STATEMENT OF PURPOSE

The Servicewide Inventory and Monitoring Program will chart the course and provide the leadership and information resources needed by the National Park Service to preserve and protect the natural resources placed under its trust by the American people into the 21st Century and beyond.

Through its accomplishments, the Program will further enhance the National Park Service's stature as an international leader in natural resources management and stewardship.

EXECUTIVE SUMMARY

Knowing the condition of natural resources within the National Park system is fundamental to the Service's ability to protect and manage the parks. Based on legal mandates and National Park Service (NPS) policy, the major goals of the Servicewide inventory and monitoring (I&M) program are: to inventory the natural resources and park ecosystems under NPS stewardship to determine their nature and status; to monitor park ecosystems to better understand their dynamic nature and condition and to provide reference points for comparisons with other, altered environments; and to integrate natural resources inventory and monitoring information into NPS planning, management, and decisionmaking. Other goals include establishing natural resources inventory and monitoring as a standard practice throughout the NPS and forming partnerships with other natural resource agencies in order to pursue common goals and objectives.

This guideline: (1) summarizes the reasons for inventory and monitoring of natural resources in units of the National Park System; (2) provides an overview of the Servicewide I&M program, including staff roles and functions; (3) describes a process for conducting I&M studies at the individual park level; (4) identifies major ecosystem components useful for resources inventory and long-term monitoring; and (5) provides data administration and reporting guidelines for the program.

The document also outlines strategic considerations needed to rank inventory and monitoring needs, standardize recording techniques, test model inventory and monitoring systems in selected parks, bring all parks up to an acceptable level of resource awareness, and develop a framework to synthesize inventory and monitoring information over large spatial and long temporal scales.

Finally, the guideline provides information which should guide national, regional, and park efforts to implement an I&M program in about 250 NPS field areas with significant natural resources. Application of the I&M approach contained herein, combined with the knowledge gained from assessing existing park I&M activities, should assist management of park natural resources proactively from a basis of knowledge. As the I&M program progresses, the individual elements of the program will be reviewed and revised; technical protocols, quality assurance plans, and data management plans will be developed; and individual park I&M plans will be initiated in direct support of park natural resources management.

TABLE OF CONTENTS

STATEMENT OF PURPOSE i

EXECUTIVE SUMMARY ii

INTRODUCTION 1

Legal Requirements for Resources Inventory and Monitoring 1
National Park Service Policy 1
Definitions and Purpose of Resources Inventory and Monitoring 2

SERVICEWIDE PROGRAM CONSIDERATIONS 5

Long-Term Programmatic Goals 5
Staff Roles and Responsibilities 5
Tactical Program Planning and Coordination 7
Program Implementation 8

CONCEPTUAL OVERVIEW OF THE INVENTORY AND MONITORING PROCESS 9

Steps in the Process 9
Alternative Approaches to Inventory and Monitoring Studies 12

BIOLOGICAL RESOURCES INVENTORY AND MONITORING 15

Phase I: Inventory 15
Phase II: Monitoring 16
Phase III: Integration 17

CHEMICAL AND GEOPHYSICAL RESOURCES INVENTORY AND MONITORING 18

Phase I: Inventory 19
Phase II: Monitoring 20
Phase III: Integration and Special Studies 21

DATA MANAGEMENT AND DECISION SUPPORT 22

Inventory and Monitoring Protocols 22
Quality Assurance/Quality Control 22
Decision Support 23
Annual Resource Status Reports 24

REFERENCES 26

APPENDIX A: Recommended minimal set of natural resource information which should be available in all natural resource parks 27

APPENDIX B: Suggested Parameters for Biological Inventory and Monitoring 30

APPENDIX C: Suggested Parameters for Geophysical and Chemical Inventory and Monitoring 33

INTRODUCTION

Legal Requirements For Resources Inventory and Monitoring

The need to know the condition of natural resources (i.e., the status of resources compared to some reference) on a continuing basis in national parks was recognized and developed in public law as early as 1872. Executive proclamations and orders clarify and further the intent of these laws. The natural resource mission of the NPS is to provide the American people with "the opportunity to enjoy and benefit from natural environments evolving through natural processes minimally influenced by human actions." (NPS *Management Policies*, Chapter 4:1, 1988). The National Environmental Policy Act of 1969 requires certain knowledge of resource conditions to direct and evaluate effects of management actions. The Forest and Rangeland Renewable Resources Planning Acts of 1974 and 1976 also express Congressional insistence on inventory and monitoring of natural resources on all public lands in the United States. Several other Federal laws and executive orders also provide legal direction and support for expending funds to determine the condition of natural resources in parks (e.g., Endangered Species Act, 1973, amended 1982; Fish and Wildlife Coordination Acts, 1958 and 1980; Migratory Bird Treaty Act, 1974; Clean Water Act (33 USC 1251 et seq.); Executive Order 11900 (Protection of Wetlands); and the Clean Air Act (42 USC 7401 et seq.) 1963, amended 1977, 1991).

National Park Service Policy

The management policy of the NPS reflects these legal mandates and directs that management be based on knowledge of resources and their conditions. The National Park Service has an obligation to "manage the natural resources of the national park system to maintain and perpetuate their inherent integrity." (NPS *Management Policies*, Chapter 4:1, 1988). NPS policy also states that "a program of natural and social science research will be conducted to support NPS staff in carrying out the mission of the National Park Service by providing an accurate scientific basis for planning, development and management decisions." (NPS *Management Policies*, Chapter 4:2, 1988).

NPS policy further states that "The National Park Service will assemble baseline inventory data describing the natural resources under its stewardship and will monitor those resources . . . to detect or predict changes. The resulting information will be analyzed to detect changes that may require intervention and to provide reference points for comparison with other, more altered environments." (NPS *Management Policies*, Chapter 4:4, 1988).

Thus, NPS policy requires that park managers know the nature and condition of the natural resources under their stewardship, have the means to detect and document changes in those resources, and understand the forces driving the changes, in order to fulfill the NPS mission of conserving parks unimpaired. Natural resources inventories tell us what resources are in trust. Monitoring is indispensable to determine desired resource conditions; to diagnose human impacts; to direct management intervention; and to measure subsequent success or failure of that intervention.

Park management is directed to integrate scientifically valid resource inventories, monitoring, research, and restoration. These interdependent activities are required for conservation of unimpaired parks (NPS

Management Policies, Chapter 4, 1988). Besides their utility in determining natural conditions and detecting ecological problems, the long-term data sets also may be used to detect correlations and pose research hypotheses to establish causal relationships, to evaluate the effects of management activities, to determine compliance with emission and discharge standards and regulations, and to develop and evaluate mitigation of specific anthropic perturbations. Although inventory and monitoring will help frame and focus research questions, studies specifically designed to determine, regulate, or mitigate impacts of known environmental perturbations are beyond the scope of the natural resource inventory and monitoring addressed by this guideline (see NPS-77; Natural Resources Management Guideline, 1991).

Definitions and Purpose of Resources Inventory and Monitoring

Definitions

Natural resource inventorying is the process of acquiring information on park resources, including the presence, distribution, and condition of plants, animals, soils, water, air, geological features, biotic communities, natural processes, and human-induced changes in park resources.

Natural resource inventories are accounts of park resources, including the presence, class, distribution, and normal variation of plants, animals, and abiotic components such as water, soils, landforms, and climate. Inventories are designed to contribute to a statement of the condition of park resources, which is best described in relation to a standard condition such as the natural or unimpaired state. Inventories may involve both the compilation of existing information and the acquisition of new information. They may be either intensive in space (synoptic) or intensive in time (i.e., designed to detect temporal variations).

Natural resource monitoring is long-term systematic repetition of a specific resource survey and the analysis of those data to predict or detect natural and human-induced changes in resource condition, and to determine if natural resource condition objectives are being achieved.

Purpose of Resources Inventory and Monitoring

Preserving the natural resources (and natural processes) in the national parks may be the most important legacy the Park Service can provide American conservation. Probably no ecosystem on earth remains totally unaffected by modern human activities. But, in a world in which natural places have become few and precious, knowledge of the composition and function of relatively unaltered natural systems is invaluable. This program will provide a fundamental knowledge of those systems and the technical basis for "ecosystem management."

Perceptions of national parks have changed over the past 120 years. National parks were originally conceived as pleasuring-grounds for the people, to be preserved in their natural condition and protected from wanton destruction (16 USC 21-22). As the nation's frontier was settled, the national parks became islands of nature and were increasingly valued as emotional retreats from the stresses of modern life.

This view of parks, reflecting the states of science and society, led to a static approach to management and protection of park resources. By the early 1960s, scientists recognized that parks were changing unacceptably despite heroic protectionist efforts. The Leopold Committee (Leopold et al., 1963) recognized the dynamic nature of parks in its 1963 report to the Secretary of the Interior, and recommended that ecological management of parks replace the protectionist approach. The 1963 Robbins Report recommended strongly that "The natural history resources of each park should be inventoried and mapped." (Robbins, et al., 1963 pg. XIII).

National parks are recognized now as reservoirs of wild genetic materials and subsequent biotic diversity that are fundamental to future bioengineering, agriculture, and pharmaceutical developments. They are outdoor laboratories for studying ecological processes. Even more importantly, as the potential adverse impacts of human activities on the globe have become more widely recognized and politically acknowledged, national parks have become "canaries in the mine" for the biosphere. Natural systems in national parks provide the best indicators of ecological effects of anthropic perturbations such as air pollution, ozone depletion, and global warming. The inventory of park resources and monitoring of park ecosystems offer an excellent mechanism for understanding natural environmental variation and for developing and evaluating attempts to mitigate adverse impacts by providing empirical evidence of ecologic change. By developing sound technical information on park resources, the NPS is better positioned to actively participate in the management of those resources, both through its own discretionary actions and through more effective involvement in broader state and Federal natural resource programs.

Purposes of Inventories

Park stewardship requires that park personnel observe and document the changes in park ecosystems to the degree necessary to interpret and analyze the cause of change. To accomplish this, it is necessary to inventory biotic and abiotic elements and document important ecosystem processes and perturbations (i.e., human use, erosion, flood, fire, wind, earthquakes, volcanic eruptions, migrations, biogeochemical cycle changes, etc.). An important first step is to document the status of each park's knowledge. A high I&M priority is to complete needed park inventories where significant information gaps exist. The inventory establishes the point of departure for required monitoring activities.

The primary purposes of resource inventories are to: (1) document the occurrence, location, and current condition of physical habitat (water, air, soil, etc.) and major associated taxa (biota); (2) identify locally rare or threatened and endangered species, locating fragile (or rare) ecosystems and potential "indicator species"; and (3) assess the full range of populations, ecosystem components, processes, and stresses from which to subsample for later long-term monitoring. It is essential to understand the representativeness of selected monitoring elements.

Park inventories include general or specific descriptive data and historical records regarding park natural resources. Information collected should include: legal description, climate, land classification, topographic maps, watershed delineation, geology, surficial and structural maps, soils, hydrology, water quality, air quality, flora (including vegetation maps), fauna, general site characteristics (e.g., land-use patterns, sources of pollution, human use and impacts), historical and prehistorical records (e.g., documents, maps, photos, fire scars, personal inquiry, permanent plot records, records of natural and unnatural perturbations such as pests, disease, floods, logging, etc.), and listing of other related past or ongoing studies in or near park ecosystems.

Purposes of Monitoring

Natural resources monitoring is designed to detect changes and quantify trends in resource conditions. Properly designed, monitoring serves to provide information on linkages between changes in resource conditions and their causes. Monitoring is designed to provide a feedback between natural resource conditions and management objectives and can serve both to trigger management actions and to evaluate their effectiveness.

Resource monitoring is currently conducted in many parks specifically to: (1) determine compliance with environmental standards; or (2) evaluate impacts of visitor and management activities. Air and water quality monitoring systems have been developed to measure physical, chemical, and biological parameters. Long-term studies are also undertaken in response to detected or anticipated human impacts on natural resources.

The purpose of a natural resource ecological monitoring system is to provide a rational basis for taking management actions. Actions based on sound scientific data from monitoring will engender a higher level of confidence and will better ensure that natural resources and ecosystem functions remain unimpaired for future generations. In short, use of monitoring information will increase confidence in managers' decisions and improve their ability to manage park resources.

SERVICEWIDE PROGRAM CONSIDERATIONS

Long-Term Programmatic Goals

To comply with legal requirements, fully implement NPS policy, and guide management activities, the Servicewide Inventory and Monitoring Program focuses on attaining the following major long-term goals:

1. Establish natural resource inventory and monitoring as a standard practice throughout the National Park system which transcends traditional program, activity, and funding boundaries.

2. Inventory the natural resources and park ecosystems under National Park Service stewardship to determine their nature and status.

3. Monitor park ecosystems to better understand their dynamic nature and condition and to provide reference points for comparisons with other, altered environments.

4. Integrate natural resource inventory and monitoring information into National Park Service planning, management, and decisionmaking.

5. Share National Park Service accomplishments and information with other natural resource organizations and form partnerships for attaining common goals and objectives.

Attaining these long-term goals is the only avenue to "manage the natural resources of the national park system to maintain and perpetuate their inherent integrity." (NPS *Management Policies*, Chapter 4, 1988).

Staff Roles and Responsibilities

In a Servicewide, multi-disciplinary endeavor like inventory and monitoring, it is important to define clearly the roles of the various staff members relative to the common goal. Here, the common goal is to understand resource dynamics to maintain healthy ecosystems. It is everyone's job.

1. **The Director** is responsible both for knowing the condition of the resources under Park Service stewardship and for directing efforts to sustain them. The Director is also responsible for securing funding for the Servicewide Inventory and Monitoring Program. The Director's staff formulates strategic and tactical plans, coordinate and guide Servicewide I&M efforts, assure Servicewide standardization of techniques and data management, and set priorities for fiscal resources. The Director's staff also works with other NPS offices, Regional Directors, and other agencies and private organizations conducting similar efforts.

2. **Regional Directors** are responsible both for knowing the condition of the resources in their region and for directing efforts to sustain them. They appoint regional I&M Coordinators to coordinate I&M activities, assure standardization and quality assurance/quality control, set priorities for fiscal resources, and document progress at the regional level.

3. **Superintendents** are responsible for setting local policy and priorities. They direct and integrate the efforts of research scientists, resource specialists, park rangers, and other park staff to assure perpetuation of unimpaired park resources. They focus the park staff's attention on critical issues, formulate strategic and tactical plans, and set priorities for fiscal resources. They are ultimately responsible both for knowing the condition of park resources and for directing efforts to sustain them.

4. **Research Scientists** conduct original research to create new knowledge about park ecosystems. They work with resource specialists and regional programs offices to design inventory and monitoring protocols (standardized as much as possible with similar programs in other parks and regions) and develop new techniques for assessing the changing condition of park ecosystems. They investigate changes, and through experimental, manipulative research, determine causative agents. They develop and test new methods to restore human-impacted ecosystems. Research scientists also assist resource specialists in analyzing and synthesizing monitoring data, preparing resource status reports, and publishing monitoring results in professional journals.

5. **Resource Managers** have the primary responsibility for implementing inventory and monitoring programs. Together with research scientists, resource managers and subject area resource specialists design and implement inventory and monitoring protocols as an operational responsibility. They monitor ecosystems through periodic sampling, and assure that complete and accurate records are maintained. They recognize atypical and human-impacted resource conditions, mitigate those conditions when necessary and feasible, and evaluate the results of those mitigation treatments. They work closely with research scientists in analyzing and interpreting data, and with other park staff to ensure accurate applications of data to management issues and interpretive programs.

6. **Field Operations** are managed and conducted by rangers, maintenance workers, and administrative staff. They may play an active role in collecting I&M data following prescribed protocols or in disseminating information to the public. In addition, maintenance personnel assist in keeping equipment operating and provide transportation and other logistical support. Like field rangers, they see resource conditions firsthand and anticipate potential effects of facilities construction and rehabilitation projects. For example, they conduct ad hoc monitoring of erosion associated with park facilities, including roads and trails, and public health concerns such as potable water supplies and sewage treatment. Also, park rangers identify overt threats to park ecosystems, such as toxic spills. They provide immediate, practical treatments to alleviate acute problems and temporarily stabilize the situation. They protect human-stressed ecosystems until the mitigation of underlying causes can be instigated. Interpretive rangers interpret scientific findings regarding park ecosystems and explain their significance. They also develop ways to explain park values and threats to those values, to ensure adequate understanding of park issues by a wide cross-section of the American public.

Because I&M bridges traditional NPS research and resource management responsibilities, it requires the explicit cooperation of those at the field level and the formal support of administration at every level of the organization.

Tactical Program Planning and Coordination

An important component of the Servicewide I&M program is planning and coordination at the Washington level. The I&M Program Coordinator directs the day-to-day development of the program at the Servicewide level. An I&M Program National Committee (consisting of Washington Office natural resource staff; region, park and CPSU scientists; superintendents and resource managers) advises the I&M Program Coordinator and provides program guidance and coordination.

The I&M Program National Committee will coordinate an inventory and evaluation of natural resources databases of all natural area parks. The primary objectives of the survey should be to: (1) provide a qualitative assessment (categorical summary) of the status of species lists for various biological groups (vascular plants, mammals, birds, reptiles, amphibians, terrestrial and aquatic invertebrates, and non-vascular plants); (2) inventory mapped information on vegetation, soils, geology, and other natural resources; (3) inventory photographic series, aerial and satellite imagery, and digitally processed information; and (4) inventory information on air and water resources.

The I&M Program National Committee will also develop and recommend minimum standards for inventory and monitoring of natural resources for all natural area parks. For example, at the very least, the Committee currently recommends that all such parks possess the information listed in Appendix A. More comprehensive listings of desirable biological and geophysical parameters are provided in Appendix B and Appendix C respectively.

Model inventory and monitoring systems will be tested in a variety of park ecosystems. A hierarchical approach (from pilot parks to surrounding parks to regions, etc.) will be used to develop an efficient regional inventory and monitoring strategy. This approach will incorporate both intensive (target parks) and expansive (all parks) research in essentially a nested experimental design. Since there are no universal "off the shelf" technologies available to inventory and monitor park ecosystems, Washington Office staff will coordinate protocol development. Standardization of information type and scope is needed to make comparisons among parks and regions. Likewise, standardized data management and reporting procedures are essential elements of the program (see Data Management and Decision Support, below).

Program Implementation

It is important to recognize that development of Servicewide inventory and monitoring programs is an iterative, experimental endeavor. Several iterations will be required to identify critical steps in the process. The success of the Servicewide I&M program will depend largely on the long-term coordination of I&M efforts at the park, region, and Servicewide levels.

Appropriate inventory and monitoring objectives at this time are to develop adequate inventory information and the expertise to design monitoring programs efficiently in the future. To meet these objectives, a systematic approach to inventory and a pilot monitoring program have been developed.

In the first 10 years, the Servicewide Inventory and Monitoring Program will complete basic natural resources inventories for the National Park System, implement comprehensive monitoring programs in a selected sample of "pilot parks," design monitoring programs for a portion of the parks, and implement a prototype Decision Support system to facilitate park management and data exchanges between parks. In addition to park management and planning, the products of this effort will also support preparation of "State of the Park Ecosystems" reports.

About 250 park units have significant natural resources requiring resource inventories. The regions will assess and document the extent (completeness) and quality of existing inventory data in these parks. Parks with the most nearly complete inventories will be completed first so they can serve as models (and perhaps as pilot monitoring parks). Parks with the most poorly developed resource inventories will be scheduled next. These parks will need the longest time to complete inventories and their early scheduling will provide managers with urgently needed data. Within each of the above categories, timing of inventories will be based on a balance of biogeographic regions and park sizes to provide a representation of the National Park System at the earliest possible date.

Eight to ten pilot park monitoring programs will be implemented during the first ten years. To minimize cost and to expedite results, parks (or park clusters) where inventory and design work is most advanced will be selected. However, to assure maximum applicability of experience gained from the pilot programs, a range of biogeographic regions and park sizes will be represented in the selection of monitoring sites.

The Service will need to develop adequate Decision Support systems to integrate the large amounts of new data generated by a Servicewide inventory and monitoring program. These efforts will be coordinated at the park, region, agency, and inter-agency levels. Enhancement of GISs can meet some data management needs, but additional systems need to be designed and implemented. This effort will probably require additional staff and expertise to operate those systems (e.g., biometricians, ecological modelers, and data base administrators.)

CONCEPTUAL OVERVIEW OF THE INVENTORY AND MONITORING PROCESS

Steps in the Process

A conceptual overview of the major steps in the National Park Service Inventory and Monitoring (I&M) process is shown in Figure 1. The first step in the process is to articulate clearly the management goals and objectives of the park-specific program in concert with regional and servicewide goals and objectives. Since it is impossible and unnecessary to inventory and monitor all the natural resources, ecological processes, and environmental stresses, park-specific management goals and objectives must be realistic and attainable.

The second step in the I&M process is to evaluate the status of available data on biotic and abiotic resources. Examples include, but are not limited to: creating an annotated bibliography of past research in the park, gathering species lists, assessing mapped information and imagery, and describing the physical environment and human use activities (Figure 1).

Usually, an assessment of the available data will facilitate the development of a conceptual model of the major ecosystem components, processes, and stresses interacting in the park. At this third step in the process, the services of a Science Advisory Team may be used to help identify resource inventory needs and priorities. Another useful approach may be to implement a "stepdown process" similar to that depicted in Figure 2.

Once a conceptual model has been completed, it should be used to identify park-specific inventory objectives. These objectives will also be essential in later efforts to design a monitoring program. These objectives may include: documenting the current biodiversity of major taxa, identifying locally rare or threatened and endangered species, locating fragile (or rare) ecosystems and potential "indicator species," and identifying the full range of populations, ecosystem components, processes, and stresses to subsample from for later long-term monitoring. Meeting these objectives is essential to understanding the representativeness of selected monitoring elements later.

Upon completion of the inventories of the highest priority elements (step 4), the next step is the design of the monitoring program. Again, the active involvement of local scientists and park staff might be useful in identifying specific hypotheses to be tested, setting monitoring priorities, and developing statistically-sound monitoring protocols. At this point, inventory information may be too incomplete or too variable to develop some protocols. Additional inventory needs might be identified for some populations, ecosystem components, processes, or stresses, while monitoring is initiated for others. A risk analysis involving an assessment of the nature of resource threats and the vulnerability of resources to human-induced impacts may contribute to the prioritization of monitoring objectives.

Figure 1. Conceptual overview of the inventory and monitoring process in natural area parks.

Once the monitoring program has been designed and protocols peer-reviewed, monitoring can begin (Figure 1). The primary objectives of natural resources monitoring are to: (1) detect changes and to quantify accurately trends in resource conditions; (2) develop information on the linkages between changes in resource conditions and their causes; (3) provide field validation for any modeling efforts associated with monitoring, and (4) provide insights into the effectiveness of resource management policies and actions. Thus, monitoring efforts must be evaluated often to assure that selected monitoring elements are sensitive to change and that the techniques employed are effective. The major components of a monitoring program are similar to those of an inventory program, including: well defined roles and responsibilities of staff, a detailed data management plan, a quality assurance and quality control program, and standardization of techniques (to the greatest degree possible) among parks monitoring similar resources.

The last step in the I&M process (although inventory and monitoring will be an ongoing, periodic process), is the Decision Support component, i.e., analysis and synthesis of data and the reporting of results in a format consistent with managerial decisionmaking needs. Analysis involves examination of individual components of the monitoring program to find out their nature, proportion, function, interrelationships, etc. Synthesis involves a hierarchical examination of a monitoring program from individual components to the combined system level changes and trends. Mathematical models may be needed to predict the long-term effects of various managerial actions and ecological stresses and processes. Together, the analysis, synthesis, and modeling efforts precede report generation, making of management recommendations, and identification of new inventory and monitoring needs.

Alternative Approaches to Inventory and Monitoring Studies

There are no universal "off the shelf" technologies available to assess ecosystems. Systems for the inventory and monitoring of biological resources are varied, and systems for the inventory and monitoring of whole ecological units, such as forests, deserts, and grasslands, are virtually non-existent. Thus, development of inventory and monitoring protocols may be an experimental endeavor that should be conducted by research scientists. What and how to inventory and monitor must be discovered. However, a comprehensive literature review and compilation of existing data is a prerequisite to designing a park-specific monitoring program. The components, processes, and stresses of park ecosystems need to be identified, techniques developed to monitor them, natural conditions defined, and treatments developed to mitigate human impacts on ecosystems. However, it is important not to "reinvent the wheel" in each park: protocols can and should be standardized to allow comparisons among parks with similar resources or resource threats.

Development of an inventory and monitoring program should be guided by an analysis of existing "completed" inventory data sets. Lack of basic inventory data invariably causes some uncertainty in planning site-specific I&M activities. Servicewide coordination of I&M program development should help to lessen these uncertainties and assist the regions and field areas in developing the infrastructure required to complete initial I&M activities.

To be effective, inventory and monitoring efforts must be focused and designed to provide information for park managers and the public. Because park staffs cannot inventory and monitor everything, inventory programs must be designed to address critical resource management issues and concerns. Once an inventory of biotic and abiotic resources has been completed, representative elements may then be selected and tested for monitoring. These representative elements should include not only natural resources, but the processes by which they interact and their human-induced stresses. Monitoring must be hypothesis-based or driven by a "monitoring question," presumably one which relates to resource conditions and the potential for change in those conditions.

The agents of change (and specific ecosystem responses to those agents) initially may be unknown, so a monitoring design must anticipate general resource threats and potential responses. Additional monitoring may be conducted to evaluate the success of specific management activities, such as prescribed burning, wildlife and fisheries restorations, or controls on visitor access or activities.

Detailed below are several approaches for describing and monitoring ecosystem dynamics developed by different disciplines. Among the more popular and potentially useful for long-term ecosystem monitoring in national parks are assessments of physical and chemical pollutant and natural constituents, and measures of population dynamics, biodiversity, biomass, and productivity. By monitoring representative portions of these components, the nature and extent of park ecosystem dynamics may be determined.

The first monitoring approach is to consider plant and animal populations and constituents of air, water, and soil as the basic components of park ecosystems. Population dynamics--the ways in which populations change over space and time--offer one way to monitor the biological components of park ecosystems. Parameters of populations such as abundance, distribution, age structure, reproductive effort, and growth rate are relatively easy to measure, are often sensitive to subtle, chronic stress, and predict future conditions. This approach is also sensitive to a wide variety of environmental conditions because organisms integrate the effects of influences like predation, competition, and pollution, and express their responses to these influences as easily measured population parameters. This integration, however, prevents certain identification of causation and accurate predictions of system behavior based only on monitoring observations. Though population monitoring is not the quickest or surest way to determine causality, it provides a potential indication of future conditions. Parameters such as age structure and reproduction permit projections of future conditions, providing early warnings of pending problems. Subtle, chronic stresses are often reflected in reduced growth and reproductive rates. Interpretation of these parameters is relatively direct and may be synthesized into system level applications. Many management controls also operate at the population level, so application to management issues is direct and measurable.

A second approach to describing and monitoring ecosystems is with respect to biodiversity. Biodiversity is an important attribute of ecosystems that functions at many levels: genetic, individual, population, community, and even ecosystem. Although complete inventories are impossible, obtaining some measure of park biodiversity is entirely consistent with one of the I & M program goals (i.e., to determine the nature and status of natural resources and park ecosystems under NPS stewardship). This approach requires highly skilled investigators to identify and catalog the elements of diversity. Monitoring biological diversity in parks is one measure of the effectiveness of NPS efforts in biological conservation when compared to the surrounding, more-altered ecosystems.

A third approach to describing ecosystems is by measuring biomass and productivity. Measures of standing crop (biomass) and productivity provide a common currency for comparisons among ecosystems by reducing all components to their mass or energetic content. These measurements are useful where classic population dynamics techniques may fail, such as with lichens where individuals are difficult to differentiate or monitor. These methods are often complex and difficult in the field, and frequently require destructive sampling (e.g., estimating cover to biomass relationships). However, these measures may provide an important linkage to causal agents by serving as biomonitors (e.g., lichens and air pollution).

A fourth approach to describing ecosystems is by monitoring key abiotic components. Ecological limiting factors, such as nutrients and other chemical and geophysical constituents, are used to characterize the sensitivity of ecosystems to rapid undesirable change. Drawing on a useful management principle, this approach to system monitoring selects a few critical control points in the system and evaluates the flow of selected constituents through those points (e.g., the effects of acid precipitation and air pollution). When knowledge of natural, background levels of the constituent are known, constituent monitoring can provide excellent early warnings that may be directly applied to management issues.

Different combinations of the above approaches will likely be needed to inventory and monitor the dynamics of national park ecosystems and assess change. However, many of the common, persistent, and troubling issues confronting the Service may be used to develop priorities for the inventory and monitoring process. One approach would be to combine the many threats identified in the State of the Parks Report 1980 and in the Natural Resources Assessment and Action Program, with a review of park programs. The following examples demonstrate how priority resource management issues can be used to provide important direction to the structure of an I&M program: (1) life zone or biogeographic changes (e.g., grizzly bear in Greater Yellowstone Ecosystem, many local individual species problems, and regional species population changes); (2) human encroachment (e.g., recreation, industrial development, resource exploitation); (3) biogeochemical changes (e.g., acidification, air and water pollution, forest decline); and (4) global climate change (e.g., temperature changes and life zone changes, melting snow fields and glaciers, mean sea level change and shoreline erosion; precipitation change--patterns and amounts, flooding, and drought).

Clearly, individual park responses to these issues will be very disparate, as they are driven by many overlapping management concerns. However, programs that address these related global, regional, and local issues (e.g., visibility; atmospheric deposition; population changes, distributions, and relationships; land use change; and resource integrity) have produced sets of similar, site-specific types of measurements. Planned, multiple-park natural resources monitoring programs with uniform data collection requirements from which we can draw experience are limited, but examples do exist. They include: National Atmospheric Deposition Program (NADP); National Acid Precipitation Assessment Program (NAPAP); visibility monitoring; fire management programs (AFFIRMS); integrated pest management, USGS-NAWQA, EPA-EMAP, and others.

Long-term monitoring must be base-funded and closely tracked at all organizational levels to assure continuity. The program cannot succeed over the long term--forever, in the context of the Park Service mandate--unless it is institutionalized fully at the level of park operations.

BIOLOGICAL RESOURCES INVENTORY AND MONITORING

Execution of a biological inventory and establishment of a long-term monitoring program should take place in logical phases because they are part of a continual process leading to the acquisition of knowledge about the biotic resources of a park. These major phases may be generally defined in terms of the tasks scheduled for completion at each level of effort. They are: Phase 1: Inventory; Phase II: Monitoring; and Phase III: Integration. Appendix B contains a list of biological parameters which should be considered for inclusion in the three phases.

In terms of the individual steps shown previously in Figure 1, Phase I includes evaluation of historical data, development of conceptual models, and collection of initial resource data sets. Phase II involves the design and implementation of long-term monitoring programs, while Phase III addresses the last step in the process, namely the analysis and synthesis of inventory and monitoring data collected during the first two phases. However, these phases are to be viewed as "suggested" Servicewide priorities, not as prerequisites. Park and regional priorities are important considerations when developing an I&M plan.

The specific priority of a task/product within a phase depends upon the urgency of the information required, cost/benefit ratio, and natural planning sequence in which some information must be collected before the methodology for the next task can be determined. Moreover, information collection begun in one phase may well continue as tasks in later phases are initiated; it may--in the case of monitoring, for example--continue indefinitely. Thus, the sequence of information development that follows must be considered only a general guide. Further, additional tasks may be recommended by the park's Science Advisory Team as issues arise. Because Phase I is designed to provide a park with a basic description of its biological resources, it is recommended that all 250 units of the National Park System with significant natural resources attain the level of information identified in Phase I. In some cases, particularly where native biotic resources are not a significant resource value, Phase I information may be sufficient.

This section describes examples of tasks and products to be completed, as well as a general order of priority for their accomplishment, but purposely excludes methods since standardized methods may vary with the resources being studied. A discussion of standardized methods will be the subject of a future addendum to NPS-75.

Phase I: Inventory

Historical data base A comprehensive picture of the present state of the park's knowledge of its biota and related factors, and the history of these resources, needs to be compiled from existing source materials, with as much information as possible (or at least references to it) transferred to computer data bases (text and map based). This information is typically manuscripts, published material, maps, photographs, and, in some cases, existing geographic information system data bases. Of special importance are records of rare but significant events (e.g., floods, major landslides, volcanic eruptions). A bibliographic data base referencing the body of published and significant unpublished documentation on park biota and related resources is essential. Critical review of this historical data base is imperative to analyze the status and quality of existing natural resource information about the park and its environs.

Geography An important aspect of Phase I is the location of resources with respect to a modern, high resolution base map series (e.g., USGS 7.5' quads) and coordinate system (e.g., Universal Transverse Mercator). Whether or not a GIS data base has been developed at this time, resources should be mapped to the accuracy and precision appropriate for eventual entry into a GIS data base. The map selected should be the largest scale, i.e., have the highest spatial fidelity, appropriate to the subject. An accurate and comprehensive representation of the park landscape and its vicinity at a known time is compiled from aerial and ground photography, satellite data, and land survey. It is most important that the "study area" include surrounding lands that influence park biota. This "study area" is determined early in the inventory process because it is used to define the universe within which data are collected. A primary data theme to be mapped is vegetation communities and other land cover, usually derived from remote sensing prior to detailed fieldwork; such a map is invaluable in stratifying other kinds of sampling. Qualitative biotic community descriptions of the map classes are developed based on preliminary ground-truthing.

Species During Phase I, the presence of as many species as possible is established. The ultimate goal is to establish an accurate inventory of all life forms within a park, but this is a long-range goal. The historical data base can be a starting point, but an inventory must be based on empirical, rather than inferential data because Phase I information must be reliable and accurate enough to serve as the basis for an effective monitoring program. Development of inventory priorities may be based upon criteria including taxonomic group; legal status (e.g., endangered); endemism; non-native species; species legally or illegally taken; species characterizing communities; heroic species; and species described in enabling legislation. Ordinarily, all vascular plants and vertebrate animals are included in Phase I inventory, as well as other species of interest or importance (e.g., lichens in tundra communities; marine mollusks; gypsy moths and other non-native insect pests; major pathogens). Distributions of plant and animal species of special interest or concern are also to be developed in Phase I but may be greatly expanded in Phase II as new systematic surveys are conducted. The collection and storage of voucher specimens is mandatory to document inventory information.

Phase II: Monitoring

Populations Monitoring of population size (or density, cover) for selected species-populations of plants and animals is initiated during Phase II based upon information collected in Phase I. This includes age, stage, or size-class structure as appropriate to understand population trends and condition. Similarly, population regulation factors are determined and monitored where appropriate: recruitment, growth, mortality, and productivity. Models of population dynamics and regulation may be developed for certain species. Species-populations selected for indepth analysis are identified based upon the criteria listed above (Phase I. Species).

Communities During Phase II, community structure and species composition is determined and monitored for all biotic communities in the park study area. This includes the proportional representation of different physiognomic types (e.g., herb, shrub, tree; invertebrate, vertebrate) and measures of abundance of the different species. These composition measures are of specific samples of biotic communities, but also can be used to characterize biotic communities throughout the park study area. Such descriptions are quantitative and objective, permitting precisely repeated measures in the future.

Geography Important landscape patterns are also mapped and studied during the Monitoring Phase. These will probably vary from place to place, but may include migration corridors, habitat fragmentation, land use, and a variety of abiotic features that help explain the distribution of biotic resources.

Phase III: Integration

Populations During integration, genetic evaluations should be conducted for species of special concern and determinations made whether genetic status must be monitored. Generally these evaluations are only appropriate for small, isolated populations, those of a rare genotype, and those where genetic diversity may be a problem. Integration for most populations will consist of quantitative descriptions of population dynamics.

Communities To achieve integration at the community level, abiotic components that help explain changes in biotic communities are recorded on the system of field sample plots established during inventory. Abiotic features recorded may include terrain, soil chemistry, soil moisture, water depth, temperature, etc. Changes in species composition are monitored quantitatively, as are other aspects of community dynamics (e.g., levels of pathology, species substitution). Population models are combined to develop community dynamics models.

Ecosystems Important ecosystem-level integration factors include nutrient pools (e.g., nitrogen, phosphorus, carbon), decomposition rates, biomass of living and dead organic matter, energy flow, and productivity. These are ordinarily monitored only at selected sites, such as designated watersheds and eco-centers of special interest. Quantitative descriptions of trophic relationships are developed. A model of energy and nutrient pools and fluxes is constructed for selected sites. Finally, an ecosystem model may be developed to predict the impacts of various perturbations, including management actions, on the park's biotic resources.

CHEMICAL AND GEOPHYSICAL RESOURCES INVENTORY AND MONITORING

Chemical and geophysical resources inventory and monitoring focuses on select substances and their sources in the environment, with the goals being to measure nutrient input and cycles, to detect undesirable substances and their modes of transport into and through the system, and to identify effects on components of ecosystems. The I&M of natural substances and pollutants comes through examination of the atmosphere, geology, water, soil and litter, vegetation, and animals.

Chemical and geophysical inventory and monitoring focuses on those geological, hydrological, and meteorological processes and variables that comprise the "physical habitat" component of park ecosystems. Physical-chemical inventory and monitoring should identify important geomorphic, hydrologic, and atmospheric processes responsible for the character of park natural resources and monitor those processes most vulnerable or likely to change measurably or to cause fundamental changes to occur among park resources and park ecosystems.

The selection of which chemical and geophysical constituents, biological taxa, and processes to monitor may be one of the most perplexing decisions to be made in design of a resource monitoring program. The actual selections will vary among parks, but the objective is the same for all systems: a representative sample of components that characterizes the structure and function of the entire ecosystem. A proven way to make these selections is to ask experts on each component identified in a conceptual model to apply independently selection guidelines and make appropriate recommendations to park managers. These then can be reviewed and modified through workshops and symposia, with traditional research investigations, or some combination of both.

Given the scope of these subject areas, particular efforts must be made to have effective standardization and quality control so that valid comparisons between data can be made later. Sampling precision and scale, and sample storage, chemical analyses, and data interpretation should be standardized and documented.

In conceptualizing physical and chemical inventory and monitoring programs, it is useful to think of three broad phases of information needs. Phase I is primarily a basic inventory phase and involves synoptic surveys of park resources. Phase I information may be useful in broad condition analyses for planning and in identifying problems. Phase II is primarily a monitoring phase and involves carefully designed programs intended to track and evaluate the condition of specifically designated resources but may also be an extension of (or more intensive look at) resources in a Phase I survey. Phase II information should be useful in detecting changes in resource conditions. Phase III is a "special studies" phase where unique, unusually complex, or non-traditional resources are being evaluated, or technologies applied. Phase III studies also may involve complex "process" studies. Appendix C contains a suggested list of geophysical parameters that should be considered for inclusion in the three phases.

Phase I: Inventory

The objective of Phase I is to gather historical and synoptic data identifying and locating the topography, geology, soils, hydrology, climate, and the chemistry of water and atmosphere. These data provide an inventory of park physical resources to be used for future reference and to determine if more detailed studies and/or monitoring are required.

Air resource Phase I activities should focus on identifying: (1) sources of air pollution which may be impacting the park's air resource; (2) existing air quality data collected in or near the park; and (3) those park resources that are particularly sensitive to, and may be adversely affected by, air pollution. Consequently, an inventory of major pollution sources and air quality monitoring stations near the park, and resources sensitive to air pollutants will generally suffice to satisfy this requirement. Air quality related values (AQRVs) include visibility, odor, fauna, flora, and geological resources; archeological, historical, and other cultural resources; and soils and water resources. Although the identification of AQRVs could be coincident with Phase I activities for other biological, physical and geochemical inventories, there are relatively few AQRVs that can be identified without prior scientific study of the resource. For example, the identification of vegetative species that may be sensitive to air pollutants (e.g., ozone) will require a literature search, at a minimum. Typically, however, it will require extensive chamber or field fumigation studies to establish pollutant sensitivity (a Phase III activity), or extensive field injury surveys by trained personnel in cases where pollutant sensitivity has been thoroughly documented (a Phase II activity). One AQRV that can be documented by resource managers without extensive study is visibility related: scenic vistas associated with the park. These vistas, which may be internal or external to the park, should be integral to the visitor experience or be based on the park's enabling legislation. Although these vistas have been identified previously for park areas designated as class I under the Clean Air Act, it is important to ensure that all parks have identified any scenic vistas associated with them.

Water resource Phase I activities should focus on locating and classifying important water resources, including a basic description of water quality. The location, size, and flow of streams, lakes, springs, wetlands, and ground water supplies should be obtained from maps and field surveys. A coordinated survey of the chemistry of streams, lakes, springs, and ground water for a basic list of chemical constituents should be closely coordinated with associated aquatic biology inventories. In addition, Phase I activities should characterize the physical components of watersheds and aquifers, including geology, soils, and topography. Procedures should be developed to obtain systematic records of weather.

The data obtained should be archived in park records and, when appropriate, a report should be written summarizing findings. The information should be reviewed by NPS technical and resources management staff to determine if further studies are required and if a monitoring program should be initiated for some natural resource categories.

Phase II: Monitoring

The objective of Phase II is to develop a routine monitoring program for physical measurements or chemical constituents to assess processes that affect natural resources and to detect trends in measured quantities.

The most frequently occurring monitoring program involves water resource studies of the chemistry, flow, and properties of streams, springs, lakes, and aquifers. Depending on the type of park hydrologic system, a water resource monitoring program could involve periodic stream gauging, periodic sampling for dissolved constituents, water level measurements in wells, or measurements of physical, chemical, and biological properties in lakes and streams. This data should be tabulated, archived, assessed for consistency, and reviewed to detect trends or possible changes. Frequency of measurements depends on the system being studied. Other monitoring programs that would be necessary in some parks are for significant thermal features, volcanic hazards, or land slide hazards. A component of any monitoring program is a basic understanding of the system being monitored. For example, it is important to know the basic determinants of stream chemistry if one is to monitor it, but this may involve nothing more than a recognition that it is produced by rock weathering. Chemical processes influencing other ecosystems may be much more difficult to understand, increasing the difficulty in developing effective monitoring programs for such resources as a deep lake or complex watershed.

Water resource monitoring should be geared towards quantity and quality concerns, and the relationships to associated aquatic, wetland and riparian resources. Because the states and other Federal agencies have key roles in the collection of water resource data, and in the administration of water quality and water rights programs, it is extremely important that NPS programs be closely coordinated, both technically and programmatically, with those other programs. For example, the USGS operates a nationwide network of water quality and quantity stations and supports standardized programs of quality assurance/quality control and data management. Other agencies (e.g. U.S. Fish and Wildlife Service, U.S. EPA) also support large national programs dealing with water quality, aquatic biomonitoring, and contaminants monitoring.

Air resource monitoring may be required in cases where air pollution or impaired visibility are suspected of affecting park values. Air quality is unique within the NPS because of the extensive Servicewide monitoring networks operated by the Washington Office Air Quality Division. Despite their extensiveness, these networks are unlikely to meet all the air quality monitoring needs of the Service. Nonetheless, there are cases where a park's I&M needs for a particular resource may be best met by a program managed at the Servicewide or regional organizational level. Creating an infrastructure at the Servicewide or regional level may result in certain economies of scale that would not otherwise be realized and also ensures the level of standardization and consistency often required of some programs. Sometimes it is advantageous for the park to become a part of existing monitoring networks by merely passing through funds to another agency or group. In addition to the Air Quality Division's monitoring programs, a good example of this is the National Atmospheric Deposition Program, which assures the required standardization and comparability of data through the use of one central analytical laboratory. Therefore, park managers must be aware of existing monitoring programs and decide whether the park's needs would best be met by participating in programs not managed or operated at the park level. This would be the preferred alternative when very stringent quality assurance requirements are imposed by other federal or state regulatory agencies (as is the case for air quality monitoring) or when extensive contractor support may be required in the collection, validation, and management of the data. Nothing precludes the park's active involvement in such programs.

Air quality monitoring programs may include integrated sampling or continuous monitoring of chemical or optical atmospheric constituents and meteorological parameters; the documentation of the incidence and severity of visible foliar injury on indicator species; or monitoring of ecosystem components sensitive to acidic deposition. Many of these activities can be satisfied by existing Servicewide programs (e.g., NPS visibility, fine particle, and gaseous pollutant monitoring networks), or by incorporating park I&M funds and activities into these existing programs. Creating an infrastructure at the Servicewide or regional level would result in certain economies of scale that would not otherwise be realized and also would ensure the level of standardization and consistency often required of these programs.

Phase III: Integration and Special Studies

Phase III geophysical and chemical inventory and monitoring involve the application and integration of techniques typically not used or applied under the routine monitoring activities performed under Phase II. Phase III techniques or studies are normally used in a research context to understand complex systems or relationships, to monitor at extreme levels of sensitivity, or to perform intensive monitoring studies having very specific monitoring objectives. Phase III studies are usually interdisciplinary in nature, requiring coordination among numerous researchers and the development of peer-reviewed research or study plans.

Work at this level should be undertaken when the problem to be studied requires more than what standard or routine monitoring can accomplish, or when the results of routine monitoring identify a significant resource problem requiring more intensive study to meet critical management needs. For example, determining the major pathways of elevated toxic pollutants (or acidic deposition) into an ecosystem or watershed would qualify as a Phase III study. The integration and/or formulation of mathematical models with monitoring results to simulate existing systems or processes will typically be required in Phase III studies. Development and testing of new monitoring methodologies may often be required in this phase. Phase III studies will normally involve publication in peer-reviewed scientific journals along with reports to NPS management.

The design of chemical and geophysical inventory and monitoring programs should incorporate the design concepts presented above.

DATA MANAGEMENT AND DECISION SUPPORT

Development of an effective data management and Decision Support system is an essential part of the monitoring design process. Once field sampling is complete, raw data are recorded, archived, and entered into computer programs that assist in summarizing information. Data standards and management protocols should be clearly documented. Data are then analyzed through lists, charts, tables, graphs, and statistical calculations as appropriate for management needs. These summaries and analyses are accomplished with standard NPS adopted software (such as dBASE III +, Lotus 1-2-3, GRASS, and WordPerfect). Geographic Information Systems (GIS) offer some of the most powerful tools for managing, analyzing, and displaying ecosystem health information. To facilitate analysis and application of data to management issues, it is important that there be one integrated data management system, rather than separate programs for each component. To the extent practical, data standards and administration for water and air resources should be compatible with national standards developed by other agencies (e.g., USGS, EPA, states) and should take advantage of data bases available to the NPS (e.g., EPA-STORET).

Inventory and Monitoring Protocols

Monitoring protocols for each park should be documented in handbooks for each ecological component monitored. Handbooks institutionalize monitoring and allow many observers to continue the monitoring process over the long term by describing data collection and analysis techniques in detail. In this way, continuity and quality of future data collection can be maintained. As field methods are further tested and experience allows for new insights, park handbooks will be reviewed and revised. An annual report provides a mechanism for reviewing and making recommendations for revisions in the handbooks.

Quality Assurance/Quality Control

A major goal of inventorying and monitoring is to detect and quantify changes in natural systems and to determine statistically if they are caused by anthropogenic factors. A commitment by scientists and other technical personnel to the collection of quality inventory and monitoring data over the long-term is necessary if anthropogenic factors are to be shown to be significantly altering natural processes. Consistency in the collection and analysis of long-term data results in precise data and the ability to detect trends. (Many data sets have been rendered useless because of inconsistency in collection, and long-term data sets are especially vulnerable.)

The principal objective of any quality assurance/quality control program is the production of data that are of a quality consistent with known levels of accuracy (the sum of random and systematic error) and precision (mutual agreement among replications). **Quality assurance**, or the application of procedures that reduce sampling and analyzing errors for improved data precision, begins with initial data collection design, and is in place throughout data collection, analysis, integration, and storage.

Common quality assurance procedures, routinely applied, include: (1) use of consistent collection and analytical methods over time; (2) use of equivalent monitoring equipment among different sites; (3) use of consistent formats in field and laboratory data reporting and structure of files; (4) use of procedures that maximize the capacity to integrate data sets with a minimum of manual data re-entry (viz., GIS technologies); (5) maximum use of automated data handling techniques that ensure quick access to recently acquired data and ease of access to all data; and (6) use of existing and proven data collection protocols.

Quality control, or the application of specific procedures in sampling and analysis to ensure accuracy of results, is to be built into any inventory and monitoring effort. It begins with data collecting.

The justification for change in any specific steps employed in gathering data is driven principally by changes in data accuracy objectives. Following the statistical analysis of data that document circumstances that could improve sampling accuracy, revised sampling procedures might be required. That is, existing data accuracy may be insufficient to detect trends. However, in no instance are new methods to be employed merely for convenience or on the suspicion that they may improve data accuracy. Rather, new methods are to be considered only when it has been determined that there is a need for data with better accuracy. At that point, change should be brought about by calibration of the "old" and "new" procedures.

A major factor in quality assurance is consistency in the use of procedures, a process best ensured by employment of qualified and committed personnel. When the I&M effort includes large numbers of both spatial and temporal data collected over a network of sites, as is the case with the NPS, the quality of personnel can be a major factor in the level of quality assurance. There is no substitute for attention to detail: this comes only from personnel who are committed to the long-term objectives of inventory and monitoring. Personnel can detect situations that appear to deviate from the norm through familiarity with the natural variables they are observing and an understanding of analytical procedures. And, it often is these persons' observations or suspicions that are the keys in detecting the need for better procedures, or perhaps even in taking a new conceptual approach in data acquisition or research.

By necessity, inventory and monitoring in the Park Service must be long-term. Personnel involved must be committed to the long-term objectives and the processes required to achieve them. There are few, if any, short-term products. The reward is the professional satisfaction that comes from doing quality work in a consistent manner.

Decision Support

Decision support generally refers to the process of developing and implementing specialized information needed to support managerial decisionmaking. The acquisition of comprehensive, high-quality data sets about the natural resources within a particular park is a vital first step in effective decisionmaking. However, to be most useful, those data need to be converted into a format consistent with decisionmaking needs at that particular park as well as at all levels within the NPS.

Effective decision support should accomplish at least two important objectives. First, it should provide the capability to integrate both biological and geophysical components of the ecosystem. A second important objective is to provide managers with the ability to conduct "what if" gaming exercises to explore the sensitivity of park ecosystems to, and likely consequences of, management policies or anticipated human-induced changes. The goal is to be able to "explore" the data sets collected in the field. In this regard, the ability to compare past ecosystem conditions with projected future conditions under alternative scenarios is a cornerstone of effective decision support. As an example, multiple regression models that allow managers to compare past trends in forest defoliation and local air quality conditions could be used to predict quantitatively how forest defoliation might increase given a projected change in air quality once a power-generating plant comes on-line outside of park boundaries.

Implementing effective decision support throughout the NPS will require that park managers be able to clearly define performance indicators (e.g., population density, water chemistry parameters, etc.) for the resources they manage and establish quantitative values for those performance indicators, which, considered collectively, equate to healthy ecosystems. In this manner, managers establish targets to be maintained or restored if the park has undergone degradation. Establishing such quantitative targets also facilitates comparisons of the park ecosystems with similar ecosystems at other locations as well as the aggregation of resource information throughout the NPS.

Annual Resource Status Reports

Resource inventory and monitoring is not complete if only the field observations and data analysis are done. The results also must be distributed in a usable form and archived for future reference. A long-term monitoring program must adapt to changes in environmental conditions and take advantage of changing technology and knowledge without losing the continuity and integrity of the data record.

Establishment of a formal reporting procedure can facilitate this continuity and document program evolution. A formal reporting procedure should define the format, determine the appropriate audience and distribution, and establish procedures and standards for professional review. An annual summary report documenting the condition of park resources should be developed as part of the annual revision of the parks Resource Management Plan. Guidelines to help authors and reviewers organize their thoughts and comments, and an outline to facilitate report consistency, are provided by the Washington Office. The reports should be edited by one or more NPS research scientists, an academic (or other agency) subject area scientist, and an editorial review board composed of the park superintendent and selected division chiefs. The reports serve as a repository for inventory and monitoring observations, a vehicle for disseminating information locally, and a mechanism for documenting management recommendations, including changes in inventory and monitoring procedures. Reports generally should be prepared each year after the field season. Review, analysis, and application of these reports should include the entire park staff to foster understanding of resource issues.

From the technical information included in these resource status reports, an annual "State of the Park's Ecosystem Report" can be produced. This report should highlight major issues and summarize technical information with graphics and other illustrations like a corporate stockholder's annual report. Its purpose is to convey a sense of park resource conditions to the public and to the NPS Directorate.

REFERENCES

Leopold, A. S., S. A. Cain, C. M. Cottam, I. N. Gabrielson, T. L. Kimball. 1963. Wildlife management in national parks. Report to the Secretary of the Interior by the Advisory Board on Wildlife Management. Mimeographed. 23 p.

Robbins, W. E., A. Ackerman, M. Bates, S. A. Cain, F. F. Darling, J. M. Fogg, Jr., T. Gill, J.M. Gillison, E. R. Hall, and C. L. Hubbs. A Report by the Advisory Committee to the National Park Service on Research. National Academy of Sciences, National Research Council. 156 p.

APPENDIX A

Recommended minimal set of natural resources information which should be available in all natural resource parks

1. Historical Database

   a. Compilation of collections of historical scientific material being stored in the park, including rare event records, maps, photographs, manuscripts, specimen collections, etc.

   b. Automated bibliography of all descriptive documents and scientific studies pertaining to park natural resources, included extended search for published and unpublished documents outside the park, incorporation into an automated program, and establishment of procedures for maintaining currency.

2. Species information

   (NOTE: Vascular plants are identified below for priority action because they are the predominant biota in most terrestrial ecosystems. Likewise, vertebrates, also identified as priorities, are a good starting point for animal species because they often are the subject of management actions or concerns, including those related to threatened and endangered status. Additionally, information is likely to be be more readily available in most ecosystems for both vascular plants and vertebrates, compared to other classes. Because this is the case for most parks, priority is accorded these organisms and Servicewide databases for vascular plants and vertebrates will be maintained.

   For parks containing significant ecosystems where vascular plants and/or vertebrates are not the primary ecosystem components, for example in marine areas, nonvascular plant and invertebrates may be as higher or higher priority species. It is intended that parks add these classes of organisms to the basic species list requirements where this is the case.)

   a. Lists of the following biota identified as occurring in the park:

      - Vascular plants
      - Vertebrate animals
      - Federally and State listed threatened and endangered species
      - Species of special concern within the park, including endemic and exotic species, and others based on legislation or other factors

   b. Surveys to confirm ocurrence of reported species and to discover new species of:

      - Vascular plants
      - Vertebrate animals
      - Federally and State listed threatened and endangered species
      - Species of special concern, as above

c. Species status and distribution information for:

   - Federally and State listed threatened and endangered species
   - Species of special concern, as above

3. Digital maps of vegetation associations in the park and environs

4. Digital cartographic data--including, digital elevation models/digital line graphs (DEM/DLGs), consisting of hydrography, hypsography, boundaries, and transportation.

5. Digital soils maps (SCS "Order 3" surveys except where more detailed surveys are specified for management purposes)

6. Digital geology maps/(bedrock and surficial)

7. Water resources inventory

   a. Location (with additional classification from that included in digital cartographic information) of:

      - streams
      - lakes
      - wetlands
      - groundwater (hot springs, cold springs)

   b. Water quality use classifications

8. Water chemistry for key water bodies, based on size, uniqueness, representativeness, threats, etc., including:

   - Alkalinity
   - pH
   - Conductivity
   - Dissolved oxygen
   - Rapid bioassessment baseline (EPA/State protocols, involving fish and macroinvertebrates)
   - Temperature

- Flow
- Other constituents **where important** as determined on a case-by-case basis:
  - Toxic elements
  - Clarity/turbidity
  - Nitrate/Nitrogen
  - Phosphate/Phosphorus
  - Chlorophyll
  - Sulfates
  - Bacteria

9. Location of existing nearby ambient air quality monitoring stations and sources

10. List of:

- Air quality-related values
- Visibility goal

11. Precipitation and meteorological data

- Precipitation amount
- Relative humidity
- Wind speed and direction
- Maximum and minimum air temperature (daily)

APPENDIX B

Suggested Parameters for Biological Inventory and Monitoring

A. Historical Database

1. Rare event records
2. Bibliography of all resource descriptive documents
3. Collection of manuscripts, old maps, photos, etc.
4. GIS and related maps

B. Species

1. Gather species lists for vascular plants and vertebrate animals
2. Inventory of vascular plants including distribution
3. Inventory of mammals, birds, fish, amphibians, and reptiles including distribution
4. Inventory of other species of special interest (e.g., sensitive to air pollution)
5. Listing of species that are threatened, endangered, endemic or non-native
6. Distribution maps of plant and animal species of special interest
7. Inventory of invertebrates and non-vascular plants

C. Populations

1. For selected species:
   a. Distribution
   b. Population size (including density/cover if appropriate)

c. Age/stage/size class structure

d. Growth/recruitment/productivity/mortality

e. Population genetics

D. Communities

1. Vegetation/land cover map

2. Community structure

3. Species composition

4. Important abiotic components associated with sample plots

E. Ecosystems

1. Important nutrient pools

2. Decomposition

3. Biomass (living and dead)

4. Productivity

5. Energy flow

F. Integration

1. Qualitative community descriptions to correspond with vegetation map

2. Landscape patterns (e.g., fragmentation, corridors)

3. Population models for species of special interest

4. Quantitative descriptions

    a. Population dynamics

    b. Trophic relationships

    c. Changes in species composition

    d. Community dynamics

5. Community models from population models

6. Nutrient cycling models

7. Ecosystem models

G. Geography

1. Determination of study area and location of resources associated with an appropriate base map series and coordinate system

2. Resources mapped accurately to GIS standards

3. Accurate and comprehensive representation of park landscape (e.g., satellite, aerial photography, survey as appropriate)

4. Digital GIS data base as appropriate (using consistent and stable base)

APPENDIX C

Suggested Parameters for Geophysical and Chemical Inventory and Monitoring

A. Geology

1. Maps at reconnaissance level

    a. Geologic maps (bed rock and surficial)

2. Special purpose maps showing:

    a. Geologic hazards (e.g., floodplain maps, special geological features)

    b. Channels and channel characteristics

    c. Other special purpose maps

    d. Soil maps

3. Physical geology, mineralogy and soils

    a. Soil analyses

    1) Organic content
    2) Water holding characteristics
    3) Mechanical analysis
    4) Physical analysis
    5) Radon flux
    6) Water erodibility (index)
    7) Infiltration rate
    8) Soil productivity (composite index)
    9) Cation exchange

    b. Principal mineral composition of geological units (same scale as bed rock geology)

    c. Geo-hazards

B. Hydrology

1. Watershed maps/delineation

2. Special purpose maps

a. Groundwater (water table)

b. Bathymetry

c. Other

3. Location and Classification

a. Streams

b. Lakes

c. Wetlands

d. Groundwater (hot springs, cold springs)

4. Physical parameters

a. Temperature (maximum/minimum)

1) Stream (monthly)
2) Lakes (seasonally)
3) Wetlands (seasonally)
4) Groundwater (seasonally)

b. Turbidity

1) Streams (episodically)
2) Lakes
3) Wetlands

c. Discharge

1) Streams
2) Lakes (in and out flow)
3) Wetlands
4) Springs

d. Sediment transport

C. Meteorology

Rainfall Amount
Snow Amount (Snow-Water equivalents)

Temperature (2 meter agl)
Temperature Difference (between 10 m and 2 m agl)
Relative Humidity (or Dew Point)
Wind Speed
Wind Direction (inclusive of standard deviation)
Solar Radiation
Fog or Cloud emersion time
Surface Wetness
Fuel Moisture
Soil Moisture
Mixing Height
UV-B Radiation*

* Global Climate Change Related

D. Water Chemistry

Alkalinity
pH
Conductivity
$SO_{4=}$
PO_4
Total P
Cl
Total N
NO_{3+}
NH_4
K^+
Na^+
Ca^{++}
Mg^{++}
SO_2
CO_2
O_3
SiO_2
Coloform & fecal strep
DO
DOC
CO_3
HCO_3
$HNO_3NH_3NO_x$
Trace metals

E. Aquatic Bio-monitoring

F. Air Quality

1. General characteristics

   Existing Nearby Emission Sources (and Non-attainment Areas)
   Existing Nearby Ambient Monitoring Locations
   Air Quality Related Values

2. Atmospheric gases

   SO_2
   O_3
   NO/NO_2
   CO
   HNO_3
   Non-Methane Organics (NMOCs), Total & Speciated
   CO_2^*
   N_2O^*
   CH_4^*
   $CFCs^*$
   Total Organic Chlorine*

3. Atmospheric particulates

   $SO_4^=$
   NO_3^-
   H^+
   NH_4^+
   Ca^{++}
   Mg^{++}
   Pesticides
   Trace Metals (Na-Pb)
   Carbon, Elemental and Organic
   Aerosol Acidity

4. Wet Deposition

   A. Precipitation, Rain and Snow

      Alkalinity/Acidity
      pH
      Conductivity
      $SO_4^=$
      NO_3^-
      $PO_4^=$

Cl^-
NH_4^+
Ca^{++}
K^+
Na^+
Mg^{++}
Peroxides
Pesticides
Trace Metals
Organic Anions

B. Cloud/Fog

$SO_4^=$
NO_3^-
H^+
NH_4^+
Peroxides

5. Visibility

Atmospheric Extinction (b_{ext})
Atmospheric Scattering (b_{scat})
View

Figure 1. Conceptual overview of the inventory and monitoring process in natural area parks.