size
1995	1.4	14.2	19.9
1996	1.4	24.0	33.6
1997	2.6	33.6	87.4

A monitoring protocol that describes the sampling methods to estimate prairie dog population size is near completion. Monitoring of prairie dogs will continue indefinitely. Five-year summaries are recommended to track status and trends.

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

Great Smoky Mountains National Park provides refuge for a significant portion of the black bear population in the Southern Appalachian region. The estimated size of the bear population in the park is near carrying capacity. However, increasing demands for timber and recreation on national forest lands around the park, increased development on adjacent private land, illegal hunting, and legal hunting outside the park are placing hardships on the bears in the park.

Black bears in the park are monitored with (1) mark-recapture and aerial telemetry to determine changes in demographics, including sex and age structures, mortality, natality, and movement patterns; (2) bait-station surveys (i.e., population indices) to determine relative changes in bear densities and distribution throughout the park, and (3) a hard mast survey (i.e., food availability index) to determine the availability of important foods (i.e., acorns) and their influence on the bears' population dynamics.

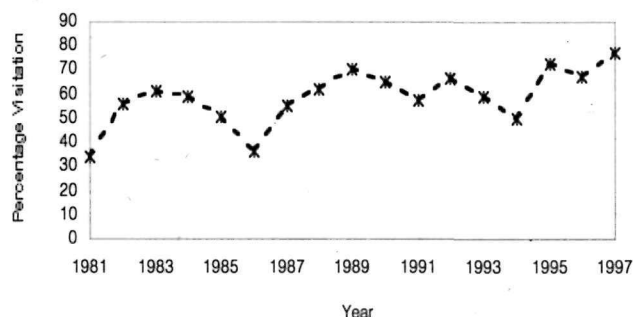


Figure 32. Park-wide black bear, *Ursus americanus*, bait station survey in Great Smoky Mountains National Park, 1981-1997.

From December 1996 until March 1997, female bears were located in their winter dens. Eight female bears were visited, and 5 cubs and 6 yearlings were recorded. Four bears denned in trees and 4 denned on the ground. From 27 May to 6 August, 85 bears were captured 90 times during 776 trap nights (8.6 trap nights/capture). Forty-six males and 37 females were captured. The sex of two bears was not determined. One of the bears escaped while attempts to immobilize it were made, and one bear was killed and partially consumed by another bear. Twenty-four marked bears (11 males and 13 females) were re-captured. Weights of captured bears averaged 53.5 kg. The males averaged 64.9 kg and the females 39.5 kg. Capture success was greater in 1997 than in previous years, indicating an increase in population density. An increase in the bear population size was also indicated by results from the bait-station survey during 10-29 July. Visitation ranged from 33.3 % to 100%. The overall visitation of 77.5% was the highest ever recorded (Fig. 32).

The hard mast survey during 4-22 August revealed poor mast production. White oak (*Quercus alba*) acorns were nearly nonexistent, and red oak (*Quercus* spp.) mast production was fair. The hardship on bears from the poor hard mast crop became apparent during October when bears move extensively in search of food. Many bears moved out of the park, which resulted in increased nuisance complaints and high mortality. In fact, a record number of bears were har-

vested in Tennessee. The harvest was three times larger than in previous years. The low mast production may cause bears to enter winter dens with less body fat that in turn may result in higher fetal absorption and, therefore, lower reproduction next spring.

Population size and survival of the bears in the park in 1997 will be estimated with the computer program JOLLY. The bait-station survey and hard mast survey will continue indefinitely. The mark-recapture monitoring in the southwest section will continue for at least one more year.

White-tailed Deer in Great Smoky Mountains National Park

White-tailed deer (*Odocoileus virginianus*) are native to Great Smoky Mountains National Park. Their density is highest in Cades Cove, which is a cultural zone under agricultural management. Deer benefit from the open vista and cultural landscape of the cove, which are maintained by haying and cattle grazing. The deer are a valuable component of the park. They are important prey for black bears (*Ursus americanus*), bobcats (*Lynx rufus*), coyotes (*Canis latrans*), and red wolves (*Canis rufus*) in the park. The deer are also valued by visitors who spend much time viewing and photographing the animals.

The deer in Cades Cove are monitored to maintain the size of the herd in balance with the carrying capacity of the environment. Excessive browsing could damage native plants, shift the composition of tree species, and alter the community structure of several unique plants. A large herd would also increase the risk of collisions of the animals with vehicles. The health of the herd is also monitored. Disease and parasites caused heavy deer mortality in the early 1970s.

During 1997, the density of the deer in Cades Cove was 0.011- 0.428/ha (0.005-0.173/acre). The estimated size of the herd was 431 deer at a mean density of 0.176/ha (0.071/acre) in the 2,454-ha (6064-acre) area. The abundance of the deer has continued to decline. The gradual decline seems to be from

predation by coyotes and red wolves whose occurrence in the park is recent.

The physical condition, amount of kidney fat, and body weight were average for deer in this region. No animal was in poor health. The mean abomasal parasite count was 472, suggesting that the herd is within and perhaps below the nutritional carrying capacity of its habitat in Cades Cove.

Monitoring of the white-tailed deer herd in the Cades Cove area will continue indefinitely. However, the health of the deer will not be examined during Fiscal Year 1999.

Exotic species, also known as *alien*, *introduced*, *nonindigenous*, and *nonnative species* or simply *exotics*, are plant or animal species that were intentionally or unintentionally introduced into areas outside of the natural ranges of such species. Hundreds of exotic species have been introduced into natural communities of North America. Although many died out, some persisted and have become pests. The invasion of exotic species is one of the most serious problems of national parks. Exotics invade and colonize parks by every possible means and frequently harm or altogether displace native species. They disrupt complex native ecological communities, jeopardize endangered native plants and animals, and degrade native habitats. Hybridization with exotics alters the genetic integrity of native species. Exotic diseases transmitted by exotic species threaten the preservation of native species that are without natural defenses against them. If invasive exotics are not aggressively controlled, the National Park System is at risk of losing a significant portion of its native biological resources.

The distinction between changes in resources by natural processes and changes of resources by human actions has been important in the management of National Park System units. This particular approach to management rests on the National Park Service Organic Act that mandates the National Park Service to "conserve the scenery and the natural and historic objects and the wild life therein . . . [to] leave them unimpaired for the enjoyment of future generations." Changes of natural communities from anthropogenic actions in the National Park System, including the invasion by exotics, would be contrary to the intentions of the act. Comprehensive control of exotics and their effects in the National Park System is therefore compulsory.

Exotic Plants in Shenandoah National Park, Virginia

A park-wide survey of exotic plant species was conducted in 1997. During the survey, the presence of 43 exotic plant species was noted along 59 300-m transects. All transects extended into the forest perpendicular to roads and other areas of human development. The information will be used for the manage-

ment of exotic vegetation. Survey work will be continued in the 1998 field season.

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

The number of rainbow trout (*Onchorhynchus mykiss*) increased in several reaches where the species does not coexist with brook trout. These reaches are in the Indian Camp Creek, Starkey Creek, and Sams Creek. The increases indicate continued encroachment by rainbow trout. Encroachment of the Indian Camp Creek has only been observed and documented since 1995. The sudden invasion of the creek may be attributable to escapes from a rainbow trout hatchery and fee fishing in reaches immediately below the boundary of the park. The densities of brown trout (*Salmo trutta*) were 0.005-0.062/m² (<0.001-0.006/ft²) and of rainbow trout, 0.010-0.160/m² (0.001-0.015 ft²). Young-of-year of the brown trout population were 7-79%, and young-of-year of the rainbow trout population were 18-73%, indicating relatively strong 1997 year classes of both species. The annual mortality of 1-4 year old rainbow trout and brown trout in the park ranges from 60 to 70%.

Exotic Fishes in Shenandoah National Park

During 1997, 604 brown trout (*Salmo trutta*), rainbow trout (*Oncorhynchus mykiss*), and tiger trout (*S. trutta* x *O. fontinalis*) were removed from three streams in the park. A total of 247 rainbow trout were removed from a 2.4-km (1.5-mile) section of Pass Run. Only 15 were adults and the remaining 232 were juveniles. Removed from a 4.8-km (3.0-mile) section of the Hughes River were 329 brown trout and 3 juvenile fishes that seemed to be tiger trout. The 26:303 adult:juvenile ratio of brown trout in the Hughes River was similar to that of the rainbow trout in Pass Run. Removed from a 1.6-km (1.0-mile) section of the Rose River were 24 brown trout and 1 rainbow trout. The latter seemed to have been a vagrant from stocking downstream by the state.

The three presumed tiger trout and four juvenile brown trout from the Hughes River were submitted to Virginia Tech for electrophoretic analysis. Four brown trout and

three juvenile brook trout from a state hatchery were used as controls. Enzyme activity was examined in liver, muscle, and eye tissues. The results confirmed the identification of the three tiger trout that were probably the progeny of a female brown trout and a male brook trout. (Such hybrids are more viable than progeny of female brook trout and male brown trout.) Adult tiger trout are sterile and pose no risk to the gene pools of the parental species. Nine tiger trout have been removed from streams in the park since 1982. They have occurred in every stream in the park that harbors populations of brook and brown trout.

DATA MANAGEMENT IN THE I&M PROGRAM



COVER: DATA MANAGEMENT IN THE I&M PROGRAM.

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 to others in and outside the National Park Service, and to archive and store data for ready access. Because the service must also make its spatial databases available on the information superhighway (i.e., on the Internet), the NPS I&M and GIS programs and others are jointly developing standards and guidelines to document natural resource data sets (i.e., metadata) and to acquire the hardware, software, and technical expertise for maintaining the data sets and making them available on the Internet.

The 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 servicewide I&M data management and data archiving, and (3) providing up-to-date information about the I&M Program activities and accomplishments on the World Wide Web (WWW).

DATA MANAGEMENT PROTOCOLS

Data Management Protocols was drafted 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 ongoing and legacy data sets (Dataset Catalog), and generalized data handling procedures. The first chapter addresses the current status of resources, goals, implementation, and budget for developing a park 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 servicewide needs. The original database was developed in Microsoft Access but was adapted during the past year to 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 about data handling procedures includes 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 and 1997. About 60 copies of the draft were given to various National Park Service staff, and a version is available for review on the world wide web (<http://www.aqd.nps.gov/nrid/im/dmproto/joe40001.htm>). The final document will be disseminated to NPS units and available on the I&M WWW site. Copies of the draft protocols and the Dataset Catalog software are available by request.

I&M DATA ARCHIVING AND DISSEMINATING PLAN

After several years of funding and initiating many servicewide 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. Reviewed here is 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 calls for increased data handling, conversion, and storage in the central office of the I&M Program and the Natural Resource Information Division in Fort Collins, Colorado. Acquisition of new equipment will facilitate recording digital inventory data on CD-ROM; scanning and digitizing maps, images, and aerial photography; serving and maintaining servicewide databases that are critical to the I&M Program; and timely providing data and archived products to parks and other entities. When the archiving facility is 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 will be done by student employees from the Colorado State University under supervision of the I&M Information Management Specialist. In general, the plan calls for the purchase of two new workstation class computers with supporting software and hardware, one Internet server with Lotus Notes/Domino software, and other hardware and software upgrades. Associated technical training and 3-5 student workers will be phased in as technical resources are acquired and inventory projects initiated. Archiving and data formats will be coordinated with other NPS programs.

ROLE OF THE TECHNICAL INFORMATION CENTER

The Technical Information Center (TIC) provides a microfilm storage and computerized information system to manage technical information and products for the National Park Service. TIC 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. TIC will handle requests for archived I&M Program inventory data.

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 data and tracking of information by NPS 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).

In addition to providing on-line services, TIC will archive digital products from I&M Program inventories. For archiving and subsequent access of digital products, the I&M Program will provide digital data to TIC on CD-ROM media for use with existing CD tower equipment. 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 and I&M Program personnel have discussed the possibility of archiving the aerial photographs acquired by the vegetation mapping inventory as high resolution digital images. A digital library of high-resolution air photographs would provide a basis for analyses of change, disaster mitigation, and ecosystem impact studies. Acquisition of a high resolution color scanner is presently not being considered, but digitizing could be incorporated in other programs in the central I&M Program office.

ROLES OF THE FIELD TECHNICAL SUPPORT CENTERS

The roles of field technical support centers (FTSC) are the establishment and support of a GIS program in NPS units. The centers coordinate GIS between NPS units and the servicewide program; provide technical support to parks; and receive, disseminate, and implement basic cartographic products. GIS support is provided also from 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.

FTSCs facilitate the use and development of GIS throughout the system. The NPS GIS Program and FTSCs are cooperating with the I&M Program to deliver all newly acquired digital cartographic data to the central office for duplicating, distributing, and archiving. The I&M Program is currently validating data records in the NPS Quadrangles (Quads) tracking database in anticipation of another comprehensive update by the FTSCs. 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 will be copied or duplicated to CD-ROM for storage at TIC before being disseminated to FTSCs and NPS units for implementation. Similarly, the I&M Program must coordinate more closely with FTSCs 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 baseline water quality inventories. The I&M Program will continue to coordinate data formats and other technical issues with FTSCs to provide long-term compatibility and access to base cartographic data.

DEEP ARCHIVING OF I&M DATA

Data archived to CD-ROM will be temporarily stored in-house at the central office. Data products can be permanently archived with a local company that maintains an environmentally controlled underground data vault in an abandoned missile site near Fort Collins, Colorado. For a nominal annual fee, the company stores analog or digital data storage containers in its secure facility. Data can be retrieved routinely or be retrieved quickly in case of disaster. This combination of offsite and multiple-site archiving will ensure the integrity of I&M data products.

Table 19. I&M Inventories and Data Resources.

Ongoing I&M Inventories	I&M Databases
Base cartographic data	Dataset Catalog (MS Access and WWW)
Baseline water quality status and trends	I&M priorities (17 topic lists)
Bibliographic database	Inventory status (needs periodic revision)
Geologic mapping	NPS quadrangles (under review and revision)
Soil mapping	NPS species lists ¹
Species lists	Geologic reports ¹
Vegetation mapping	Vegetation mapping
Geologic mapping	Geologic bibliographies ¹
	¹ under development

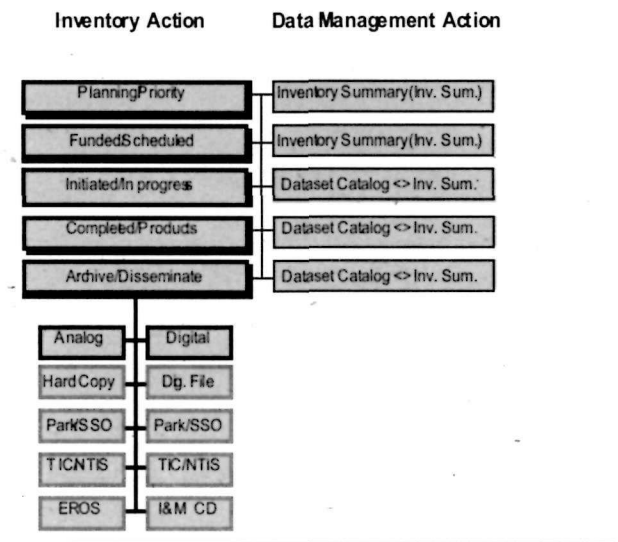


Figure 33. Natural Resource Inventory Process.

SERVICEWIDE MANAGEMENT OF INVENTORY DATA

The I&M Program manages several baseline inventories of natural resource data (Table 19). The goal is to provide resource managers with baseline data and with data from 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 will improve management. In general, each inventory consists of several steps from planning to archiving the completed products (Fig. 33). 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 provides managers with a quick look of 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.

Base Cartographic Data

The inventory of base cartographic 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.

Relations with Data Standards and Programs. Base cartographic data are acquired primarily from the US Geological Survey (USGS) by the Base Mapping Working Group of the Interior Geographic Data Committee (IGDC). In addition, the NPS GIS and I&M programs contracted with Land Info International to acquire DRG data products during the current year. Data acquisition is mostly funded by the I&M Program and the DOI High-Priority Digital Base Data Program (via the IGDC), but NPS units occasionally purchase data directly from USGS. The products are based on standard 7.5' or 15' quadrangles or quarter quadrangles and meet the National Mapping Standards established for each product. The digital formats are suitable for import into a geographic information system (GIS).

Data Archiving. Digital products for the current base cartographic inventory are purchased for NPS units and systematically provided to the I&M Program for duplicating, distributing, and archiving before going to the FTSC 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 cataloged in the I&M Dataset Catalog on WWW. On-line access to the tracking and products lists by parks, clusters, regions, and central offices must 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 FTSCs is a primary inventory goal in the next year.

Baseline Water Quality Inventory

Collection of water quality data and determination of baseline status and trends are joint efforts by several cooperators: Horizon Systems Inc, the Colorado State University, the I&M Program, the Water Resources Division (WRD) of the National Park Service, the US Environmental Protection Agency (EPA), and numerous other federal, state, and local government agencies that store water quality data in the EPA STORET database.

Inventories and analyses of baseline water quality data from all NPS units with significant water resources are being documented in standardized reports by WRD. The data were collected in and near NPS units and stored in EPA's STORET national water quality database. Report information includes descriptive statistics, graphics, and digital cartographic products. Completed reports are provided to the I&M Program, TIC, NTIS, and the NPS units. One hundred and twenty water quality reports have been completed. The inventory may be concluded by late 1999.

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 WRD is a digital park boundary data set based on NPS land status maps or on GIS data from the NPS unit. However, WRD generally has had little access to the base cartography inventory products and has not routinely provided 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 geologic maps with WRD is proposed to aid with ongoing and future water quality, geomorphology, hydrology, and groundwater studies.

Data Archiving. Analog and digital products on an NPS-unit-priority basis are being produced, delivered, and archived. However, at present, the I&M Program is not systematically acquiring and archiving the associated GIS data. The I&M Program is coordinating with WRD to acquire and convert the existing Atlas GIS data to ArcView format, archive the data on CD-ROM, and distribute them to the FTSCs and NPS units.

Furthermore, the full text of each report should be made available servicewide. An on-line database should facilitate the tracking of reports and GIS data. On-line access of the report and tracking list by NPS units, regions, support offices, and central offices must be implemented to maximize the usefulness of the data. Preliminary plans are being discussed to accomplish these goals.

Geologic Resources Inventory

Bedrock and surficial geologic maps and information provide a critical basis for groundwater, geomorphology, soils, and environmental hazard studies. The ongoing and proposed NPS Geologic Resources Inventory consists of three main phases: (1) a bibliography of park geologic literature and maps, (2) evaluation of existing, needed, and in-progress map coverage and subsequent digital products, and (3) compilation of a geologic report incorporating basic geologic information, hazards and issues, and existing park data and studies. In addition to existing geologic data, new mapping projects may be considered on a case by case basis after careful evaluation of park needs, associated costs, potential cooperators, and funding sources. The initial phase of the inventory, i.e., bibliographies of geologic maps and literature, is presently being completed. The I&M Program and GRD are cooperatively developing an inventory plan and pilot projects with input from parks, USGS, and state geological surveys. Plans are being finalized to evaluate maps and scope park issues for eleven NPS units in Colorado and for a pilot map digitizing project for Craters of the Moon National Monument in 1998. Task groups are also currently working on digital geologic map and report format standards.

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 USGS and converted to Procite data files. On-going work is converting the Procite data for the intranet system, editing the map citations for duplicate entries, and preparing a map list file and index map of associated geologic maps. When com-

plete, the GeoBib database will contain about 100,000 references to geologic resource literature in an on-line database. With GRD and I&M funding, a Colorado State University student was hired to work on the GeoBib database. Bibliographies for 27 parks in the three pilot states have been edited for duplicate map citations and used to compile a list of park-associated geologic maps. Bibliographies for additional 15 western parks are also in progress. When a park's duplicate map citations have been removed, 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 boundaries. The map lists and index maps are converted to word processing documents for electronic file transfer to co-operators.

Digital Geologic Map Coverages. A few agencies are digitizing geologic maps with conventional methods and with vectorization or heads-up digitizing of scanned images. The NPS should evaluate these methods to allow versatile data acquisition. Scanning and vectorizing of geologic map masters will be tested in a pilot digitizing project of four geologic maps of Craters of the Moon National Monument by the Columbia Cascades Support Office GIS personnel. In addition, as part of the inventory proposal, the I&M Program and GRD will obtain conventional digitizing technology and digitize some geologic maps in house.

Baseline Geologic Inventory Report. The inventory report will be a summary of the exploration history, geology, unique features, paleontology, disturbed lands issues, available geologic data, geologic hazards, and other geology-related issues as needed to describe the basic geologic resources of each park. Several report sections, such as stratigraphic columns and geologic cross sections graphics, will be developed with student employee assistance. Other sections will be summaries of ongoing NPS programs such as disturbed lands and paleontology. A database system is being developed to provide WWW access for report development and dissemination.

Relations with Data Standards and Programs. Like vegetation mapping, soil mapping depends on the availability of aerial photographs and digital orthophoto quadrangles (DOQs). The goal of produc-

ing maps of soils in each NPS unit at a 1:24,000 scale is compatible with similarly specified scales for base cartography and vegetation maps. However, suitable map scales are determined case-by-case to be compatible with existing products, specific needs of units, and available funds. NRCS is digitizing some maps, but digitization of soil maps of all NPS units can probably not be accomplished without in-house or contracted work by the I&M Program.

Data Archiving. As proposed for geologic mapping, an I&M system to digitize soil maps may be needed to complete the inventory. Digital map data will be archived and distributed on CD-ROM. Tracking of soil map data could be done by modifying the existing soil survey status database and entering the data sets in the I&M Dataset Catalog. Access of the tracking database by NPS units, clusters, regions, and central offices would maximize the usefulness of the data.

SPECIES LISTS, SURVEYS, AND DISTRIBUTION

The objectives of the species inventories are the documentation of 80% of all plant and animal species except invertebrates within the boundaries of NPS units and the production of maps of the distribution of species of special management concern, including threatened and endangered (T&E) and nonnative species. Species lists of NPS units in the southwestern region have been verified and validated. Verification and validation of species lists in units elsewhere are in progress. Some species lists are stored in two different versions of NPFlora and NPFauna (NPF databases) which will be replaced by an I&M database system. Species list updates and mapping of species distribution requires additional planning.

Relations with Data Standards and Programs. The I&M Program is charged with production of species lists inventories, including vascular plants, mammals, birds, reptiles, amphibians, and fish, for all NPS units with significant natural resources (about 265 units). NPS resource managers and scientists have also expressed a need to collect and maintain other species

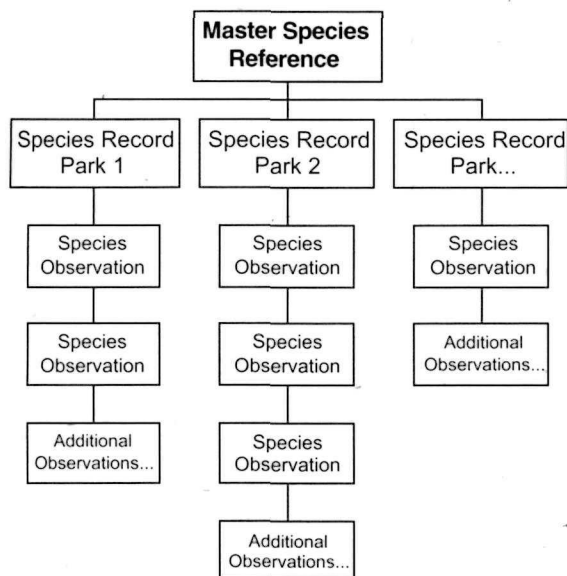


Figure 34. NPSpecies Database Organization.

data (e.g., macroinvertebrates, insects, and fossils) that are outside of the purview of the I&M Program. In the past, NPS units have maintained species lists mostly on an individual basis using a variety of methods, protocols, and record-keeping systems. Much of the accumulated data were incorporated into the NPFlora and NPFauna databases, often without verification and validation. NPFlora and NPFauna were never universally adopted, so systematic validation and updates of Servicewide data were never standardized or accomplished. Successive generations of NPFlora/Fauna databases were developed outside of the NPS, and resulting software compatibility and data issues have reduced the system to minimal use. Along with the need to initiate new species inventory projects for parks, the I&M Program is developing a comprehensive species list database that can accommodate not only new I&M inventory data but other species as well. The basic structure and database model are summarized below.

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

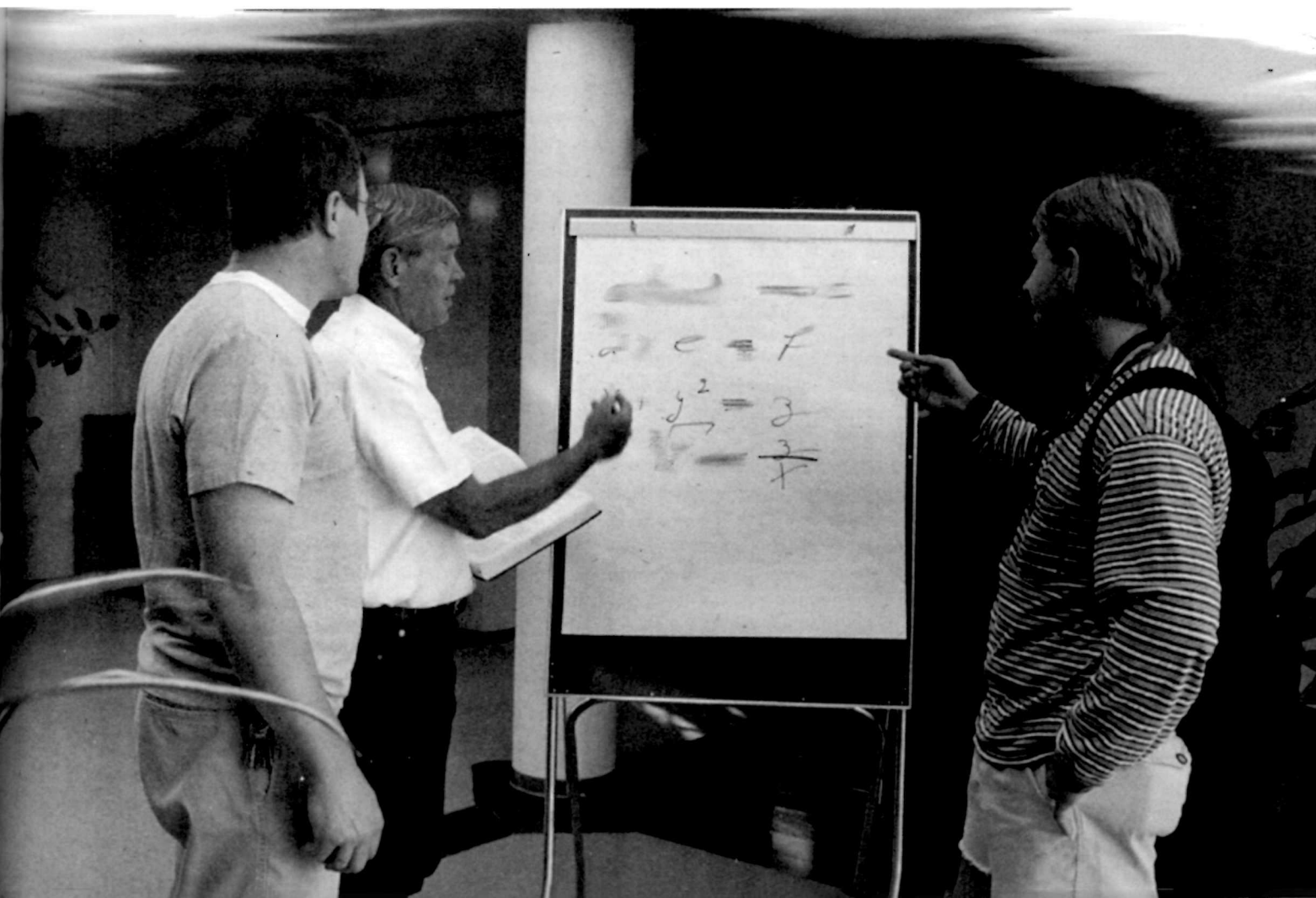
NPSpecies incorporates three levels of documentation for species occurrence (Fig. 34) and extensive help with standard nomenclature authorities, software assistance, and additional species references. The three levels of documentation include 1) species reference documents with systematic taxonomy, 2) 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 NPS resource staff and scientists, and access security for sensitive resources. The pilot NPSpecies database will be implemented via an intranet system model that will 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 NPF 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, clusters, regions, and central offices 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

I&M staff developed a World Wide Web home page (<http://www.aqd.nps.gov/nrid/im/>) that features the *Natural Resource Inventory and Monitoring in National Parks* brochure. The brochure contains general information about the natural resource inventories and long-term environmental monitoring in the National Park Service. Fact sheets about the status of each inventory are also posted on the WWW. The pages maintain links to partners and other National Park Service entities associated with inventory and monitoring. I&M staff is also planning to provide on-line access by the public to selected inventory data.

THE I&M TRAINING PROGRAM



COVER: PREPARATIONS FOR THE I&M TRAINING PROGRAM.

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

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

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

Specific objectives of the developers were:

- the presentation of a systematic approach to developing an integrated, holistic I&M program
- the introduction of the concepts of ecology as applied to an integrated I&M program
- an explanation of the major steps in the I&M process outlined in NPS-75 and the development of a strategy for designing an integrated I&M program that meets specific park needs
- a discussion of the ecological components, experimental design, statistical analyses, quality control, and assurance needs of an I&M program

- a discussion of the role and methods of information management in an I&M program
- a presentation of alternatives and methods for accomplishing I&M
- and a presentation of a diversity of I&M case studies from parks.

When the 32-hour course was last conducted during 15-18 September 1997 in Ventura, California, several prominent scientists and managers from the National Park Service and other agencies presented lectures. Two new sessions were added to the course in 1997: *Legal and Policy Framework* presented by Dennis Vasquez from the Albright Training Center and a session on *Complexity, Uncertainty, and Risk Assessment* presented by Fred Euphrat, a private consultant from northern California. Gary Davis, Senior Scientist from Channel Islands National Park, provided a conceptual overview of the I&M program development process. 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 of the service-wide I&M Program, presented a session on Information Management, GIS, Data Management Systems, and Metadata.

Harold Smith, former superintendent of Organ Pipe Cactus National Monument, gave an inspiring account of the critical need for long-term inventory and monitoring data sets and their roles in park management and resource protection. A presentation of case studies was also an important component of the course. It included a one-day field trip to have participants observe some of the long-term ecological monitoring projects that are parts of the Prototype Ecological Monitoring Program in Channel Islands National Park. In addition to observing first hand some of the monitoring in Channel Islands National Park, the participants were introduced to similar monitoring in Denali National Park and Preserve by Penny Knuckles and Lake Meade National Recreation Area by Kent Turner.

Tentatively, *Natural Resources Inventory and Monitoring* will again be offered for 25-30 participants in Luray, Virginia, during September 1998.

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APPENDIX B. REPORTED RESOURCES BY PROTOTYPE ECOLOGICAL MONITORING PROGRAM, 1996-1997.

Number in parentheses denotes page number of the treatment of the resource in this report.

Cape Cod National Seashore (Atlantic-Gulf Coast Biome)

1996

Piping Plovers

1997

Air Quality (32)

Piping Plovers (67)

Salt Marsh Restoration (48)

Shoreline Processes (29)

Channel Islands National Park (Pacific Coast Biome)

1996

Brown Pelicans

Deer Mice

Island Fox

1997

Abalone (72)

Air Quality (32)

Kelp Forest (48)

Peregrine Falcon (69)

Denali National Park and Preserve (Arctic-Subarctic Biome)

1996

Dall Sheep

Effects of Global Warming on Vegetation at Tree Line

Glaciers

Golden Eagle

Land Birds

Population Trends of Wolves and Caribou

Small Mammals

1997

Air Quality (32)

Cooperative Monitoring of Productivity and Survivorship of Migratory Land Birds (79)

Dall Sheep (87)

Effects of Global Warming on Vegetation at Tree Line (55)

Glaciers (26)

Golden Eagles (80)

Land Birds (79)

Small Mammals (84)

Water Quality (24)
 Weather (45)
 Wolves and Caribou (84)

Great Plains Prairie Cluster (Prairie and Grassland Biome)

1996

Aquatic Macroinvertebrates
 Black-tailed Prairie Dog
 Prairie Restoration
 Western Prairie Fringed Orchid

1997

Black-tailed Prairie Dog (89)
 Butterflies (73)
 Climate and Missouri Bladderpod Population Dynamics (62)
 Missouri Bladderpod (60)
 Prairie, Glade, and Woodland Plant Communities (53)
 Western Prairie Fringed Orchid (60)

Great Smoky Mountains National Park (Deciduous Forest Biome)

1996

Aquatic Macroinvertebrates
 Black Bear
 Brook Trout
 Fish Communities in Large Streams
 Forest Insects and Diseases
 Terrestrial Vegetation
 Threatened and Endangered Species
 Water Quality

1997

Air Quality (32)
 American Columbo (58)
 Black Bear (89)
 Brook Trout (75)
 Exotic Fishes (92)
 Fishes in Large Streams (76)
 Forest Pests and Diseases (70)
 Long-term Vegetation Monitoring (57)
 White Mandarin and Sword-leaved Phlox (58)
 White-tailed Deer (90)

Shenandoah National Park (Deciduous Forest Biome)

1996

Air Quality

Fish Populations
Water Quality

1997

Air Quality (32)
Black Bear (89)
Brook Trout (78)
Exotic Fishes (92)
Exotic Plants (92)
Forest Pests (71)
Land Birds (82)

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

1996

Coral Reefs
Reef Fishes on St. John

1997

Conchs and Lobsters (75)
Coral Reefs (50 and 51)
Hawksbill Sea Turtle (64)
Reef Fishes (78)



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