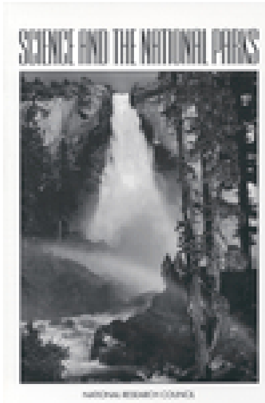

Science and the National Parks

Committee on Improving the Science and Technology Programs of the National Park Service, National Research Council

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SCIENCE AND THE NATIONAL PARKS

Committee on Improving the Science and Technology Programs of the National Park Service
Board on Environmental Studies and Toxicology
Commission on Geosciences, Environment, and Resources
National Research Council

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This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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The National Park Service has reached a time in its history, and in the history of the nation, when science and research should be given a much greater and clearly recognized responsibility in policy making, planning, and operations. Seat-of-the-pants guessues in resource preservation and management are open to challenge and do not stand up well in court or in the forum of public opinion. To be right in decisions affecting natural environments, and to serve its educational missions, the Service requires an increasingly sophisticated system of gathering new facts and getting them applied at all levels, from the back country to [the Washington office].

DURWARD ALLEN AND STARKER LEOPOLD, 1977

Preface

America's national parks are more than just special and often spectacular pieces of landscape; they are a shared, precious part of our national heritage. For more than three quarters of a century, through the lifetime of most of us, the National Park Service has held a dual responsibility to conserve the resources of the parks and to provide for their enjoyment by the American people. But increasing numbers of visitors and the myriad stresses of the modern world are turning that dual mission into a losing battle. Today, many distinguishing features and resources of the national parks are in serious jeopardy.

Over the past 30 years, more than a dozen major reviews by independent experts and the National Park Service itself have concluded that park management must be guided much more by scientific knowledge and less by managerial guesswork. Yet, over three decades, little meaningful and consistent action has been taken by the National Park Service in response to repeated recommendations for a substantially stronger research program.

In 1990, National Park Service Director James M. Ridenour stated his intent to place high priority on strengthening the research program and the role of science in park man agement, and he asked the National Research Council for assistance. In response to his request, the Council convened the Committee on Improving the Science and Technology Programs of the National Park Service, which prepared this report.

The 12 members of this independent, multidisciplinary committee brought a wide array of expertise and experience in various fields of research, as well as experience with the National Park Service and other federal agencies. Four members of the committee had served with the National Park Service at one time in their careers, and virtually all members have conducted research in the parks. The committee's meetings included extensive discussions with National Park Service staff and a site visit to observe research activities at Sequoia-Kings Canyon National Park. A National Park Service working group organized by Dr. Eugene Hester, the Associate Director for Natural Resources, was very helpful in providing information and insights, as were the thoughtful letters and calls from many other individuals throughout the Service, from Regional Directors to park scientists.

Writing this report was challenging for several reasons. First, the scope of the needed research is quite broad, including such fields as biology, physics, chemistry, meteorology, geology, anthropology, sociology, archaeology, and data management. Second, the administrative and organizational questions required consideration at various levels ranging from individual parks, to cooperative park study units, to the Service's ten regions, to the Washington office and the Servicewide programs operated by that office. Also, we wanted to write a report worded strongly enough to prompt real change by the Service but not implying criticism of the scientists and other National Park Service employees who have been making outstanding contributions, often under extremely demanding conditions. Finally, the committee was aware that many previous reviews examining essentially the same issues have seen little response from the National Park Service, so there was considerable discussion about how to present the committee's conclusions and recommendations in ways that could really help make a difference.

Throughout this process, several National Research Council staff members were extremely dedicated and effective. Chris Elfring, David Policansky, and James Reisa performed valuable roles in helping the committee reach consensus on complex points, in writing and editing the report, and in responding to the comments of reviewers. Robert Smythe assisted during the committee meetings. And throughout the project, Sandi Fitzpatrick supported all of us cheerfully, patiently, and effectively. On behalf of the entire committee, I extend grateful appreciation to these fine professionals for a job well done.

Finally, I wish to express my personal appreciation and admiration to the members of the committee. Throughout this effort, we all felt an enormous sense of responsibility because of the importance of the national parks and our knowledge of the needs and opportunities for science to help protect them. Dealing with the issues dispassionately was difficult at times. Yet, each committee member listened carefully to the opinions and ideas of others, weighed the various arguments, and worked together toward a common understanding and set of recommendations that we fervently hope will benefit the Service and the national parks.

Paul G. Risser, Chair

Committee on Improving the Science and Technology Programs of the National Park Service

THE NATIONAL ACADEMIES

National Academy of Sciences
National Academy of Engineering
Institute of Medicine
National Research Council

The **National Academy of Sciences** is a private, nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. Upon the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr. Bruce M. Alberts is president of the National Academy of Sciences.

The **National Academy of Engineering** was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers. It is autonomous in its administration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encourages education and research, and recognizes the superior achievements of engineers. Dr. Wm. A. Wulf is president of the National Academy of Engineering.

The **Institute of Medicine** was established in 1970 by the National Academy of Sciences to secure the services of eminent members of appropriate professions in the examination of policy matters pertaining to the health of the public. The Institute acts under the responsibility given to the National Academy of Sciences by its congressional charter to be an adviser to the federal government and, upon its own initiative, to identify issues of medical care, research, and education. Dr. Harvey V. Fineberg is president of the Institutedicine.

The **National Research Council** was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both Academies and the Institute of Medicine. Dr. Bruce M. Alberts and Dr. Wm. A. Wulf are chair and vice chair, respectively, of the National Research Council.

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SCIENCE AND THE NATIONAL PARK

Executive Summary

The National Park Service (NPS) protects and preserves some of the finest examples of the nation's natural and cultural heritage. Rugged mountains, desert solitude, dynamic beaches, historic battlefields, and rare archaeological sites—in all, the system includes nearly 80 million acres in 361 units. It is a system emulated around the world, a distinctive contribution of the people of the United States to world conservation.

The 1916 Organic Act, still in effect today, provides the basic statutory authority for the NPS, declaring its mission to be

> to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations. (16 U.S.C.A. Sec. 1)

At the time the 1916 Organic Act was written, it was innovative and far-sighted. Protection, it was thought, was the key to the conservation of park resources. We now know, however, that accomplishing the mission of the Park Service requires far more than passive protection; it requires sound understanding of park resources, their status and trends, the threats they face, and the measures needed to correct or prevent problems in these dynamic ecosystems. We now know that balancing the call to protect resources and the call to provide citizens with opportunities to enjoy the parks is a constant challenge.

THE IMPORTANCE OF RESEARCH

The 1916 act's mandate has been invaluable in setting a basic course for the NPS, but it is insufficient to guide the agency in a world of accelerating change. Informed resource management is impossible without science in its broadest sense—that is, the acquisition, analysis, and dissemination of knowledge about natural processes and about the human influences on them.

Protecting the resources of the national parks[1] requires scientific knowledge, and an increasingly sophisticated application of that knowledge. The problems faced by the parks today are too many and too complex to solve without the help of science. Threats to indigenous species caused by exotic species, threats to park resources caused by air pollution or overcrowding, and threats to long-term ecosystem viability caused by the myriad stresses of the twentieth century all jeopardize this unique and invaluable system. Although an adequate science program alone cannot ensure the integrity of the national parks, it can enable faster identification of problems, greater understanding of causes and effects, and better insights about the prevention, mitigation, and management of problems. Science supports resource management so NPS staff can manage park resources wisely, and it supports interpretive programs for the public. Science today is an investment in the future of the parks.

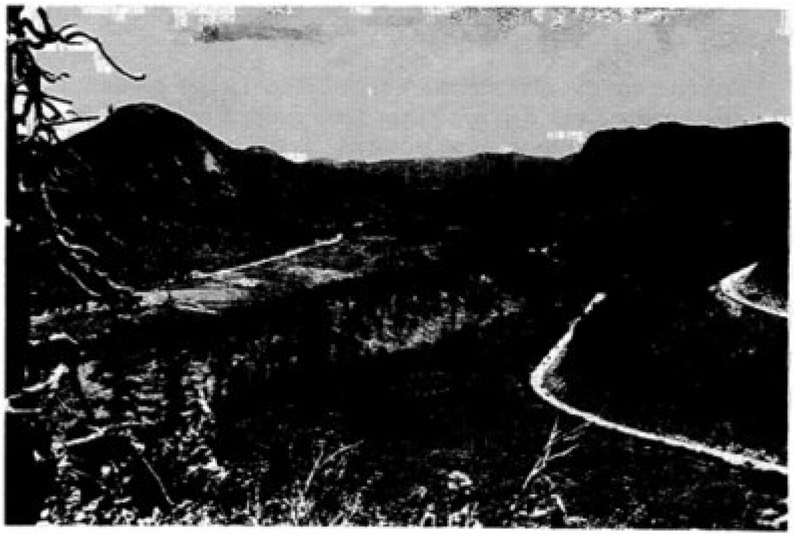
With the 20/20 vision of hindsight, any examination of the national park system can uncover many cases in which a lack of understanding of park resources has led to problems—degradation of resource quality, increased conflicts between visitors and resources, or the escalation of minor issues into major problems. Visitor facilities were developed in habitat critical to endangered species before the con-

[1] The term "park" as used in this report refers to all units of the national park system—national parks, monuments, seashores, historical parks, and other units managed by the NPS.

cept of endangered species was appreciated. Exotic fish species were introduced to improve recreational fisheries without thought to the implications for native species and the predators that feed on them. Fire suppression led to unanticipated changes in the distinctive character of forests. A common thread seen in virtually all such examples is that almost invariably, the initial establishment and management of the parks was done with inadequate understanding of ecological systems. Today, our information base is substantially greater, but so too are the threats the parks face. Today's threats to the parks are difficult to mitigate because they are extraordinarily complex.

Research is important in the national parks for three broad purposes:

- To determine what resources are present in order to protect them, manage them, and detect changes in them.



Each park has a special character. Research can guide the National Park Service in preserving it for future generations. In Rocky Mountain National Park, for instance, research runs the gamut from studies of the effects of acid precipitation to surveys of amphibian populations to assessments of the impacts of visitors on alpine tundra environments. CREDIT: NPS photo by Wayne Alcorn.

- To understand the natural dynamics and processes of populations, ecosystems, and other park resources.
- To assess the effects of specific threats and to devise and evaluate management responses.

PREVIOUS REVIEWS OF THE NPS RESEARCH PROGRAM

Since the early 1960s, when the first major independent reviews of the adequacy of the NPS science program were conducted, many experts have assessed the Park Service's research efforts. Two particularly noteworthy reviews appeared in 1963: "Wildlife Management in the National Parks," known as the Leopold report after A. Starker Leopold, who chaired the special committee, and "A Report by the Advisory Committee to the National Park Service on Research," commonly called the Robbins report after William J. Robbins, the chair of that National Research Council committee. Both reports recommend strengthening the science program. The Robbins report noted

> Research by the National Park Service has lacked continuity, coordination, and depth. It has been marked by expediency rather than long-term considerations. It has in general lacked direction, has been fragmented between divisions and branches, has been applied piecemeal, has suffered because of a failure to recognize the distinctions between research and administrative decision-making, and has failed to ensure the implementation of the results of research in operational management.... It is inconceivable that property so unique and valuable as the national parks, used by such a large number of people, and regarded internationally as one of the finest examples of our national spirit, should not be provided adequately with competent research scientists ... as elementary insurance for the preservation and best use of the parks.

There was little significant progress in response to the recommendations of these reports. Two major problems continued to plague the NPS science program at the beginning of the 1970s: inadequate funds to support a continuing program, and disagreement about who should direct the work of scientists. In 1977, another review of the NPS natural science program was published. Known as the Allen and

Leopold report, after co-chairs Durward Allen and Starker Leopold, it clearly called for the NPS to give science and research much greater responsibility in policy making, planning, and operations. It found no fault with the general direction of the science program, only with its lack of funding, staffing, and influence.

Again, however, little action to implement the report's recommendations ensued. Private groups such as the National Parks and Conservation Association and The Conservation Foundation published other reports critical of the Park Service, focusing wide public attention on the threats to the national park system. Under congressional pressure, the NPS conducted a comprehensive assessment of park threats in 1980. That report documented widespread and serious problems in the parks and recommended four actions to better protect park resources: conduct a comprehensive inventory of park resources; establish accurate baseline data and conduct monitoring to detect changes in resources and ecosystems; focus

As critics of the National Park Service science program have noted, property as valuable and unique as the national parks should not go without adequate research staff as elementary insurance to preserve the parks. Long-term environmental monitoring is especially needed. CREDIT: NPS photo by Robert J. Krumenaker.

attention on threats associated with adjacent lands; and improve the ability of park managers to quantify and document the effects of various threats. In essence, the NPS identified the same problems and recommended the same solutions as had previous independent review committees.

In 1989, yet another report, "National Parks: From Vignettes to a Global View," also known as the Gordon report, criticized the degree to which the NPS has fulfilled its obligations in research and in management of natural and cultural resources. This report recommended that the NPS adopt a "new vision" to meet the environmental challenges of the twenty-first century, "a vision based on the principles of ecosystem management [and] on sound research."

In all, a dozen major reviews of NPS science and management over a period of 30 years provided specific recommendations for strengthening science in support of better management of the national parks. Many of the suggested improvements were recommended time and time again. But very few of the recurring recommendations have been effectively or consistently implemented.

THE CURRENT RESEARCH PROGRAM

According to the NPS, the primary objective of the current science program is to conduct directed research studies that provide information in support of park planning, development, management, and visitor education and enjoyment. Because the resources that are studied run the gamut from biological (e.g., vegetation, wildlife, fisheries) to geophysical (e.g., water, air, caves, soils, islands, minerals) to cultural (e.g., archaeological ruins, monuments) to aesthetic (e.g., scenic vistas, quiet places), the NPS science program must include elements of the biological, geophysical, and social sciences.

The current NPS organization considers research part of resource management. Because there is no separate research authority, all scientific studies are funded as part of management. These two distinct but closely related activities were combined to encourage cooperation, although critics argue that the approach is less effective than intended because it reduces the importance of the two separate and vital activities.

Park Service research and resource management activities are organized at three levels of authority: in the Washington office (WASO), in the 10 regional offices, and in the individual park units. The Washington office develops general policies and standards, sets national priorities, and coordinates servicewide research programs. Most research is planned by and conducted under the direction of the 10 regional offices. As a result, there is not one science program in the NPS, but 10 separate programs, each different in form, function, and effectiveness. All are ultimately funded by management and dependent on the emphasis committed by senior managers in the regions and parks.

The Park Service maintains a smaller research staff than is found in other federal land management agencies—typically around 2 to 3 percent of its staff. By contrast, 8 to 10 percent of the staff of the U.S. Fish and Wildlife Service are research personnel. The organization of responsibilities varies significantly from region to region within the NPS. In some cases, members of the resource management staff, including any scientific staff, report to the superintendent of a park. In other cases, scientific staff members at parks and in cooperative study units report to regional chief scientists, while resource management specialists report to the superintendent. Some regions arrange for much of their research through extramural contracts or cooperative agreements; in others, most research is done by NPS staff.

The question of whether the leadership of the NPS science program should be centralized or decentralized is controversial. The decentralized, regional approach to the science program was instituted in the early 1970s to make research more responsive to park needs. But the decentralized approach sometimes is inefficient and results in fragmentation of effort. It creates great variations in research quality and effectiveness and in scientists' morale from region to region and from park to park. Also, where research and resource management are funded from the same part of the budget, the two activities end up competing for support. Given the shortage of staff and funds throughout the NPS, conflicts between researchers and managers—with their different goals and methods—can be severe and counterproductive.

Millions of visitors enjoy the national parks each year—267,841,000 in 1991—and they benefit from science. After the fires of 1988, an interpretive display at this burned site in Yellowstone National Park explained that the devastation here was particularly severe because the trees were already dead and very dry before the fire, casualties of a major windstorm a few years earlier. CREDIT: Chris Elfring, National Research Council.

The absence of a distinct science program hampers research planning, tracking of expenditures, and accountability for results. The lack of formal structure and clear leadership in the NPS science program also hampers attempts to assess it. The decentralized approach brings many different operational models and reporting structures and makes any kind of an audit of scientists, funding, and other characteristics extremely difficult. It is not possible, for instance, to determine accurately the amount of money allocated to NPS research, because research and resource management are funded under the same budget activity—natural resource management. In addition, it is not always possible to separate resource management from law enforcement and various other activities undertaken by park rangers. In fiscal year (FY) 1992, about $92.7 million was allocated for natural resource management. The NPS estimates that research funding grew from about $18.5 million in FY 1987 to about $29 million in FY 1992, but it is not possible to confirm this estimate. At the same time, NPS identified $250 million to $300 million in needed but unfunded natural resource projects.

Questions about the effectiveness of science to support park management—and especially questions about organizational structure and funding levels—have been raised throughout the history of the NPS science program. Park personnel, advocacy groups, and independent advisory groups have repeatedly concluded that the science activities are not meeting management needs. If it is so easy to identify the deficiencies in the program, why is it so difficult to change or restructure it? The NPS science program is unnecessarily fragmented and lacks a coherent sense of direction, purpose, and unity. As the trustee for irreplaceable samples of the nation's natural and cultural heritage, the NPS should be among the most forward looking and progressive resource management agencies in the federal government, and research should be an essential element in its mandate.

RECOMMENDATIONS

In conducting this study of science in the national parks, the National Research Council's Committee on Improving the Science and Technology Programs of the National Park Service originally set out to evaluate the scope and organization of current NPS natural and social science by performing a peer review of NPS research activities. However, the committee soon determined that the crucial problems in the NPS research program are not at the level of individual projects. Instead, they are more fundamental, rooted in the culture of the NPS and in the structure and support it gives to research. Thus, the committee concluded that the real need was for an assessment more broadly focused on the research program and its place within the agency.

The call for change made in this report is not new. But given the lack of response to so many previous calls for change, how can the present report succeed in inspiring action? The members of the committee believe that increased funding or incremental changes alone will not suffice, and they call in stead for a fundamental metamorphosis. It is time to move toward a new structure—indeed, toward a new culture—that stresses science in the national park system and guarantees long-term financial, intellectual, and administrative support. There are three key elements:

- There must be an explicit legislative mandate for a research mission of the National Park Service.
- Separate funding and reporting autonomy should be assigned to the science program.
- There must be efforts to enhance the credibility and quality control of the science program. This will require a chief scientist of appropriate stature to provide leadership, cooperation with external researchers, and the formation of an external science advisory board to provide continuing independent oversight.

AN EXPLICIT LEGISLATIVE MANDATE

- To eliminate once and for all any ambiguity in the scientific responsibilities of the Park Service, legislation should be enacted to establish the explicit authority, mission, and objectives of a national park science program.
- The National Park Service should establish a strong, coherent research program, including elements to characterize and gain understanding of park resources and to aid in the development of effective management practices. To provide a scientific basis for protecting and managing the resources entrusted to it, the Park Service should establish, and expand where it already exists, a basic resource information system, and it should establish inventories and monitoring in designated park units. This information should be obtained and stored in ways that are comparable between park units, thereby facilitating access, exchange, integration, and analysis throughout the park system and with other interested research institutions. The NPS should support and develop intensive long-term, ecosystem-level research projects patterned after (and possibly integrated with) the National Science Foundation's Long-Term Ecological Research program and related activities of other federal agencies. The ways

resources are used and appreciated by people should be documented. In addition, National Park Service researchers should have more input into the development of resource management plans. Effective interaction between research results and resource management plans cannot take place without both a strong science program and a strong resource management program.

- The National Park Service should also establish and encourage a strong "parks for science" program that addresses major scientific research questions, particularly within those parks that encompass large undisturbed natural areas and wilderness. This effort should include NPS scientists and other scientists in independent and cooperative activities. The goal is to facilitate the use of parks for appropriate scientific inquiry on major natural and related social science questions.

SEPARATE FUNDING AND AUTONOMY

- The National Park Service should revise its organizational structure to elevate and give substantial organizational and budgetary autonomy to the science program, which should include both the planning of research and the resources required to conduct a comprehensive program of natural and social science research. The program should be led by a person with a commitment to its objectives and a thorough understanding of the scientific process and research procedures.
- The National Park Service science program should receive its funds through an explicit, separate (line item) budget. A strategic increase in funding is needed, especially to create and support the needed long-term inventories and the monitoring of park resources.

BUILDING CREDIBILITY AND QUALITY

- To provide leadership and direction, the NPS should elevate and reinvigorate the position of chief scientist, who must be a person of high stature in the scientific community and have as his or her sole responsibilities advocacy for and administration of the science program. The chief scientist would work from the Washington office and report to the Director of the NPS, provide technical direction to the science and resource management staff at the regions and in the parks, and foster interactions with other research agencies and nongovernment organizations. In addition, the chief scientist should establish a credible program of peer review for NPS science, reaching from the development of research plans through publication of results.

- To help the NPS expand the science program and increase its effectiveness, the Park Service, in cooperation with other agencies, should establish a competitive grants program to encourage more external scientists to conduct research in the national parks. The program should include scientific peer review that involves both NPS scientists and external scientists.
- The National Park Service should enlist the services of a high-level science advisory board to provide long-term guidance in planning, evaluating, and setting policy for the science program. This independent advisory board should report to the director, and its reports should be available to the public.

REALIZING THE VISION

To build a science program that fulfills its potential—that meets the needs of resource managers, helps the public understand and enjoy park resources, and contributes to understanding our changing world—the Park Service must give the science program immediate and aggressive attention. Pressures on these national treasures are increasing rapidly. It is shortsighted to fail to organize and support a science program to protect the parks for future generations. And it is a waste of a unique resource if the parks are not used, with proper safeguards, to help address the scientific challenges faced throughout the biosphere. The current Park Service leadership has expressed its recognition of the need for a reinvigorated science program, as well as the importance of the parks in a broader scientific context. It is time to translate that recognition into action.

The conduct of research is fundamentally different from that of most other NPS functions. It operates on a schedule not determined by the calendar of Congress, but on the calendar of the natural or cultural phenomena being studied. Products from research come with answers frequently surrounded with small or great uncertainty. The design of an experiment and the interpretation of the results often depend on the scientific process as it is conducted in another discipline or in a different part of the world. If the NPS is to meet the scientific and resource management challenges of the twenty-first century, a fundamental metamorphosis must occur within its core. This committee's vision for the NPS science program is ambitious but obtainable. The national parks are, after all, simply too valuable to neglect.

1

Introduction

The national park concept is a distinctive contribution of the people of the United States to world conservation. More than 100 nations have followed this country's lead in establishing parks or equivalent reserves to protect areas of natural, scenic, or cultural importance. Most of these nations have studied the U.S. system as a model for national park management.

Today, the U.S. national park system contains nearly 80 million acres in 361 different units, including such diverse areas as Yellowstone National Park, Antietam National Battlefield, Indiana Dunes National Lakeshore, Mammoth Cave National Park, and the White House. The enormous diversity within America's national park system is reflected in the broad mission and responsibilities of the National Park Service (NPS), the federal agency charged with primary responsibility for conserving the physical, biological, and cultural resources of the parks.[1] The NPS is responsible not only for conserving geographic sites that range from extensive wilderness ecosystems to urban recreational areas and historic places, but also for protecting rare geologic features, managing diverse plant and animal populations, and preserving

[1] The term "park" as used in this report refers to all units of the national park system—national parks, monuments, seashores, historic parks, and other units managed by the NPS.

priceless scientific and cultural artifacts. In carrying out its responsibilities, the NPS must consider both natural and cultural resources, as well as the interactions between people and these resources.

The national parks are more than natural and cultural treasures—they are an important source of national self-esteem. They give Americans pride as well as access to places of significant aesthetic, recreational, and spiritual value. These interests, and a devotion to the concept of public stewardship of the nation's heritage, have been important forces behind maintaining and expanding the national park system.

CONDITIONS TODAY

Conditions in the parks today give cause for concern. Against a backdrop of significant human alterations to the Earth's landscape, the national parks have become "besieged treasures" (Forgey, 1990). Although the national parks were created for the enjoyment of the American people, increasing numbers of park visitors, and the facilities needed to accommodate them, are overwhelming some parks. Air pollution, often from distant and diffuse sources, already has compromised aesthetic values within several of the largest national parks, especially Grand Canyon, Yosemite, Sequoia-Kings Canyon, Shenandoah, and Great Smoky Mountains national parks. Actions outside park boundaries are producing critical changes in ground and surface water, accelerating pest introduction, increasing stream sedimentation, and threatening wildlife populations.

The parks are increasingly subject to diverse human influences that threaten further attrition in biological diversity and accelerated damage to aesthetic values, and imperil the integrity and stability of park ecosystems. In some instances, destruction of the very resources for which individual national parks were established is now increasingly probable and, in fact, is under way in some areas. For example, air pollution has degraded the renowned scenic vistas of Grand Canyon National Park (NRC, 1990), beach erosion has threatened the historic lighthouse at Cape Hatteras National Seashore (NRC, 1987a), and operation of the Glen Canyon Dam on the

The national parks are subject to a range of threats—including the proliferation of exotic species, water quality degradation, and air pollution. Problems that result from activities on adjacent lands, such as pollution from power plants like this one in the Four Corners area, are particularly difficult to address. CREDIT: David Policansky, National Research Council.

Colorado River upstream of Grand Canyon National Park has caused significant damage to riparian ecosystems (NRC, 1987b).

Increasing human populations, pervasive changes in the environment, and increasing demands on the nation's natural resources present the managers of our national parks with a critical challenge to bring about better public understanding and more effective conservation of the "besieged treasures" contained within our national parks. Park managers also are challenged to make use of the national parks as unique, protected ecosystems where research can extend science and improve society's ability to deal with environmental change.

CONSERVATION AMIDST CHANGE

The idea of keeping special places and their natural and cultural resources inviolate for the benefit of unborn genera tions is a powerful one, yet the language of some of the early national parks legislation was not adequate to ensure full realization of that concept. The Yellowstone Park Act of 1872, which created the world's first national park, calls for a "public park or pleasuring-ground" (30 U.S.C.A. §21), and its enactment ushered a revolutionary idea into human thought and values. But over time it became clear that the Yellowstone legislation and other acts that created park sites did not accomplish the whole job of protecting natural and cultural resources. To enhance the legislative mandate, in 1900 Congress passed the Lacey Act (16 U.S.C.A. §§701, 3371–78, and 18 U.S.C.A. §42) to protect wildlife and natural features, and in 1906 it passed the Antiquities Act (16 U.S.C.A. §§431–33) to allow for the reservation of federal lands as national monuments and to halt commercial exploitation of cultural and historic objects taken from the public lands (Coggins and Wilkinson, 1987).

But it is the National Park Service Act of 1916 (the Organic Act), still in effect today, that provides basic statutory authority for the NPS, declaring the agency's mission to be

> [T]o conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations (16 U.S.C.A. §1).

In this simple language, the Organic Act united the well being of the American spirit, perhaps indeed the human spirit, with the survival of the nation's aesthetic, natural, and cultural heritage. At the time it might have seemed that the resources would survive in the newly protected areas without much additional help from humankind, but we now know that accomplishing the agency's mission in the face of myriad growing and complex threats requires sophisticated understanding of park resources, the forces of change that affect them, and the measures needed to protect them.

The NPS's original management strategy generally assumed that its mission could be achieved through passive management, simply by keeping direct human encroachment to a minimum and by maintaining the "natural" status quo for recreational enjoyment. The 1916 mandate emphasized conservation and suggested a simple inventory of land forms, vegetation, creatures, and artifacts. It assumed a natural equilibrium, where the task was to ensure an "unimpaired" state. Today, as an established federal agency guided strongly by tradition, the NPS remains in many respects committed to this philosophical tenet. The 1916 mandate, however, was written before ecology began to mature as a scientific discipline; before the changing nature of natural systems was recognized; before the landscape-changing processes of succession were well understood; before population dynamics, habitat fragmentation, and ecosystem disturbances began to be understood; and indeed before human intervention was felt in the parks on a scale that ranges from local to global.

Ecological science now recognizes that change is central to the structure and functioning of all ecosystems, and it is now evident that the managers of the parks must understand the changes—both natural and anthropogenic—that occur. To conserve ecosystems unchanged is simply impossible. Natural events, such as the eruptions of Kilauea and Mount St. Helens, have accomplished massive transformations; earthquakes, hurricanes, floods, forest fires, landslides, and subsidence all affect land forms and life. Succession, weather, food supplies, predation, and disease affect animal populations and plant communities. Human events also have brought vast changes—acid rain, chemical pollution, ozone depletion, and now perhaps global warming with its attendant climatic changes, all contribute to changes in the parks.

As the importance and prevalence of ecological change has become increasingly recognized, there has been an evolution in the interpretation of the NPS mandate. This evolution has occurred even though the law itself has stood unaltered for 75 years. In the infancy of the agency, with the best of intentions but contrary to the directive to leave resources unimpaired, the NPS carried out massive interventions in the national parks which by today's standards would be appalling. Wolves, cougars, coyotes, and grizzly bears were killed; deer and elk were fed artificially; natural fires were suppressed aggressively; parks were logged; introductions of exotic fish radically changed native river and lake ecosystems; exotic plants were introduced to convert mead ows to livestock pastures; swimming pools and laundries were developed on geysers and hot springs; hotels and roads were built in sensitive wildlife habitat or in scenically obtrusive locations; ski lifts were erected and slopes were cleared in several parks; and many large concession complexes were built in sensitive environments. Today, public concern, the increasing sophistication of park managers, and the efforts of some enlightened biologists, conservation-minded citizens, and political leaders have largely deterred such interventionist practices. The era of "firefalls"—when concession employees pushed bonfires from the top of Glacier Point in Yosemite to entertain visitors with cascades of sparks—has ended. But the challenge remains to find a balance between conserving natural resources and providing visitors with a memorable experience.

The park system is diverse—361 units including national parks, seashores, riverways, battlefields, and monuments. There is diversity within each park as well. Fort Jefferson National Monument, at the southern tip of Florida, preserves a fort built in 1846. At the same time, the monument protects a coral reef ecosystem that supports a diversity of marine life, including the sea turtles that were once more abundant in these warm waters. CREDIT: NPS photo by Richard Frear.

The 1916 act's mandate has been undeniably valuable in setting a basic course for the Park Service, but it is insufficient to guide the agency in a world of increasing scientific knowledge and accelerating change. To maintain the nation's parks as unique places where natural processes predominate, the NPS must increase its understanding of the natural processes and phenomena that characterize the parks. Informed resource management requires science in its broadest sense—that is, the acquisition, analysis, and dissemination of knowledge about natural processes and about human influences on those processes.

There is a lengthy history of scrutiny of the NPS science program by external advisory groups, as discussed in Chapter 3. Although prompted by differing concerns, those reviews all conclude that research is necessary to ensure effective management of the parks. Unfortunately, these repeated exhortations have gone largely unheeded, even though they are all the more relevant today. And even where action has been undertaken, it has been marred by inconsistent administrative support and fluctuating budgets.

THE CHARGE TO THIS COMMITTEE

At the request of NPS Director James M. Ridenour, the National Research Council (NRC) in 1990 convened the Committee to Improve the Science and Technology Programs of the National Park Service. Members of the committee were appointed for their expertise in botany, forestry, ecology, geology, hydrology, wildlife management, air pollution, atmospheric chemistry, sociology, landscape architecture, scientific research program management, and park system management. Under the supervision of the NRC's Board on Environmental Studies and Toxicology and its Commission on Geosciences, Environment, and Resources, the committee received the following charges:

- Review the evolution of NPS scientific studies and research programs, their coordination and integration with other NPS programs, and the results of earlier evaluations of the NPS science program.

- Analyze the scope and organization of current NPS natural and social science activities related to current and potential environmental issues, national park planning and resource management, and environmental information needs.
- Evaluate current NPS systems for quality control, quality assurance, funding, and financial management of NPS natural science, social science, and technology programs.
- Produce a report of the committee's findings and recommendations, including options for enhancing the quality, productivity, efficiency, and relevance to planning and management of NPS scientific research activities.

This report is about the role of science in park management and the ways by which the parks can contribute to the natural and social sciences. Information was gathered from formal sources (e.g., past published reviews of the NPS science program) and from extensive conversations with scientists, managers, and other experts both in the Park Service and elsewhere. The report discusses the value of research for managing and protecting the resources of the parks, the real costs of failing to conduct and use adequate research, the history of previous reviews of science in the NPS, and the lack of progress toward improving the use of science in support of the NPS mission. Because the national parks today contain some of the least disturbed ecosystems in our country, this report also argues that the parks are increasingly valuable as sites for scientific research on ecological problems that transcend the boundaries of the parks. In this role, the parks contribute to a basic understanding of ecosystem dynamics and natural processes and provide a valuable baseline for comparison with human-altered ecosystems.

This report argues that science should pervade the NPS's resource planning and management philosophy; without an adequate science base the NPS cannot solve today's problems or meet tomorrow's challenges. This will require substantial reorientation and commitment within the agency, for good science requires strong leadership and continuity of support.

2

The Importance of Research for the National Parks

The importance of research in the national park system has never been greater than it is today. The National Park Service (NPS) research program must generate sound information to help resource managers deal with increasingly serious and complex threats, withstand increasingly detailed scrutiny, enhance public understanding, and foster cooperation with outside scientists and other agencies. Because many issues that affect parks, such as air and water pollution and the fate of migrating animals, cannot be confined within park boundaries, proposed solutions can affect areas that surround the parks and require regional cooperation. Even when management decisions apply strictly within park boundaries, public review can be contentious. Moreover, because litigation and other challenges to federal land management decisions have become commonplace, the quality and validity of research is critical when park management decisions come before the courts and other arenas of public exposure and scrutiny.

Any examination of the national park system can uncover many cases in which a lack of scientific understanding of park resources led to problems—loss of resource integrity, increases in conflicts between visitors and resources, or escalation of minor issues into major problems. For instance, visitor facilities were developed in habitat critical to endan gered species before the concept of endangered species was appreciated. Exotic fish species were introduced to improve recreational fisheries without thought to the implications for native species and the predators that feed on them. Fire suppression led to unanticipated changes in the distinctive character of forests. A common thread in these examples is that almost invariably, the establishment and early management of the parks was done with inadequate scientific knowledge of these ecological systems. Today, our information base is substantially greater, but so too are the threats the park system must face.

Illustrations of the importance of scientific understanding in the management of the parks can be found in every NPS unit. When parks were first established, there was often a lack of understanding of the resources they contained. Problems arose when park boundaries failed to encompass complete ecosystems or enough land to support critical ecological processes (e.g., Everglades National Park), or because visitor facilities were built in inappropriate places (e.g., Sequoia-Kings Canyon, Yosemite, and Yellowstone National Parks), or because of inappropriate management actions (e.g., predator removals, control of native species perceived as pests, control of natural fire, disruption of natural hydrologic regimes, and introduction of exotic fish) (Soulá and Wilcox, 1990; Holland et al., 1991). In the early years of park management, many resources were damaged or lost simply because managers were unaware of their existence or did not know how to manage them (Allen et al., 1981).

These examples illustrate that research is needed for several purposes ranging from simply identifying resources to deciding on appropriate short-and long-term management strategies. In summary, research is important in the national parks for three broad purposes:

- To determine what resources are present in order to protect them, manage them, and detect changes in them.
- To understand the natural dynamics and processes of populations, ecosystems, and other park resources.
- To assess the effects of specific threats and to devise and evaluate management responses.

RESOURCE INVENTORIES AND MONITORING FOR CHANGE

Beaches in Kenai Fjords National Park and Katmai National Park and Preserve in Alaska, like vast stretches of the Alaskan coast, suffered serious damage from the 11 million gallons of crude oil spilled by the Exxon tanker *Valdez* in 1989. Before the spill, coastal resource inventories in these parks, both biotic and archaeological, were virtually nonexistent. Because of the paucity of data about prespill conditions, the full extent of wildlife losses and the magnitude of eventual recovery will never be known. A more adequate information base would have helped the NPS assess the losses, allowed for a better understanding of what changes could be expected, and helped park managers develop appropriate mitigation and restoration programs.

The oil spilled into Prince William Sound from the 1989 grounding of the Exxon tanker *Valdez* damaged beaches in Kenai Fjords and Katmai national parks. The lack of scientific data about conditions before the spill made it difficult to assess the losses and plan appropriate mitigation. CREDIT: David Policansky, National Research Council.

Basic inventories of park resources and consistent long-term monitoring need to be fundamental aspects of any park's research program. Researchers working in Great Smoky National Park tag bears as part of a long-term black bear population study. CREDIT: Ken L. Jenkins.

In the 1950s, an era when there was little attention to science in the NPS, Great Smoky Mountains National Park in Tennessee and North Carolina was the site of a misplaced effort to improve recreational fishing by removing native nongame fish from a park stream. Because knowledge of the park's fish populations was limited, several species of fish previously unknown in the park were both discovered and extirpated during that operation. For many years it appeared that one species—the Smoky madtom—was both discovered and made extinct by that management action; this fish has subsequently been found outside the park, and a reintroduction trial is now under way.

Similar problems were caused by the introduction of New England brook trout, which has come to predominate over the native southern Appalachian brook trout. Research now indicates that the native trout is a genetically distinct subspecies, and its gene pool has been contaminated by the release of the exotic trout. Now only a few streams in the park (at high elevations, in remote areas, and above natural barriers) harbor native populations. Introduced rainbow and brown trout also have reduced the range of the native brook trout.

In Great Smoky Mountains National Park, an inventory of black bear populations showed that only about 500 bears were present, far fewer than expected in the ecosystem, so managers were motivated to develop a regional management plan. When population monitoring showed unexpectedly low bear populations in several sections of the park, illegal hunting was suspected, and an enforcement program was instituted. A multi-agency state and federal operation led to the arrests of several persons allegedly involved in exporting bear parts to the Orient.

Defining cause-and-effect relationships, in particular, requires sustained, interdisciplinary research at a variety of spatial and temporal scales. Because change is universal in nature, research must determine whether a given amount of change represents natural fluctuation around a steady state or a net trajectory in a desirable or undesirable direction. In Yellowstone National Park, for instance, the deteriorating condition of the northern range continues to create controversy. Scientists external to the park say the deterioration is caused by excessive populations of elk; research by park biologists, however, indicates that the changes are natural and caused, in part, by climatic changes. The controversy stems in large part from the lack of long-term data. Since ecosystems operate under fluctuations in climate, the need to detect actual directional change in resources poses a significant challenge that requires a substantial and sustained research effort. Such efforts require sophisticated and sensitive research techniques. Because the parks often lack even the most basic inventory of resources and baseline data, research often must start from an inadequate data base for the design of key studies.

STUDIES OF NATURAL DYNAMICS AND PROCESSES

The population dynamics and interactions among gray wolves, moose, and vegetation at Isle Royale National Park in Michigan have been studied for more than 30 years. This research, conducted largely by scientists outside the NPS, has generated new hypotheses about natural population regulation in large mammals that have received wide scientific review and public scrutiny. During the initial 12 years of study, 1958–1970, scientists found apparent stability in high-density wolf and moose populations that reinforced a popularly held belief of balance and constancy in wild populations, often attributed to the lack of harvesting or other manipulation by humans. But stability dissolved in the 1970s as the moose population declined by more than 50 percent while the wolf population increased to an unprecedented level. For scientists, a belief in static equilibrium was replaced by knowledge of cyclic change in populations of wolves and moose, with fluctuations occurring over decades. The change caught the attention of the public, and there was considerable demand for information that was met by an ongoing monitoring effort.

Further perturbation of this classic predator-prey story became evident in the 1980s, as a wave of disease was circumstantially linked to a decline that jeopardized the survival of the famous wolf population. Forced by the unprecedented decline, the NPS abandoned its attempt to let natural processes prevail on the island (even to the exclusion of common research techniques such as radiotelemetry, which necessitates animal capture and handling), and it allowed scientists to capture wolves, take blood samples, and attach radiocollars to monitor them and study the possible roles of food shortage, disease, and genetic deterioration in their decline. Once again, public interest was intense. Notably, the answers came from scientists outside the NPS, who were supported by and interacting closely with Park Service staff. The example of the Isle Royale wolves provides an invaluable demonstration of the hazards that face all small isolated populations, and it highlights issues that face conservation biologists worldwide. The fate of the Isle Royale wolves is unclear. Their future dynamics might not emerge, as in the past, as a simple outcome of supply and demand for prey. In the short term, managers and scientists must accept this uncertainty and research must continue.

Studies of the wolves at Isle Royale National Park have taught scientists many lessons about population dynamics. A decline in the famous wolf population in the 1980s led the Park Service to allow scientists to put radiocollars on some wolves to better study the population's status and health. CREDIT: NPS photo by Robert J. Krumenaker.

Denali National Park in Alaska (formerly Mount McKinley National Park) is another park at the forefront of wolf research worldwide. Studies there began in the 1940s, when the NPS was under pressure from trophy hunters to reduce or eliminate the wolf population. Among the handful of NPS biologists at the time was Adolph Murie, who went to McKinley to investigate the role of wolves in reducing Dall sheep populations. Murie undertook a pioneering program of basic ecologic research, providing the first scientific look at this controversial carnivore. His collection of Dall sheep skulls provided the first life table for a species of wildlife, and his findings are still used in theoretical analyses of mammalian mortality patterns and applied research into wolf-prey relations. The tradition of ambitious research on predator-prey interactions, using state-of-the-art technology, continues at the park today, and evidence about the movements of the

VISITOR SERVICES PROJECT

NPS social science research has been limited, but of great value in several locations where studies of visitor behavior have guided management. For instance, the Visitor Services Project (VSP), a project of the NPS and the University of Idaho Cooperative Park Studies Unit, was created in 1982 out of the realization that social science research in the parks was uncoordinated and incomplete. Although various studies were being conducted at parks around the nation, there was little consistency, little opportunity to build on the work of others, and a good deal of frustration that the research did not really meet the needs of managers.

The project was developed to standardize the method for studying park visitors. The survey methodology was carefully designed, tested, and revised, and its rate of response is so successful (75–85 percent) that it has been published in the social science literature and widely used, even in other countries. The survey has two elements: a standardized series of questions about visitors (age, group size, group type, residence, visiting patterns, and activities attended) that is used consistently from park to park, and a series of questions customized to the particular needs of the park. To date, 46 studies have been done in 38 national parks. Even though parks must pay for the work ($10,000–$17,000, not including VSP staff time and other overhead expenses), demand for the research team is great and an advisory committee was established to help select parks for the 10 studies possible each year.

NPS and cooperative park study unit staff work closely with park personnel in planning, conducting, and interpreting the studies. Because of the growing body of information being compiled, VSP is now building an important data base on visitor needs. The customized portion of the research provides park managers with insights about changes and improvements in park operations:

- Grand Teton National Park managers built a new information station at a location different from that originally planned after learning that more visitors stopped at the new site first.
- At Lincoln Home National Historic Site, the visitor study helped managers plan ways to make the home more accessible to visitors with disabilities, and the study's results were used as the basis for the park's request for increased funding to keep the home open longer hours.
- Studies at the White House revealed that many visitors are children, and managers began to provide more information for youngsters. Interpretive signs and bulletin boards were lowered, and a White House visitor center is planned.

- At Canyonlands National Park, managers used information from a visitor study to help justify hiring personnel in additional seasonal interpretive positions.
- Glacier National Park planning documents now incorporate information from a visitor study, including the need for a visitor center on the west side of the park.
- Because visitors at John Day Fossil Beds National Monument identified the need for more camping facilities near the monument, managers are working with nearby towns and other government agencies to encourage construction of additional campgrounds.

wolf population helped lay the groundwork for delineation of new park boundaries.

Research on natural processes also has been important in fire management. Beginning with the pioneering use of fire in the management of Everglades National Park in the 1950s, research in the national parks, some funded by the NPS, has had a major influence on the acceptance of fire as a natural process in wilderness landscapes. Studies of natural fires, the effects of fire suppression, and the use of planned fires have produced a large body of literature. Fire is now a universally accepted management tool in conservation biology, and the NPS has been a major force in this change in thinking.

In Sequoia-Kings Canyon and Yosemite National Parks in California, fire suppression was once believed essential to protect park resources. However, after decades of fire control, fire-intolerant species of pine and fir spread into the meadows and giant sequoia groves, respectively. Research that began in the 1960s provided a better understanding of the significant role of fire in maintaining the distinctive character of Sierra Nevada forests, and prescribed burning began in the 1970s. Recent public challenges to this practice have led to outside review of the fire management and research program. The reviewers endorsed the fundamental concept of vegetation management through burning and recommended additional research to provide a better basis for planning and evaluation of prescribed fire. A synergy among management, public information, and research was found to be needed.

At Yellowstone National Park in Wyoming, intensive study of fire history began in the early 1980s. Scientists found that high-intensity, stand-replacing fires occurred at long intervals and affected large percentages of the study area in a single burn. Their description was published before the dramatic 1988 fires—and it is remarkable that the results produced a convergent picture with studies of those large fires. In fact, the research was an asset to park scientists and managers in dealing with the fires and is being used to shape new management policies.

Another example of the value of research on natural processes is evident today in how park units along the coasts are managed. When NPS began acquiring land for Cape Hatteras National Seashore (authorized in 1937) and for some time thereafter, its policies included expensive structural attempts to stabilize beaches, dunes, and shorelines. By the time more recent National Seashores such as Cape Cod (Massachusetts), Cape Lookout (North Carolina), Assateague Island (Maryland), and Cumberland Island (Georgia) were acquired in the 1960s, NPS's policies had begun to evolve toward more flexible approaches that recognized the natural dynamics of coastal systems. Even where historic structures are involved, NPS's policy now requires that "control measures, if necessary, be predicated on thorough studies taking into account the nature and velocity of shoreline processes ..." (NPS, 1978). The evolution of NPS's management of shoreline processes was based in part on the accumulation of scientific evidence that demonstrated the futility of trying to control beach erosion in these dynamic, ever-changing ecosystems.

ASSESSING THREATS AND MITIGATION MEASURES

At Cape Cod National Seashore in Massachusetts, off-road vehicles were blamed for serious dune erosion, visitor annoyance, and harm to the endangered piping plover, a bird that requires extensive sand beaches for nesting. A five-year study of off-road vehicles, complemented by separate social science and ornithological studies, resulted in the development of an off-road vehicle management plan that was instituted after public review and comment. The plan allows vehicular access to some of the better surf fishing areas while protecting dunes, vegetation, and shore birds, including the piping plover, and minimizes conflicts between different types of uses at swimming beaches. The plan, based on careful scientific studies, has withstood challenges in a U.S. District Court.

The Devil's Hole pupfish, endemic in a single undisturbed pool in Death Valley National Monument in California, has a smaller range than any other North American vertebrate. A decline in water levels began in 1968 when groundwater pumping for agricultural irrigation began on adjacent private lands. Scientific studies revealed that reproduction necessary to sustain the endangered species could only occur if the water level in the pool was high enough to support growth of algae on a shallow rock shelf within the pool. With this knowledge, the NPS mitigated the problem by purchasing certain adjacent lands to protect against groundwater overdraft and obtaining a permanent court order that prevents pumping of groundwater that lowers the water level below the rock shelf. The court order, which was based on scientific research, was upheld by the U.S. Supreme Court.

The protection of Everglades National Park in Florida seemed at first glance assured by the setting aside of some one million acres in south Florida, a total since increased by the creation of Big Cypress National Preserve adjacent to the national park. However, the park boundaries did not encompass all of the areas that proved critical to the functioning of park ecosystems, and the effects of land use and water management outside the park soon became evident. Today the park faces a variety of serious problems related to water levels and water flow patterns, agricultural pollutants, exotic species, and habitat destruction. One result is that the population of wading birds has declined more than 90 percent since the 1930s, from about 250,000 in 1934 to 7,800 today. The population of endangered wood storks has declined from 5,000 birds in 1956 to 375 birds today.

In response to such threats, cooperative research on hydrology and biotic responses is being conducted, and researchers are developing models to predict water flow under various conditions. These tools have helped park managers negotiate better schedules for water release from the South Florida Water Management District to the national park. Research also is under way to assess the effects of agriculture, in part to determine how water coming from agricultural areas north of the Everglades and coursing through canals to the park threatens to increase the amount of phosphates and nitrates in park wetlands. Other research is being done to determine the effects of sport fishing, which has grown by almost 10 percent each year, and the associated effects of the increase in recreational boat use on the seagrass beds. These efforts and others in the park should increase our understanding of this unique ecosystem and help park managers protect the resources for the future.

The native cutthroat trout of Yellowstone Lake, a key species in the food web of the Yellowstone ecosystem, is both a top predator in the river ecosystem and prey for many terrestrial carnivores, including grizzly bears, white pelicans, bald eagles, and ospreys. The cutthroat trout provides an important link between aquatic and terrestrial productivity. The cutthroat trout fishery was a major early attraction of the park, and liberal fishing regulations led to the decline of fish stocks beginning in the 1920s. By the late 1960s, the popular sport fishery had virtually collapsed. A study of long-term measurements of rates of spawning and harvest left little doubt that overharvest had jeopardized the trout population. The NPS data base, coupled with an increased public awareness of the role of the fish in the park's ecosystems, led to the imposition of restrictive yet innovative regulations that have permitted the trout to increase and once again flourish. From Fishing Bridge in the park (which is now closed to fishing) visitors can witness a trout spawning run almost without parallel. Increases in the number of carnivores in Yellowstone National Park have been attributed in part to recovery of the trout. A fine sport fishery also has been restored and is once again an attraction for many park visitors.

In many parks, early attempts to improve recreational fishing for visitors caused declines in native species. In Rocky Mountain National Park, the native Greenback Cutthroat Trout, now an endangered species, is being restored to some of its original habitat. CREDIT: U.S. Fish and Wildlife Service photo by Jim Williams.

Mammoth Cave National Park in Kentucky comprises a spectacular cave system in classic karst topography, where water quickly leaves the surface to enter groundwater channels that carry large volumes of water. Outside the park, in the plain that drains directly into Mammoth Cave, septic tanks and sewage drain fields contribute effluent that quickly enters the groundwater system. A nearby commercial cave, in similar karst terrain, was closed because water pollution had resulted from poor local sewage and wastewater disposal practices. Studies using tracer dyes have shown that Mammoth Cave groundwater comes in large part from the surrounding drainage plain, which receives both untreated and inadequately treated sewage effluent. The studies resulted in the development of a plan for regional sewage treatment facilities. Although the studies showed the potential for pollution damage, insufficient research was done to identify the actual amounts of pollution that might affect park resources. The Park Service now finds itself in a difficult position because legislators and residents are not convinced, without more conclusive data, that the threat is real.

In Great Smoky Mountains National Park, considerable research on threats and mitigation is under way. For example, research has addressed the high-elevation spruce and fir forests of the southern Appalachians. These unique, island-like ecosystems at the summits of the highest peaks are rich in rare northern vascular plants and southern endemic plant species. The balsam woolly adelgid, an introduced pest insect, has caused nearly complete mortality of Fraser fir, a southern endemic tree, and is causing great structural change within the forest. Research to establish the pattern and cause of mortality is assessing remnant groves of mature fir, the protection of the gene pool through seed collections and tissue culture, and the efficacy of spraying infested trees with an environmentally benign fatty acid. Several rare bryophytes and lichens occur only on the bark of the Fraser fir. In the short term, research will help managers decide whether it is necessary to manage these elements of biologic diversity directly. Research also has addressed fuel loads and the risk of fire in these stands, as well as successional patterns of recovery.

Other research on the influence of acid deposition in Great Smoky Mountains National Park has focused on the spruce-fir ecosystem because acid deposition is greater at higher elevations than it is in low-lying areas. Research has shown unusual reductions in red spruce growth on some sites. These systems are long lived and the mineralization of organic matter is a slow process, so a better understanding of mineral cycles will require additional years of work. The results of the research, however, could help NPS prevent the addition of new sources of pollution in its airshed and suggest the development of other strategies for protecting biological diversity.

Science programs in several national parks, including Great Smoky Mountains National Park, Sequoia-Kings Canyon National Parks, and Rocky Mountain National Park have been important in the National Acid Precipitation Assessment Pro gram (NAPAP). The NPS has cooperated with government agencies and other organizations to support research and analyses under the NAPAP, including the U.S. Forest Service, Environmental Protection Agency, the Electric Power Research Institute, National Aeronautics and Space Admin

THE NATIONAL ACID PRECIPITATION ASSESSMENT PROGRAM

The National Acid Precipitation Assessment Program (NAPAP) was authorized by Congress in 1980 to quantify and explain the causes and consequences of acid atmospheric deposition. The 10-year, multi-agency effort cost approximately $500 million and culminated in 1990 with the delivery of 34 volumes of reports to Congress. The NPS participated in NAPAP in several ways. It received NAPAP funds to conduct watershed research in sensitive but relatively unaffected remote areas of the West and Midwest. Funds were provided to 16 park areas to participate in long-term monitoring networks (NPS, 1991). The NPS Office of Historic Preservation was involved in research into the effects of acid deposition on building materials. Park Service scientists worked with other investigators both inside and outside of parks to avoid duplication and to maximize expertise.

The effort offered many lessons. It confirmed that acid deposition causes acidification of sensitive aquatic ecosystems and can affect soil fertility. It showed that acid deposition in conjunction with other air pollutants and climatic fluctuations can harm forests and that the mechanisms through which damage occurs are not simple. An important body of knowledge about deposition chemistry, surface water sensitivity, forest response, and ecosystem processes was generated. With the data, parks with damaged and at-risk resources can be ranked and managers can devise strategies for addressing the effects.

Beyond this information, however, the program brought intangible benefits to the Park Service (Baron, 1991). During the 10 years of the program, the NPS built a core of experienced, respected researchers able to address the interdisciplinary issues that characterize natural resource management today. They became involved with researchers in other agencies and in universities in addressing these complex questions, and the patterns of communication will bring other benefits in the future. The experience of peer review also should translate into continued high-quality reporting of results.

istration, National Oceanic and Atmospheric Administration, and several state governments. The 10-year program of research generated critical information about the effects of air pollution and pollutant disposition on ecosystems. Although NAPAP itself lasted only for 10 years, new science programs, such as the Global Change Program, will use many of the sites established for NAPAP monitoring. Also, the inter-agency cooperation stimulated by NAPAP facilitated regional analyses of systems, an effort that continues. Research included studies of the effects of acid precipitation on vegetation in the Sierra Nevada, on forests in the southern Appalachians, and on air quality in the Colorado Front Range.

CONCLUSION

These examples illustrate some of the array of problems facing park scientists and managers, who must grapple with pervasive human influences; determine appropriate levels of human involvement in ecological processes and in the lives of endangered species; deal with the importance of spatial scale in recommending land acquisitions and management of land already in the system; and balance the inevitable tradeoffs between the need for information, aesthetic considerations, appropriate public use of park lands, public perceptions, and affordability. The folly of dealing with this range of issues without adequate scientific information should be readily apparent.

Some overall insights can be gained from the examples:

- Simple isolation of a national park from neighboring human influences, even if possible, will not ensure its preservation.
- For many ecological processes, long-term data collection, whether it is called monitoring or research, is absolutely critical to scientific study and resource management.
- The credibility of NPS management decisions and its research in general will be enhanced by involving the external scientific community.
- The public, a critical constituency of the parks, expects timely answers to their questions about park resources. Science and interpretation should be closely allied.

The progress brought by research is a continuum—each generation of scientists builds on the knowledge gained by the last. If we look into the past, we can find clear examples of where the lack of scientific understanding actually harmed park resources—for instance, the 1950s attempt at Great Smoky to improve recreational fishing that both discovered and almost made extinct an endemic species, the Smoky madtom. We see an evolution in NPS attitudes regarding human interference with the natural functioning of park ecosystems—a trend toward less interference that represents a learning process (Wright, 1992). All parks start with an inadequate knowledge base. As research answers some questions, it inevitably raises others. It is only through such an iterative process that parks can be preserved.

It is important to note that virtually all successful research efforts in the national parks in some way involve coordination with the external scientific community. This con

Balancing the needs of visitors who seek to enjoy the nation's parks with the need to protect park resources will always remain a challenge for park managers. Park scientists and park managers must work together to meet this challenge. CREDIT: National Research Council.

clusion has implications for the future of the NPS program. One way to strengthen the NPS science program will be to strengthen cooperative research elements.

By itself, an adequate research program will not eliminate the many, complex threats faced by the national parks. But it will allow faster identification of human perturbations, greater understanding of cause and effect, better insights into prevention, and more appropriate strategies for mitigation so that managers can maintain systems in a desirable condition or restore them where necessary. Virtually all parks have a backlog of unaddressed research questions. This is noted in NPS's own assessment of threats to the parks (NPS, 1980), and it is illustrated clearly in the long lists that typically appear in the "research needs" sections of park resource management plans. Science must be a permanent fixture within the NPS and that research must be an ongoing, iterative process.

3

Previous Reviews of Research in the National Park Service

Research in the National Park Service (NPS) got its start in 1929 when George M. Wright, a former park naturalist at Yosemite, used his own funds to conduct a survey of national park wildlife to identify wildlife problems and assist in wildlife management. The momentum grew in 1932 when the NPS established a separate Wildlife Division within the Branch of Research and Education, with Wright as its first chief. Under Wright's leadership, and using funds from the Civilian Conservation Corps, the division grew to a staff of 27 scientists. However, the new program lost influence with Wright's death in 1936. Budget constraints during the Depression and a lack of support from park managers for scientific research led to reduced funding, and by 1939 the three remaining staff members of the division were transferred to the Fish and Wildlife Service (Sumner, 1983).

Research received very little attention from the NPS during the next two decades. Then in the early 1960s, Secretary of the Interior Stuart Udall called for two independent scientific reviews of resource management and research in the national parks. The first was done by a blue ribbon committee, the Leopold committee, which was chaired by A. Starker Leopold. Its mandate was to advise the secretary regarding wildlife management in the national parks. The second re quest for assistance asked the National Academy of Sciences (NAS) to recommend "a research program designed to provide the data required for effective management, development, protection, and interpretation of the national parks; and to encourage the greater use of the national parks by scientists for basic research." This committee was chaired by William J. Robbins.

As a result of Secretary Udall's requests for advice, two landmark documents appeared in 1963: "Wildlife Management in the National Parks" (Leopold et al., 1963), broadly known as the Leopold report, and "A Report by the Advisory Committee to the National Park Service on Research" (NRC, 1963), known as the Robbins report. These two documents provided the first comprehensive reviews of science and resource management in the parks. Their recommendations urged a stronger role for science in the parks. Unfortunately, the reports' assessments of the NPS research and resource management programs remain as relevant today as they were nearly three decades ago, because very few of their recommendations have been implemented effectively.

Many additional reviews and studies of the NPS research and resource management programs have been made since the Leopold and Robbins reports were completed (Table 3-1). Some of these have been conducted by bodies external to the NPS; others were developed internally, sometimes in response to congressional inquiries. This chapter focuses mainly on reports generated outside the agency, especially the Leopold Report; the Robbins Report; a National Parks and Conservation Association (NPCA) report titled "Research in the National Parks: An Assessment of Needs" (NPCA, 1988a); and a report of the Commission on Research and Resources Management Policy in the National Park System (NPCA, 1989), also known as the Gordon report, after its chair, John C. Gordon of Yale University. The NPS's 1992 report "National Parks for the 21st Century: The Vail Agenda," and other internal reports are noted, however.

PAST REPORTS

The Leopold report was precedent setting in that it recommended management and research directed at whole park

Table 3-1 Major Reviews of NPS Research or Resource Management Programs

Date	Author	Title
1963	Leopold et al.	Wildlife Management in the National Parks
1963	National Research Council	A Report by the Advisory Committee to the National Park Service on Research (Robbins report)
1977	Allen and Leopold	A Review and Recommendations Relative to the NPS Science Program
1979	National Parks and Conservation Association	External Threats to the Parks
1979	Conservation Foundation	Federal Resource Lands and Their Neighbors
1980	National Park Service	State of the Parks: A 1980 Report to Congress
1981	National Park Service	State of the Parks: A Report to the Congress on a Service Strategy for Prevention and Mitigation of Natural and Cultural Resource Management Problems
1987	Castleberry	Workshop of NPS Regional Chief Scientists, Omaha, Nebraska, Dec. 3–5, 1986
1987	General Accounting Office	Limited Progress Made in Documenting and Mitigating Threats to the Parks
1988	National Parks and Conservation Association	Research in the Parks: An Assessment of Needs
1989	National Parks and Conservation Association	National Parks: From Vignettes to a Global View (Gordon report)
1992	National Park Service	National Parks for the 21st Century: The Vail Agenda

ecosystems, with attention paid to all biological components. Controls on populations were to be by natural means. Spraying for native insect infestations was to cease. Fire suppression practices, extensive at that time, were to be halted. The report recommended that modern, scientifically based management techniques be applied and that park research programs be expanded. Although noting that the NPS could benefit from research conducted by other federal agencies or by groups outside the government, the Leopold committee concluded that the NPS research program should be strengthened and controlled from within the Park Service. The report concluded that "the agency best fitted to study park management problems is the National Park Service itself."

Secretary Udall embraced the Leopold report's recommendations. In a memorandum dated May 2, 1963, he instructed the NPS to incorporate the Leopold findings into its operations. It states, "a primary goal of park management is to maintain the biotic associations within each park as nearly as possible in that relationship which existed at a predetermined time period. The goal then is to maintain or create the mood of wild America." Udall's memorandum also states that "research to prepare for future management and restoration programs should be accomplished by the National Park Service. Research should also enable critical appraisal of ecological relationships in various plant and animal associations."

In the same year, the Robbins report (NRC, 1963) recommended the following:

- Greater distinction between administration, operational management, and research management.
- Inventorying and mapping of the natural history resources of each park.
- The creation of a permanent, independent, and identifiable research unit within the NPS.
- The appointment of an assistant director for research reporting to the director.
- The preparation of research programs plans for each park, establishing research laboratories or centers where justified.

- That research should be publishable and should be published.
- That additional financial support should be given to NPS.
- Closer relations with the scientific community.
- Greater consultation between management and research units.
- The creation of a scientific advisory committee.

The National Park Service responded to the Leopold and Robbins reports in several ways. An Office of Natural Science Studies was created to build a program in scientific studies; this office was a quality control unit directly under the supervision of the chief scientist, who reported to the director. The Leopold committee was in part reconstituted as a permanent Natural Sciences Advisory Committee. In response to the Robbins report, formal research plans were developed for a few major park units. The social sciences were added in an attempt to better understand the human dimensions of park use and management. Also, a mutual interest developed between the NPS and some academic researchers.

There were two major problems, however, that combined to plague the NPS science program at the beginning of the 1970s: inadequate funds to support a continuing program, and a question of who should direct the work of scientists. In 1972, the position of NPS chief scientist was assigned to the associate director for professional services. This not only reduced direct access to the NPS director, but it also decreased the prestige and effectiveness of the chief scientist and of the science program.

At the request of then-NPS Director Gary Everhardt, in 1977 Durward Allen and Starker Leopold reviewed the service's natural science program. Their findings appear in a document known as the Allen and Leopold report (Allen and Leopold, 1977), which was submitted to the new NPS director, William Whalen. It states,

> The National Park Service has reached a time in its history, and in the history of the nation, when science and research should be given a much greater and clearly recognized re

> sponsibility in policy making, planning, and operations. Seat-of-the-pants guesses in resource preservation and management are open to challenge and do not stand up well in court or in the forum of public opinion. To be right in decisions affecting natural environments, and to serve its educational missions, the Service requires an increasingly sophisticated system of gathering new facts and getting them applied at all levels, from the back country to [the Washington Office].

The Allen-Leopold committee found no fault with the direction of the NPS science program itself, only with its lack of funding, staffing, and influence in the agency. The committee recommended the creation of a position of associate director for natural science, with line authority over regional chief scientists and park scientists; park superintendents would have only administrative control over research in their parks. The report expressed concern about "inadequate utilization by management of scientific information already available" and proposed that resource management biologist positions be established in the larger parks as a liaison between management and research. The committee also expressed the need for a more formal promotion ladder for scientists.

But Director Whalen did not support a science initiative, despite a new NPS science and technology reorganization (which included making the chief scientist an associate director) that had been approved by Robert Herbst, assistant secretary for parks and wildlife. The Allen-Leopold report's recommendations were not implemented.

Two concurrent assessments of threats to the parks took place in 1978, and reports appeared the following year. First, the NPCA undertook an assessment of the external threats to the national parks, and a report, "NPCA Adjacent Lands Survey: No Park Is an Island," appeared in the March/April issue of *National Parks & Conservation Magazine* (NPCA, 1979). The summary stated

> In short, unless all levels of government mount a concerted effort to deal with adjacent lands problems in a coordinated manner, the National Park Service mandate to preserve areas within its jurisdiction in an unimpaired state for the benefit of future generations will be completely undermined.

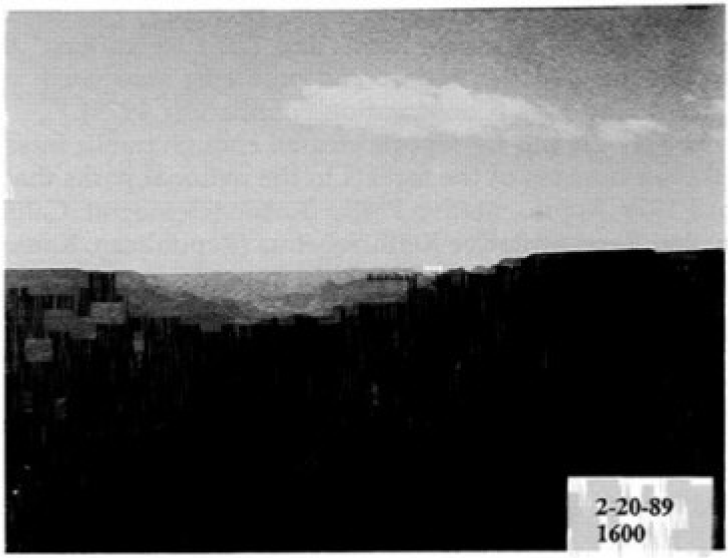
Second, The Conservation Foundation (CF) published a report, "Federal Resource Lands and Their Neighbors," that also documented the widespread problems associated with adjacent land uses (Conservation Foundation, 1979).

The NPCA and CF reports created enough public interest in the seriousness of the threats to the national parks that in April 1979, Representative Philip Burton (Democrat, California) and Representative Keith Sebelius (Republican, Kansas), respectively the chair and ranking minority member of the Subcommittee on National Parks and Insular Affairs of the House Interior Committee, formally asked the NPS to prepare a report on the threats to the park system. In response, NPS began a comprehensive assessment that included a questionnaire that was sent to every park unit. In May 1980, the NPS submitted "State of the Parks: A 1980 Report to Congress" (NPS, 1980), which made the following admissions:

- Seventy-five percent of the reported threats were classified by on-site park observers as inadequately documented.
- Scenic resources were reported to be significantly threatened in more than 60 percent of the parks.
- Air quality was reported to be endangered in more than 45 percent of the parks.
- Mammal, plant, and freshwater resources were reported to be threatened in more than 40 percent of the units.
- More than 50 percent of the reported threats were attributed to sources or activities external to the parks.

In addition, the NPS listed four actions essential to protecting and preserving the resources of the parks:

- Prepare a comprehensive inventory of the important natural and cultural resources of each park and develop a plan at the park level for managing these resources.
- Establish accurate baseline data on park resources and conduct comprehensive monitoring programs designed to detect and measure changes both in these resources and in the ecosystem environments within which they exist.
- Pay additional attention to those threats which are associated with sources and activities located external to the parks.



Activities on adjacent lands can pose significant threats to the nation's parks. In Grand Canyon National Park, inner-canyon haze caused by air pollution can reduce visibility significantly. The 2-10-89 view shows extremely high pollution, with a visual range of less than 30 km. CREDIT: NPS Air Quality Division, Denver.

- Improve our capability to better quantify and document the impacts of various threats, particularly those which are believed to most seriously affect important park resources and values.

In summary, the report stated

> To accomplish these objectives will require that the Service significantly expand its research and resource management capabilities. At the present time, the natural science research program of the National Park Service is base funded at a level of only nine million dollars and is staffed by fewer than 100 scientists; this is an average of less than one researcher for each three units of the System and represents only 1.1 percent of the total Park Service staff (NPS, 1980).

The 1980 NPS assessment revealed its unequivocal awareness of serious science-related problems in the park system and of what was needed to correct them. These were the same problems that had been identified repeatedly by independent review committees over a period of nearly 20 years.

In response, Congress asked for a second report to outline an implementation strategy for addressing threats to the parks. A "State of the Parks—A Report to the Congress on a Service Strategy for Prevention and Mitigation of Natural and Cultural Resource Management Problems" was submitted to Congress in 1981 (NPS, 1981). It proposed a strategy for both short-and mid-term actions to prevent or mitigate the problems, including the identification of so-called significant resource problems for immediate attention. Other actions included the development of information baseline standards, special protection zone guidelines, biological monitoring and environmental indexes, and a resource information tracking system; the initiation of a boundary study of historic and archaeological parks; an assessment of cooperative park study units; major natural resource management training programs for superintendents, midlevel, and beginning employees; and a special natural resource management trainee program. In addition, the 1981 NPS report called for a science program review by the National Academy of Sciences.

Five years later, concern was expressed by members of Congress that most of the actions proposed by the NPS had not been implemented, so the General Accounting Office (GAO) was asked to assess NPS progress on its prevention and mitigation strategy. The resulting 1987 GAO report, "Limited Progress Made in Documenting and Mitigating Threats to Parks," concluded that "the Park Service's strategy for better managing park resources has yet to be fully implemented. Some parks do not have approved resource management plans, and the plans that have been prepared are not being used in formulating the Park Service's annual budgets. Further, many of the 11 initiatives intended to support the development and use of the plans were not followed through" (GAO, 1987).

Further deficiencies in the NPS science program were identified by the Park Service when, in December 1986, the 10 regional chief scientists participated in a workshop to develop their own recommendations for improving their science programs (Castleberry, 1987). They recommended the following actions:

- Make better use of cooperative agreements for research.
- Revise NPS planning to better integrate natural-and cultural-resource research.
- Hold regular meetings of managers to review research proposals.
- Identify emerging national problems.
- Subject all research to periodic evaluations.
- Relax limitations on attendance at scientific meetings.
- Develop mechanisms for job exchanges between scientists.
- Evaluate the NPS publications program.
- Hold semiannual or annual meetings of regional chief scientists.
- Make science program presentations to the regional directors.

Most of the recommendations from the regional chief scientists were designed to give greater autonomy and responsibility to NPS scientists, and to allow their interaction with the broader scientific community.

More recently, NPCA conducted a detailed analysis of NPS operations and prepared a nine-volume report, based on extensive interviews with managers, scientists, and other concerned persons within and outside of NPS (NPCA, 1988b). Volume 2 of that study, "Research in the Parks: An Assessment of Needs," examines the NPS's cultural, historical, and natural science research (NPCA, 1988a). It recommended the following:

- Specific new legislation for research, standardized resource inventories, and permanent monitoring programs.
- A separate budget line item for research, equivalent to 10 percent of the total NPS operating budget.
- Establishment by Congress of an NPS science advisory board.
- Creation of an independent NPS research arm under the associate director for research, with line authority to regional chiefs of research.
- Establishment of national park science centers and cooperative park study units for each major biome.
- Clear definitions for science, research, and management of natural and cultural resources.
- Greater use of research findings.
- Increased support for publishing, attendance at professional meetings, and sabbaticals.
- Greater use of specialized performance evaluation systems for scientists.
- More effective data management.

A more recent comprehensive review of research and resource management in the parks was conducted by the Commission on Research and Resource Management Policy in the National Park System, which produced the report "National Parks: From Vignettes to a Global View" (NPCA, 1989). This 17-person commission, also known as the Gordon commission after chair John C. Gordon, was funded primarily by the Andrew W. Mellon Foundation, and its work was facilitated by NPCA. The commission was very critical of the degree to which the NPS has fulfilled its obligations in research and in management of natural and cultural resources.

The Gordon commission recommended that the NPS adopt a "new vision" to meet the environmental challenges of the twenty-first century, "a vision based on the principles of eco system management [and] on sound research." Four major tasks were proposed:

- Develop and use the concept of ecosystem management.
- Implement a research program to meet the needs of the Park Service and to educate the public.
- Adopt professional standards for the recruitment, promotion, and continued development of park managers.
- Educate Americans and the international public about natural and cultural systems and the ways in which those systems change.

All four tasks are highly interrelated: "These strategies are interdependent: an improved ecosystem management program requires an adequate research base and professionals to implement it, and the information thus gained must be presented to the public effectively" (NPCA, 1989).

The Gordon report included an extensive commentary on the meaning of ecosystem management and on the NPS failure to comprehend and apply this concept. The commission recommended aggressive stewardship and management structured in the context of well-defined objectives. The commission concluded that "The concept of 'naturalness' is not a simple and comprehensive guide for management and will not anywhere substitute for identification of well-defined, park-specific, and research-based objectives."

The Gordon commission's recommendations about research in the national parks were extensive and strongly worded. It found that "research is basic to the mission of the National Park Service. Yet, the Park Service, unlike other federal agencies ... lacks an explicit mission for research. Without a sufficient knowledge base, it is impossible to make wise management decisions. Research must be broad-based because the national park system is so huge and diverse. Research must also be ongoing, incorporating new techniques and interpretations as appropriate." The report calls for "a quantum leap in both the quantity and quality of research supported by the National Park Service." Particularly important are long-term as opposed to short-term research; holistic inves tigations of entire ecosystems; and experimentation, an approach typically discouraged by NPS management.

The Gordon report provided 13 recommendations for development of a credible NPS research program. These included provision of a formal mandate for a research program independent of park management and given a line-item budget equivalent to at least 10 percent of the agency's budget, establishment of long-term ecosystem-level research projects in at least 6 to 10 parks, significant support for extramural research, peer review during all phases of in-house research, and development within parks of zones specifically for research.

The Gordon report was emphatic about the need for the NPS to take major steps to enhance the professional qualifications of its staff. This is equally applicable to research, resource management, and park protection. Recruitment of professionals, development of clear career ladders, and support for training programs are all discussed. A final recommendation called for developing and implementing a system of accountability for managing and protecting natural and cultural resources at all levels of the agency.

In 1992, the NPS released "National Parks for the 21st Century: The Vail Agenda," prepared for the director by the Steering Committee of the 75th Anniversary Symposium. The effort is yet another voice in the gathering momentum calling for change within the NPS. The report outlines a vision built on six strategic objectives:

- **Resource stewardship and protection**: The NPS's primary responsibility must be to protect park resources.
- **Access and enjoyment**: Each park unit should be managed to provide the nation's diverse public with access to and recreational and educational enjoyment of the lessons contained in that unit, while maintaining unimpaired those unique attributes that are its contribution to the national park system.
- **Educating and interpretation**: The NPS is responsible for interpreting and conveying each park unit's and the park system's contributions to the nation's values, character, and experience.
- **Proactive leadership**: The NPS must be a leader in

local, national, and international park affairs, actively pursuing the mission of the national park system and assisting others in managing their park resources and values.

- **Science and research**: The NPS must engage in a sustained and integrated program of natural, cultural, and social science resource management and research aimed at acquiring and using the information needed to manage and protect park resources.
- **Professionalism**: The NPS must create and maintain a highly professional organization and work force.

The fifth objective, fostering science and research, reiterates the message that science is critical to the NPS mission. The report acknowledges that the lack of a specific legislative mandate for science has hampered systemwide support and that the science program in general has suffered from a lack of independence and broad peer review. To engage in a sustained, integrated program of natural, cultural, and social science, the Vail Agenda recommends that secure legislation and funding be mandated; that training in information management and the role, use, and production of research information be accelerated; and that resource protection, access, and interpretation decisions be based on full consideration of the best available scientific research.

Whether this NPS-generated report is any more successful than past reports in sparking change within the agency remains to be seen, however.

CONCLUSION

The recommendations of many serious reviews over nearly three decades reveal both a unanimity of opinion about the need for research to support resource management in the national parks (Table 3-2) and an abysmal lack of response by the NPS. There is a broad concurrence in the basic recommendations among the four major external reports, and these opinions are echoed by the NPS's internal documents.

Major expansion of the NPS research program, including budgetary and administrative restructuring to provide for its financial and directional independence from management,

Table 3-2 Major Categories of Recommendations on NPS Research and Resource Management from Past External Reviews

Action Recommended	Leopold et al., 1963	NRC, 1963 (Robbins)	NPCA, 1988a	NPCA, 1989 (Gordon)	Other
Research					
Congressional mandate		x	x	x	
Independent research arm	x	x	x	x	
Major expansion	x	x	x	x	d
Basic and applied missions	x	x	x	x	
Coordination with other research programs	x	x	x	x	b,e
Quality control improvements		x	x	x	e,f
Establishment of science centers		x	x	x	
Internal restructuring for emphasis		x	x	x	a,f
Recruit and develop qualified personnel			x	x	a,b,c
Resource Management					
Mandate			x		b
Set objectives, develop plans	x		x	x	b,f
Apply ecosystem principles	x		x	x	
Inventory and monitoring		x	x	x	d,e
Recruit and develop qualified personnel			x	x	a,b,d
Accountability with criteria			x	x	
Cooperation with other owners in resource management				x	

a, Allen and Leopold, 1977; b, NPCA, 1979; c, Conservation Foundation, 1979; d, NPS, 1980; e, NPS, 1981; f, Castleberry, 1987.

is a consistent recommendation from external reviews. Three of the reports call for legislation to provide a congressional mandate for science in the NPS because the lack of such a mandate has often been cited by agency sources as a problem. All the major external reports also call for basic and applied research, for expanded coordination with research programs carried out by other institutions, and for better integration overall with the broader scientific community. Much better quality control of NPS research (through peer review) and establishment of centers of excellence are called for in many of the reports.

Resource management issues were given major attention by three of the four major external reviews (the Robbins report focused almost exclusively on research). There is strong agreement about the need for NPS to set specific management objectives and develop plans that reflect those objectives, to apply ecosystem principles to the management of park properties, and to develop credible inventory and monitoring programs.

Both the Gordon report (NPCA, 1989) and "Research in the Parks—An Assessment of Needs" (NPCA, 1988a), the two most recent external studies, identify the hiring of qualified personnel as a major issue, a call repeated by internal documents. This involves recruitment of professionally trained scientists, resource managers, and rangers and their continued professional development and advancement. Implicit in these findings is that selective recruitment and consistent support for training and development programs are not currently emphasized in the Park Service.

Since the first major independent reviews of the adequacy of the NPS science program were conducted in the early 1960s, many experts have shared their views on the scope and quality of the NPS research program. In all, the many reviews provide both general and very specific recommendations for strengthening science in support of the parks. Many of the suggested improvements were recommended repeatedly, yet few have been effectively or consistently implemented. Where responses have been attempted, they have always had to struggle to compete for funds and consistent organizational support. Despite repeated admonitions, the importance of a strong science program—although recognized by some regions, parks, and personnel—simply has not garnered servicewide support. The question of why the Park Service has been so reluctant to strengthen its reliance on science is difficult to answer, in part because the reasons are often subtle and political. Sometimes the reasons relate to training—managers without backgrounds in science often do not think of science when they attack their problems; it is not in their tool kit and they may have had little contact with scientists during their careers. Their reluctance to use science comes in part because they do not fully recognize its potential. Indeed, many administrations have come and gone during the past 30 years and they have operated in very different settings, but with the same result—science has not taken hold as a key element in the foundation of the NPS mission.

4

The Current Research Program of the National Park Service

According to the National Park Service (NPS), the primary objective of its research program today is to conduct directed studies that provide information on which to base park planning, park development, and park management decisions. Current research often deals with management problems in the parks and is designed to support decision-making. It includes laboratory and field investigations, analytical studies, and data collection directly related to protecting and preserving the resources of the parks and the vistas that surround them. It is also needed to find ways to enhance the use and the enjoyment of the parks by visitors. Because park resources run the gamut from biological resources (e.g., vegetation, wildlife, fisheries) to geophysical resources (e.g., water, air, caves, soils, islands, minerals) to cultural resources (e.g., archaeological ruins, monuments) to aesthetic resources (e.g., scenic vistas, quiet places), the NPS science program includes elements of the biological, geophysical, and social sciences.

Information from research is needed at many levels throughout the Park Service. For example, individual parks often have specific issues of importance, such as wolf-moose interactions at Isle Royale National Park or coral reef degradation at Virgin Islands National Park. In other cases, research transcends questions raised at individual parks. For example, the problems created by the gypsy moth affect many eastern parks, and control of kudzu, an introduced plant species native to Japan, is an issue throughout the south. The answers to still other research questions have nationwide implications. For example, air pollution, water resource management, and uses of the parks by visitors are issues in virtually all parks.

Baseline resource inventories and long-term monitoring of the status of park ecosystems are particularly important to all park units. The information is necessary to determine the current ecosystem structure and the nature and rate of change of these ecosystems. Research results can be used in models developed to predict future conditions in the parks, and such models can lead the way to management strategies. Through the monitoring of actual conditions, undesirable effects on resources and ecosystem processes can be detected as the first step toward mitigation. Park use patterns and impacts similarly need to be documented. Among the most serious issues is the need for documentation of the direct and indirect impacts of human activity on park resources.

In conducting this study of science in the national parks, the Committee on Improving the Science and Technology Programs of the National Park Service originally set out to perform a standard peer review of NPS research activities. However, the committee soon determined that the real problems in the NPS research program are not at the level of individual projects. Instead, they are more fundamental, rooted in the culture of the NPS and in the structure and support it gives to research. Thus, the committee concluded that the real need was for an assessment more broadly focused on the program and its place within the agency.

ORGANIZATION

Levels of Authority and Functions

The national park system consists of 361 individual units administered by the NPS to maintain their intrinsic natural, cultural, or recreational values. The units are called by some 20 different names including monuments, historic sites, seashores, and recreation areas. Their sizes range from 13.2 million acres (Wrangell-St. Elias National Park and Preserve in Alaska) to 0.2 acres (Thaddeus Kosciuszko National Memorial in Pennsylvania).

The current organization and philosophy of the NPS treats research as part of resource management. The two areas were combined to enhance cooperation between the two functions. Some observers charge, however, that merging the two activities was motivated at least in part by a desire to create the illusion of an increase in science activities and funding.

Park Service research and resource management generally are organized at three levels of authority: in the Washington office, in the 10 regional offices (Figure 4-1), and in the individual park units. Natural science research is administered from Washington by the associate director for natural resources, who directs the deputy associate director and four divisions (air quality, water resources, geographic information systems, and wildlife and vegetation). These divisions conduct research that generally is of value to the entire system. Cultural resource management and research fall under the authority of the associate director for cultural resources and of a deputy associate director; they oversee the divisions of Curatorial Services, Interagency Resources, History, Park Historic Architecture, Preservation Assistance, Historic American Buildings Survey/Historic American Engineering Record, Anthropology, and Archeological Assistance. Figure 4-2 shows the basic organizational structure of the Washington office.

As described by the NPS, the roles of the Washington office are to develop general policies and standards, set national priorities, coordinate servicewide research programs, and request funds for research and resource management from the Department of the Interior and Congress. Most of the actual research planning and activity, however, is carried out by the 10 regional offices. The Washington office maintains no separate research division because research is considered mainly a regional and park responsibility. As a

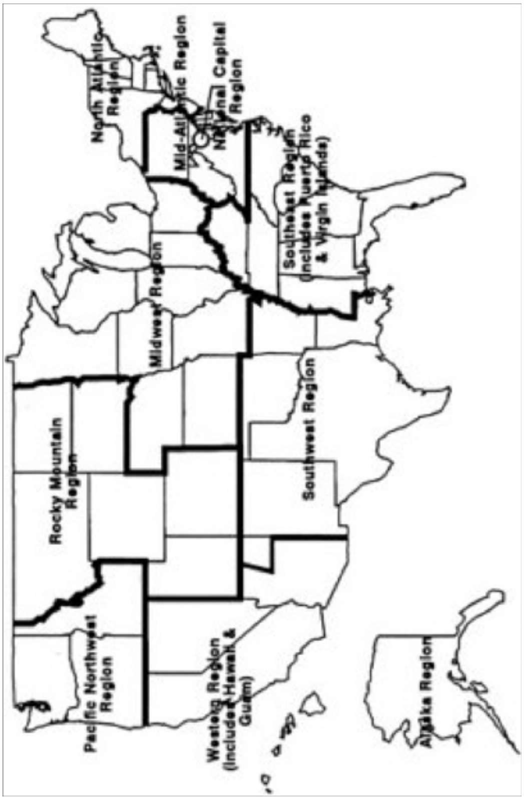


Figure 4-1 Regions of the National Park Service.

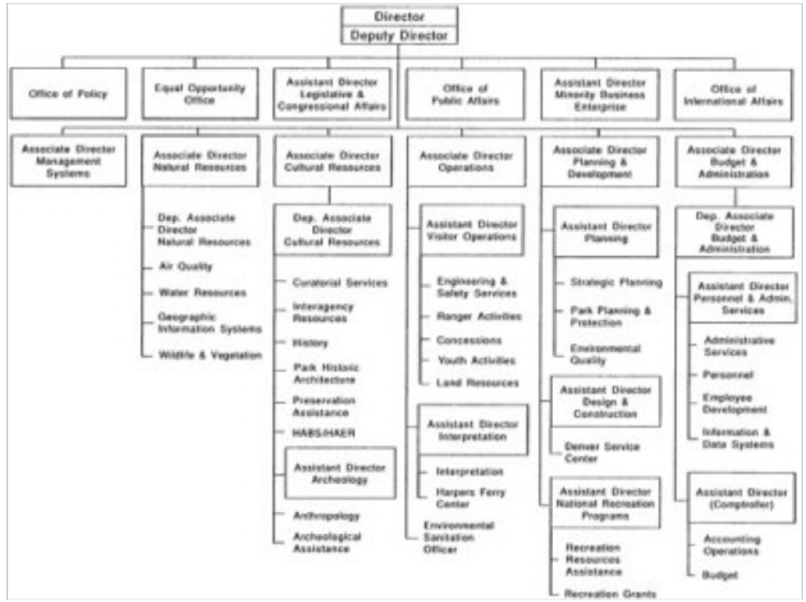


Figure 4-2
Organizational chart.

result, there is not one NPS science program, but 10 separate programs, each different in form and function.

Science serves five separate but closely related NPS functions: research and studies; resource management, preservation, and restoration; interpretation; resource protection; and program management.

Research and Studies

This area includes activities such as making inventories and short-and long-term monitoring undertaken to provide data for decision making, preservation, mitigation, rehabilitation, restoration, interpretation, and resource protection. Research design, data collection, synthesis, analysis, preparation of reports and publications, and development of management recommendations are part of this category.

Resource Management, Preservation, and Restoration

This category includes all activities that involve resource manipulation or change, including aid in management, preservation, and restoration related to sustaining natural systems or restoring altered resources to a more functional or natural state. Preservation can include habitat protection and maintenance, control of non-native species, prescribed burning, and integrated pest management. Restoration includes actions such as repairing eroded sites; replanting and reintroducing native species. and restoring sites, landscapes, and habitats.

Interpretation

This category includes all activities designed to explain, translate, or define research and implementation activities for management personnel and visitors to the park units. Close communication between those who work in research, resource management, and interpretation is essential to the success of the NPS science program because it is through interpretation that the knowledge gained through science is conveyed to decision makers and, ultimately, to the owners of the park system—the public. Resource management is the implementation arm of the science program; interpretation is the explanation of science and resource management. Each of the three must be effective for the others to be successful. Because the perpetuation of a park's natural and cultural resources is a park's highest purpose, these three related activities—science, resource management, and interpretation—require strong support, as do operational activities such as administration and maintenance.

Resource Protection

This area includes activities that protect park resources from overuse, vandalism, or other kinds of destruction. It also includes back country and wilderness patrols; special permitting; and enforcement of regulations and laws pertaining to fish and wildlife, federally listed threatened and endangered species, agriculture, grazing, mineral resource management, and air and water quality.

Program Management

This function includes all supervision, management, planning, and administration of natural resource management activities. These include setting program goals and objectives, establishing priorities, programming and budgeting, information management and tracking, personnel actions, meetings and communications, publications, and developing resource management plans.

Reporting Structures

The current organization of responsibilities for natural resource management and research varies considerably from region to region, but it generally follows one of two models. In one, the resource management staff, including any scientific staff, report to the superintendent of a park. In the other model, the scientific staff at the parks and in cooperative park study units report to the regional chief scientist while resource management specialists, who translate research

A 1988 survey revealed that over 120 endangered or threatened species were known to occur in the national park system. The peregrine falcon can be found in 59 parks and is the subject of restoration efforts in some units, including Acadia National Park. Less well known are the many threatened and endangered plants that are protected, such as these lady's slippers. CREDITS: U.S. Fish and Wildlife Service, peregrine by Jo Keller, lady's slippers by Peter Carboni.

findings into management strategies for park managers, report to a park superintendent. The second model gives the research staff some independence from the temporary crises, political influences, and immediate needs of front-line park managers. It offers the potential disadvantage that scientists might miss critical information that can be gained from the management perspective on priorities and problems. Some regions have consolidated research and resource management; others keep the two separate. Some regions arrange for most research to be done through extramural contracts or cooperative agreements; in other regions, most research is done by NPS staff, sometimes funded in part or whole by other agencies
.

This decentralized approach was instituted early in the 1970s to give greater flexibility at the regional level, and thus to be more responsive to the needs of individual parks. But the decentralized management of NPS has been a source of controversy. It is sometimes inefficient and results in fragmentation and duplication of effort. In addition, the Washington office has little authority and funding to provide adequate leadership in the face of the mounting problems and pressures in the system, especially for problems of national or international scope. Other critics charge that the decentralized approach creates extreme (and inevitable) variations in research effectiveness and in the morale of scientists from region to region and park to park. In areas where the line manager understands the usefulness of research as a management tool, research flourishes. In other areas, research fares poorly.

Another problem can arise when research and management are too closely entwined: the long-term vision and continuity needed for productive research often is not compatible with the short-term decision making needed for resource management. Each function offers different skills, as well, and misplaced responsibilities create problems—for instance, resource management staff assigned to take the lead in monitoring sometimes lack the training to design sampling programs or analyze the data collected. The political pressures inevitable in the management arena often do not foster good science. Because research and resource management funds come from the same pool in the NPS budget, the two activities compete for support. Given the overall shortages of staff and funding faced by the NPS, conflicts between researchers and managers —with their different goals and methods—can be severe and counterproductive. Without a clear mandate, research (like resource management and interpretation) very often loses out to the more immediate concerns of law enforcement and park operations.

In fact, when the NPS science program was being developed in the 1960s the original structure selected was a centralized organization patterned after the U.S. Forest Service and the U.S. Fish and Wildlife Service. A centralized structure also was recommended by the Robbins committee in

1963 (NRC, 1963). This structure gave the NPS a chief scientist in Washington with line authority to supervise all field scientists, whether they were assigned to parks, universities, or regions. The structure changed in 1971 when the current decentralized plan was instituted. The regional chief scientists now administer the regional programs in concert with the line managers (regional directors and superintendents). The regional chief scientists serve as the technical directors of their programs, and the line officers administer them.

Coordination and Planning

Park Service research activities must be well coordinated to ensure that research funds are spent wisely, accounted for properly, and that unnecessary duplication of effort is minimized. This is a major responsibility of the regional chief scientists and the chief scientist. Examples of servicewide coordinated research can be seen in the four divisions under associate director for natural resources. The divisions offer important avenues for research of national scope and have tightly defined missions that increase their effectiveness.

The Air Quality Division is responsible for air quality studies both through individual park projects and through servicewide activities; in 1991 it had a staff of 25 and funding of about $6.2 million. Through this division, the NPS monitors air quality in some 74 parks. Efforts also are under way to inventory and monitor air pollution effects on native vegetation. Research has focused on symptoms, location, and extent of ozone injury to native vegetation; on the origins and trajectories of air masses that impair visibility in parks; and on developing regional transport models for sulfates and ozone.

The Geographic Information Systems Division supports the use of geographic information data bases for resource inventories and monitoring in park management. Working with park or servicewide funding, the division acquires data, digitizes them, and does field work to verify them. Geographic information data bases can be used to determine trends in biological diversity; determine fidelity or deviation from desired resource conditions, assess the impacts of hu man activity, and forecast the consequences of management actions. For instance, in the North Cascades, Landsat data were processed in conjunction with topographic and precipitation information to map vegetation classes. The vegetation profile was used to produce two fire fuel models, and to model potential habitat for bald eagles and peregrine falcons.

The Water Resources Division activities include formulating water resources policy; offering planning assistance and regulatory reviews; conducting water resources inventories and monitoring; and identifying, evaluating, and mitigating threats to park water quality and quantity. The division also conducts flood plain and flood hazard analyses, and it has projects for erosion and sediment control and protection of wetland and riparian habitats. It tests water sources for potability; and secures and protects NPS water rights and resources.

Scientists working on research in the parks—whether NPS scientists or others—need to coordinate their efforts. Research at St. Croix International Historic Site is examining freshwater mussels as an indicator of contamination by polychlorinated biphenyls (PCBs) and mercury. CREDIT: NPS.

GLOBAL CLIMATE CHANGE RESEARCH IN NATIONAL PARKS

One recent example of the kind, of broad research that needs centralized leadership is the NPS's new efforts in the area of global climate change. The parks make good sites for this kind of research. Large tracts of relatively undisturbed natural ecosystems remain in the parks, so researchers can work toward differentiating global change effects from anthropogenic disturbances. Such research is essential to the future of the parks because changes in climate—including those caused by or evidenced in drought, storms, and wildfires—could threaten natural and cultural resources. Research data can help resource managers better understand the changes and help them make policy decisions for dealing with the affected areas.

In FY 1991, the NPS and cooperating park study units began work on 14 research projects in 6 biogeographic areas—the Colorado Rockies, the Glacier National Park area, the Olympic Peninsula, the Ozark Highlands, Southern and Central Sierra Nevada, and the Western Lake Forest. Research includes studies of tree rings, aquatic ecosystems, nutrient cycling, pollen analysis, fluvial geomorphology, fire history, and forest demography, as well as studies of forest succession and regional and landscape modeling. As other relevant research is conducted throughout the park system, continued efforts at coordination and communication will be necessary.

There are, however, problems in the NPS global change research program. The Park Service's response to the call for global change research was to build a large program at too many sites to effectively study the numerous processes and resources at risk. At the peer review of proposals submitted by individual parks, a strong recommendation was mode to concentrate on three or four locations based on science needs; the number of sites to be included was expanded based on political needs. While there is no question that the NPS must participate in national and international global change programs, the dollar investment is small ($3,000,000) compared to other agencies and could be better used to understand those sites at greatest risk under a changing climate scenario or where the baseline data base provides the greatest opportunity to evaluate change.

The Wildlife and Vegetation Division provides direction and technical input to servicewide programs in management of wildlife and vegetation, including threatened, endangered, and exotic species. It is responsible for the NPS integrated pest management program. It provides expert scientific assistance to support management and policy decisions throughout NPS. The division coordinates the NPS's involvement in the National Natural Landmarks Program and the Man and the Biosphere Program, and it coordinates servicewide research on issues of national and international significance, including biological diversity, global climate change, and the biological effects of acid precipitation.

Although these divisions are useful in facilitating servicewide coordination, coordination of research does not end within the agency itself. It must extend outward to other agencies and to the academic community. One example would be outreach to the U.S. Forest Service, which conducts extensive research of direct application to the NPS. The National Aeronautics and Space Administration, National Oceanic and Atmospheric Administration, and the Department of Defense all have substantial experience with remotely sensed data and geographic information systems that is relevant to NPS needs. NPS science personnel need to know what is happening in other quarters, to share information, and to transfer knowledge.

The recognition that national parks cannot operate as islands separate from their surroundings has resulted in greater efforts to cooperate with other agencies to solve natural resource problems. This is especially true in areas where adjacent lands are managed by other agencies. Fire management research, for example, has a long history of interagency scientific cooperation. Because of the unique needs of land management agencies in controlling, predicting, and understanding the behavior and effects of fire, there has been considerable cooperation between NPS and Forest Service scientists. Although research information can be integrated through such forums as annual conferences, land managers do not always use the available information in their decision making. Other examples of interagency research integration include studies to support grizzly bear recovery (with U.S.

COOPERATIVE PARK STUDY UNITS

An important mechanism for NPS to obtain research information is the cooperative park study unit (CPSU). As of May 1992, there were 23 functioning CPSUs across the country. CPSUs are located at institutions of higher learning with which the NPS has cooperative agreements to facilitate research and provide technical assistance to the parks. The CPSUs were established to create a mechanism for better access to current scientific information and expertise. The park service scientists act as liaisons to enlist faculty and graduate students to conduct research needed by the parks.

Under the cooperative agreements, each CPSU has a resident scientist responsible for administering the operations of the unit. This person is usually an NPS scientist, but in some cases is a university faculty member, a portion of whose salary (at least 20 percent) is paid by the NPS. CPSUs typically are responsible for providing research and technical support to several parks within a geographic region. In some cases this means all of the park units in a state (e.g., the CPSU at University of California-Davis serves all of the parks in California). In other cases this means the CPSU is responsible for all parks in a biogeographic province (e.g., the CPSU at Northern Arizona University serves all parks on the Colorado Plateau). CPSUs generally report to the regional chief scientist in the regional office. The first CPSU (University of Washington) was established in 1972. The network continues to grow as research demands and funding allow.

NPS Cooperative Park Study Units, May 1992

Clemson University
Colorado State University
Northern Arizona University
Oregon State University
Pennsylvania State University
State University of New York-Syracuse
Texas A&M University
University of Arizona
University of California at Davis
University of Georgia
University of Hawaii
University of Idaho
University of Maine
University of Minnesota
University of Nevada-Las Vegas
University of New Mexico
University of Rhode Island
University of Tennessee
University of Virginia
University of Washington
University of Wisconsin
University of Wyoming
Virginia Tech University

Forest Service and U.S. Fish and Wildlife Service); studies of the spotted owl (with U.S. Forest Service, U.S. Fish and Wildlife Service, Bureau of Land Management); and studies of exotic species management in Hawaii (with U.S. Fish and Wildlife Service).

The most effective method of integrating research with other programs is through multiple year programming, combined with daily coordination of programs to allow continuous interaction among the officials involved. There is some danger of losing integration of programs where park scientists report to regional scientists, and some observers fear that research activities might become estranged from individual park needs. Far more difficult, however, is the integration of research programs with service programs, such as planning, design and construction, and interpretive design and production. For example, the geographic information system is a sophisticated data-gathering unit that is not fully exploited, and the computer systems in use in different areas are not compatible for transfer of data.

PERSONNEL

In theory, the NPS conducts research using its own staff scientists stationed in the parks, in science centers, and in regional offices; in cooperation with university scientists associated either with cooperative park study units or under other cooperative agreements; in cooperation with other government agencies; or through competitively negotiated contracts. In practice, only a few parks employ enough research scientists to have a research division or center on site. The South Florida Research Center in Everglades National Park Field Research Laboratory and the research divisions in Yellowstone and Glacier national parks are among the few examples. Some parks have one or two full-time employees dedicated to research, but most parks have no in-house research staff at all.

The Park Service maintains a smaller research staff than is found in most other federal land management agencies. For fiscal year (FY) 1987, NPS employed about 286 researchers and research administrators, or about 2.3 percent of its

PERSONNEL CLASSIFICATIONS

Most positions in the NPS are assigned grade and pay scale using standard government classification schedules. The grades for these jobs, which include ranger and resource management positions, are determined by the duties listed in job descriptions. Promotion and advancement comes mostly through transfer to other positions, typically elsewhere in the NPS.

The research grade evaluation (RGE) is a special classification system for use in properly determining the grade and pay for federal employees involved in natural science research activities. It is a peer evaluation system and has as its basic tenet the belief that peer-reviewed scientific publications are the best measure of the accomplishments and scientific contribution of any researcher.

Under the RGE system, a researcher can enter federal employment at GS-11 or GS-12 and through successful research and publication advance over his or her career to GS-15 or higher, much the same way that academic researchers advance through the ranks within a university tenure system. Advancement rests on the scientific accomplishments and documented professional reputation of the individual researcher. The system was created to improve the ability of the federal sector to recruit and retain competent scientists. Scientists are not forced to transfer to a new job to get a promotion.

Closely related is the grants grade evaluation, which is used to determine the proper grade and pay for those scientists involved primarily with research administration (e.g., regional chief scientists) rather than with the conduct of original research.

12,475 permanent employees. In comparison, in 1989 the U.S. Fish and Wildlife Service employed 509 scientists, about 9.3 percent of its 5,471 permanent staff (NPCA, 1988a). In 1987, the NPS natural science staff included 73 scientists classified under the research grade evaluation located primarily in the parks, 22 employees who conducted some research within a resource management context, and 20 research administrators. The NPS cultural research staff included 114 archaeologists, 4 cultural anthropologists, and 29 research historians (NPCA, 1988a). Critics argue that inadequate staffing is a serious problem, and that it is compounded by inefficient use of personnel—such as the diversion of scientists into resource management and nonresearch administrative tasks.

They also argue that limited staffing prevents the NPS research program from becoming more long-term oriented.

> A limited staff with inadequate support can only deal with immediate "brush fire" problems; that is to say, it can only deal with situations which have already become critical and perhaps irreparable. A research staff adequate in competence and numbers can conduct research from long-term considerations, detect problems before they become critical and offer alternate choices of action for their solution (NRC, 1963).

Although resource management staff members are closely involved in the scientific aspects of park operations, there are two job categories designed specifically for scientists in the NPS: research grade scientists and grants grade scientists (Table 4-1). Research grade scientists are required to spend at least half of their time on publishable research activities for the benefit of the park system. They are subject to evaluation every four years, and they include most of the scientists stationed in parks, many of the scientists in the cooperative park study units, and a few regional office scientists. The position is similar to a tenure track faculty position in a university.

Table 4-1 Research and Grants Grade Scientists; May 1992

	Research Grade	Grants Grade
Alaska	6	1
Mid-Atlantic	1	1
Midwest	8	4
National Capital	5	1
North Atlantic	8	1
Pacific Northwest	7	2
Rocky Mountain	17	2
Southeast	13	3
Southwest	1	3
Western	15	1
Washington office	8	0
Total	89	19

SOURCE: NPS, 1992.

Grants grade scientists spend most of their time supervising and administering the research of others. These employees also have a separate evaluation procedure. The grants grade currently includes the regional chief scientists, some cooperative park study unit leaders, and one park scientist. These positions correspond to department chairs and administrative officers at a university.

Although many researchers and park managers acknowledge the benefits of the special evaluation system, it is not without problems. Current lines of authority in the NPS often put research scientists between two masters. On one hand, they must conduct their science in a way professional enough to succeed under the research grade evaluation. On the other, they must succeed in the eyes of their superintendents, who are necessarily focused on immediate management problems. The research grade evaluation sets standards that require attaining national and, at the highest level, international reputations. Yet conversations with NPS staff in numerous forums indicate that internal pressures born of their ties to management lead them to stay in the parks and forgo participation in national and international professional meetings and other normal activities of science. Superintendents and park staff sometimes see the emphasis on publishing as decreasing a scientist's contributions to solving park problems. This puts the scientist in the position of working primarily on short-term applied problems but being expected to produce longer term, more basic research products to achieve promotion. NPS scientists who try to balance these demands often end up doing management-focused, applied science and thus they have difficulty attaining the upper levels of the research grade. Too often, scientists seem to spend more time trying to deal with the system than they spend in the productive pursuit of stated research goals. This has encouraged some good personnel to leave the NPS for other agencies and organizations more conducive to science.

RESEARCH BUDGETING

The formulation of the NPS budget is a complex process that involves interactions among park superintendents, re gional directors, the director, the secretary of the interior, the Office of Management and Budget, and both houses of Congress (National Audubon Society, 1986). In general, budget needs are first identified in the 361 park units, then molded into requests from the 10 regional offices, and then finalized by the Washington office. General management plans and natural resource management plans in individual parks often guide the determination of priorities. Budget planning is guided at the national level, but regions and parks have considerable discretion in the ultimate allocation of funds. The annual budget call focuses on the most urgent management priority at each level, often at the expense of long-term, basic research. The parks identify their most urgent needs; the regions add their current needs and then rank all these needs before sending them on to Washington. The budget office in Washington then must evaluate approximately a billion dollars' worth of requests and formulate coherent groupings of requests to be sent to the director. The entire process takes 6 to 10 weeks.

The structure of the NPS budget makes it difficult to determine how much the Park Service spends specifically on research because research is not identified separately. It is difficult even to define precisely what constitutes a "science" expenditure, because the line between research and resource management is often indistinct. Some activities called "research" or "science" actually are resource management, and, conversely, some resource management funding might be more properly classified as going to research or science. Numerous resource management activities undertaken in the field by park rangers often are classified as visitor protection.

Most NPS funding is combined into one legislative appropriation, called "operation of the National Park Service," or ONPS. (The total NPS appropriation is a larger figure that includes additional, specially earmarked funds assigned by Congress.) Within that appropriation nearly 90 percent of the funds are set aside for one activity, park management. Subactivities within the park management category include management of park areas, maintenance, visitor protection, interpretation and visitor services, park police, information and publications, international park affairs, volunteers-in-the-parks programs, and resource management. Most research and science funding for the natural sciences will be included under the natural resource management section of the budget. For FY 1992, the ONPS appropriation was $953.5 million, of which about $92.7 million was for natural resource management (Table 4-2). In recent years, the aggregate annual budget for all natural resource activities has been between 5.7 percent and 6.7 percent of the total ONPS appropriation.

Although the NPS budget structure does not list research funding separately, the NPS estimates that it grew from $18.5 million in FY 1987 to $29 million in FY 1992 (Figure 4-3) (NPS, 1992). Although the sources of the numbers in Table 4-2 and Table 4-3 differ and thus make comparisons difficult, the $29 million devoted to research and development in FY 1992 would be about 3 percent of the total $953.5 million ONPS appropriation. The Park Service's budget for scientific research is often contrasted with the budgets of other federal land management agencies (Figure 4-3). For example, in FY 1987 the Forest Service spent $122 million for research, or 5.6 percent of its budget (this does not include substantial administrative studies which would be comparable to management-oriented research in the NPS); the Fish and Wildlife Service spent $53 million for research, or 8.7 percent of its budget (NPCA, 1988a).

Another problem arises from the NPS budget structure. Even though funds are appropriated for research, they can be moved to other activities by regional directors and park superintendents. Again, the system forces emphasis on only the most urgent, short-term priorities. No system exists to track research or ensure that research funding actually funds research.

Various organizations also have attempted to estimate science funding in the NPS. A 1986 conference on science in the national parks estimated that the NPS used about $15 million for science annually. The National Parks and Conservation Association estimated that the service's natural science program cost $11.1 million in FY 1980 and $13.4 million in FY 1987 (NPCA, 1988a). Most of these analyses conclude that the NPS's modest increases in funding for science and natural resource management over the past two decades have not kept pace with the expansion of the park system and the accelerating need for information to protect threatened natural and cultural resources. The lack of a specific allocation for research and the absence of a legislative mandate calling for research often are cited as the reasons for the historically poor funding status of research within the NPS.

There have been many calls for increased funding for the parks, especially for increased research and science funding. The Park Service itself clearly recognized the need for more science funding in its 1988 document "Natural Resources Assessment and Action Program." This report identifies $250 million to $300 million of unfunded natural resource projects from the parks' five-year plans. The Conservation Foundation, in its report "National Parks for a New Generation" (Conservation Foundation, 1985), recommended a $50 million annual program for natural and cultural resources management. The National Parks and Conservation Association report "Investing in Park Futures" (NPCA, 1988b) identified a $522 million backlog of needs and recommended a $50 million increase in natural science funding.

In 1988, the National Parks and Conservation Association published a multivolume analysis of park needs. Volume 2, "Research in the Parks: An Assessment of Needs," (NPCA, 1988a) recommended that Congress earmark 10 percent of the annual appropriation solely for research. These line item funds would be devoted to servicewide research projects, regional and park research, resource inventories and monitoring, and emergency needs. Based on a FY 1990 operating program budget of $785 million, this would mean about $80 million designated for research.

In 1990 the National Fish and Wildlife Foundation report "FY 1991 Federal Agency Needs Assessment" (NFWF, 1990) recommended substantial increases for science and natural resource management in the parks. The report recommended that staff levels and expertise be increased in the parks (adding $1.8 million and 40 full-time positions for each of the next five years), that regional science programs be strengthened (adding $666,000 and 10 full-time staff positions), and

Table 4-2 Natural Resource Operations Budget Historya

Appropriation/Activity/ Subactivity	FY 1987 $000	FY 1988 $000	FY 1989[b] $000	FY 1990 $000	FY 1990 $000	FY 1991 $000	FY 1992 $000
Total NPS Appropriation[c]	956,980	960,004	1,077,926	1,139,755	1,112,447	1,377,905	1,387,168
ONPS Appropriation	705,981	730,799	744,835	778,419	767,804	876,699	953,498
ONPS/Park Management							
Park Operations Program[d]			29,054	33,227		34,898	42,254
Regional Programs			11,069	12,074		14,931	16,825
Natural Resources Preservation Program[e]			6,971	7,721		9,340	9,668
Inventory and Monitoring[e]			660	660		660	1,883
Air Quality			5,204	5,204		5,300	5,699
Servicewide Program Support			3,082	3,128		3,137	3,368
Mining and Minerals			1,466	1,511		1,518	1,563
Acid Rain			1,230	1,230			
Geographic Information Systems			561	572		1,500	2,069
Fire Management (transferred in FY 1991)			452	467	461	0	0
Global Climate Change						1,900	2,610
Oil Spill Pollution Act							987

Appropriation/Activity/ Subactivity	FY 1987 $000	FY 1988 $000	FY 1989[b] $000	FY 1990 $000	FY 1990 $000	FY 1991 $000	FY 1992 $000
Natural Resources Management Subtotal	55,908	60,443	59,749	65,794	64,923	74,284	86,926
Less Fire Management[f]	55,435	69,991	59,297	65,327	64,462		
ONPS/Park Recreation and Wilderness Water Studies	2,909	3,036	3,032	2,929	2,889	4,000	5,754
Total ONPS Natural Resources	58,344	63,027	62,329	68,256	67,351	78,284	92,680
Natural Resources as % of ONPS	8.26	8.62	8.37	8.77	8.77	8.93	9.72
Natural Resources as % Total Budget	6.10	6.57	5.78	5.99	6.05	5.68	6.68

SOURCE: NPS, 1992.

[a] The "operations" budget excludes the National Natural Landmarks Program.

[b] In FY 1989, total ONPS reduced by portion of unspecified $3 million decrease from FY 1988; figures provided do not reflect this decrease.

[c] Reflects supplementals, recisions, and transfers, so may differ from other "enacted" figures.

[d] Includes recent park-specific line item increases for Yellowstone fire research, grey wolves studies, and for operation of new and expanded parks.

[e] In some years, NRPP and Inventory and Monitoring shown as combined in budget justification.

[f] Removed from analysis of percent of total budget so consistent figures compared.

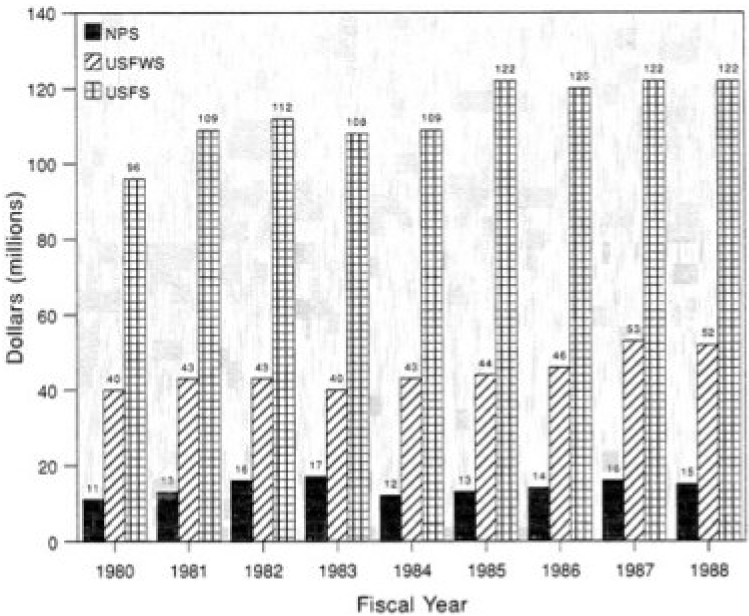


Figure 4-3
Annual research budgets of National Park Service, Fish and Wildlife Service, and Forest Service. SOURCE: National Park Service/U.S. Fish and Wildlife Service/U.S. Forest Service.

that regional natural resource management programs be established and funded at $10 million annually.

CONCLUSION

A critical reason for conducting research in the national park system is to provide managers with the information necessary to make better decisions about the resources for which they are responsible. Research also is important to help park personnel better interpret the features of their areas and for helping managers cope with ever-increasing numbers of visitors. The connections between resource management, interpretation, and research are critical. There is still a need for more attention to synthesis—transforming data into information—as it is part of the scientific process to interpret

Table 4-3 National Park Service Research and Development

FY	FUNDING
1987	$18,500,000
1988	$18,800,000
1989	$19,200,000
1990	$19,500,000
1991	$25,200,000
1992 (estimated)	$29,000,000

SOURCE: NPS, 1992.

the meaning of data, to show what the research means in relation to management questions.

The 1980 NPS report to Congress concluded that 75 percent of the 4,345 threats to the units of the national park system were inadequately documented by research. The report stated that "current levels of science and resource management are completely inadequate to cope effectively with the broad spectrum of threats and problems" facing the parks, and it concluded that NPS must "significantly expand its research and resource management capabilities" (NPS, 1980).

Overall, based on its review and discussions with NPS officials, the Committee on Improving the Science and Technology Programs of the National Park Service found much to be admired, much to be added or expanded, and very little to be eliminated from the current NPS science program budget. Some research has resulted from political crises, with funding and direction from Congress to solve or mitigate the problems. Some has happened only because of the energy and enlightened advocacy of individual managers or scientists to obtain the funds or staff needed for the research. Yet for every such example of good research leading to a problem's solution, there are dozens of park units for which the needs are not yet recognized and the research not sought because of a lack of awareness at the park level and a vacuum of direction and funding support.

Although the committee sees an obvious need for greatly expanded science funding and personnel allocations, addi

Research is necessary at all types of parks— whether the units are dedicated to the protection of natural, historic, or cultural values. CREDIT: NPS photo of Mesa Verde National Park by Jack Boucher.

tional funding alone is not enough. NPS research needs its own leadership and budget allocation and tracking system that is on a par with and independent from other major program elements of the NPS budget, such as management, maintenance, and visitor protection.

Closely allied with the budget process is planning. In particular, the resource management planning process is an important in determining research needs. The involvement of scientists in the preparation of resource management plans varies significantly among different parks and regions. Yet active participation from scientists is an ideal way to ensure that research truly supports resource management. Conversely, the process of developing and updating resource management plans can be used as an increasingly important vehicle for research planning. Research objectives for the parks need to be clearly stated, administrative procedures outlined, and systems established for ranking the projects, evaluating the science, and archiving and managing data. Care must be taken that both short-term and long-term perspectives are incorporated, including presentation of long-term priorities directed toward ecosystem understanding and compatible management of human use and enjoyment. This fuller participation puts additional demands on research staff already spread thin among varied responsibilities, so it will be necessary to find new ways to increase the research-planning component in the preparation of resource management planning.

Questions about the effectiveness of science in park management have been raised throughout the history of the NPS. Again and again, park personnel, advocacy groups, and independent evaluators have reached the conclusion that the NPS's science and research programs are not meeting management needs. Yet if it is so easy to identify the deficiencies in the science program, why is it so difficult to change or restructure the program to eliminate the problems and truly increase its effectiveness? Why is there controversy among NPS personnel about the role of science? Have the stewards of some of the nation's most precious resources become so engulfed in the flames of short-term crises that they believe they cannot afford long-term vision? Are they inhibited by structure or by culture from using research to its full potential?

5

A New Mandate for Science in the National Parks

In its 1963 assessment of science in the national park system, the National Research Council stressed the critical need for a strong research program in the parks. Today, nearly 30 years later, that need still remains:

> A permanent, independent and identifiable research unit should be established within the National Park Service to conduct and supervise research on natural history problems for the entire national park system. In order to maintain objectivity, the principal research organization should be independent of operational management.... The research staff should have complete freedom in the execution of an approved research program, in evaluating the results, in reporting the findings and in making recommendations based on the findings. (NRC, 1963)

The National Park Service (NPS) science program has been unnecessarily fragmented, and it has lacked a coherent sense of direction, purpose, and unity. The lack of consistency over time—especially with regard to leadership from the Washington office—has impeded the success of science programs and thus has made park management less effective. Strong leadership is necessary for the long-term stewardship needed to protect the parks for future generations. The NPS should be forward looking and progressive in using science as a management tool. Science needs to be integrated fully into all Park Service functions, and the administrative framework should allow coordinated, effective research programs at the national, regional, and individual park levels.

The call for change made in this report is not new. But given the consistent lack of response to so many previous calls for change, how can this report inspire action? The Committee on Improving the Science and Technology Programs of the National Park Service concludes that increased funding or incremental changes alone will not suffice, and it calls instead for a significant metamorphosis. It is time to move toward a new structure—indeed, toward a new culture—for science in the national park system that guarantees long-term financial, intellectual, and administrative stability. Given that culture can be defined as a complex of beliefs, values, ideas, tools, and skills perpetuated by a group of people, such a change will be difficult and require concerted attention. Three elements are vital:

- There must be an explicit legislative mandate for a research mission of the National Park Service.
- Separate funding and reporting autonomy should be assigned to the science program.
- There must be efforts to enhance the credibility and quality control of the science program. This will require a chief scientist of appropriate stature to provide leadership, cooperation with external researchers, and the formation of an external science advisory board to provide continuing independent oversight.

AN EXPLICIT LEGISLATIVE MANDATE FOR SCIENCE

To eliminate once and for all any ambiguity in the scientific responsibilities of the Park Service, legislation should be enacted to establish the explicit authority, mission, and objectives of a national park science program.

As described in Chapter 3, numerous experts both inside and outside of the Park Service have provided advice about the importance of the science program. There is a remark

The National Park Service's scientific responsibilities should be made clear and unambiguous so that advantage can be taken of the best scientific information in protecting its valuable resources. CREDIT: NPS photo of Nebesna Glacier at Wrangell-St. Elias National Park by M. Woodbridge Williams.

able consistency, both in spirit and in detail, in their recommendations. Yet few of the recommendations have been implemented, to the detriment of park resources. Some of the difficulty arises from the chronic limitation of resources and the ever-increasing demands on the parks. The leadership in the NPS science program and personnel in key positions have changed frequently. Also, the NPS has not given science a stature equal to that of resource management, perhaps because it is easier to focus on the immediate at the expense of the long term—a tendency that is exaggerated when budgets are limited. Finally, the NPS has been inconsistent in distinguishing strong from weak science, thereby damaging the credibility of science in the eyes of park staff and others (NRC, 1990). As a result, the NPS science program has contributed far less than it can and should. Its full potential lies largely untapped just when science is most needed to clarify and combat the enormous pressures the parks face, and just when the parks are most needed to help address research questions that affect the entire biosphere.

Specific calls for science are included in the enabling legislation for several individual parks. Examples include Redwood National Park, where restoration activities are required to be based on sound science; Channel Islands National Park, where the long-term effects of adjacent kelp harvesting must be monitored; and Everglades National Park, where the NPS is required to study the fisheries of the Florida Bay. There also are national laws that either state or imply the need for adequate scientific and technical knowledge to address the kinds of actions required. Among the most important are the Lacey Act (1900), Historic Sites Act (1935), the Wilderness Act (1964), the Concessions Policy Act (1965), the National Environmental Policy Act (1969), the Endangered Species Act (1973), and the Clean Air Act (1977). In addition, international programs in which NPS participates also have helped define the scope of NPS science, including the Man and the Biosphere and the World Heritage programs (Franklin, 1985).

Despite these periodic calls for science, the most critical foundation for science in the parks is missing: Although the Organic Act of 1916 implies the need for science in the national parks, it does not provide an explicit legislative mandate. The absence of an explicit legislative mandate has allowed uncertainty about the importance and the role of science in the parks. A new mandate for science is long overdue.

The committee was not charged or constituted to write specific legislation to establish a new mandate for science in the parks, but its vision for a strengthened NPS science program includes the following elements:

- A science program that is organizationally equivalent to park operations, with its own funds in a separate line item budget, to support a comprehensive program of natural and social science.
- Areas in the national park system designed and managed as protected repositories of biological diversity at the genetic, species, and ecosystem levels.
- Broad use of parks as research sites, with expanded opportunities for experimentation and research installations, and as monitoring posts to detect and evaluate changes in environmental quality, plant and animal communities, and

the human environment, perhaps with special research areas designated within some parks.

- Cooperation with other agencies and institutions in designing, conducting, evaluating and reviewing scientific studies, including those that will characterize and enumerate park resources and aid the development of effective management practices.
- A leadership role for NPS in sharing the results of scientific studies with researchers in government, academic, and private organizations.
- Continuing scientific communication with park managers and scientists in other countries.
- Translation of scientific findings, wherever feasible, into information for the public and into effective guidance for resource managers and interpreters.

Science for the Parks

The National Park Service should establish a strong, coherent research program, including elements to characterize and gain understanding of park resources and to aid in the development of effective management practices.

A new NPS mandate for science should encompass two distinct but related components, which this committee calls for convenience "science for the parks" and "parks for science." Each component offers contributions critical to the stewardship of park resources, but the first approach—science for the parks—is the most obviously related to the NPS mission to conserve the scenery and the natural and historic objects and the wild life therein and leave them unimpaired for the enjoyment of future generations. Science for the parks encompasses two types of research: research to characterize and gain understanding of resources, and research to develop and implement effective management practices. These two areas are interdependent; that is, the search for sound resource management techniques cannot occur without careful characterization and understanding of those resources. Conversely, the design and conduct of research and moni toring to characterize resources can be guided by questions about how the resources are to be managed. Both types of research should be conducted by NPS scientists, scientists from other agencies, and university scientists.

Research to Gain Understanding of Park Resources

To provide a scientific basis for protecting and managing the resources entrusted to it, the Park Service should establish, and expand where it already exists, a basic resource information system, and it should establish inventories and monitoring in designated park units. This information should be obtained and stored in ways that are comparable between units, thereby facilitating access, exchange, integration, and analysis throughout the park system and with other interested research institutions. The NPS should support and develop intensive long-term, ecosystem-level research projects patterned after (and possibly integrated with) the National Science Foundation's Long-Term Ecological Research program and related activities of other federal agencies. The ways resources are used and appreciated by people should be documented.

It is dangerous to attempt to manage and protect resources that are not understood (Leopold et al., 1963). Most parks lack long-term information bases from which to determine park resource conditions, trends, and relationships, and there is no reliable way to determine whether vital park resources are, in fact, surviving or will survive to become part of the heritage of future generations. Without a basic knowledge of the resources and an ability to detect change, scientists cannot reliably identify or forecast problems, and neither park managers nor regulatory officials can be expected to mitigate threats effectively. Under these conditions, the ability of the NPS to accomplish its basic mission is at serious risk.

Natural disturbances, including processes of birth and death, long-term successional changes in ecosystem development, and climate change are characteristic of natural sys tems both inside and outside of the national parks (Wright, 1974; Pickett and Thompson, 1978; Dolan et al. 1978; White and Bratton, 1980). Because parks are not static islands impervious to human and natural influence—the effects of human populations and their activities now permeate even the most remote wilderness areas—sound park management for the future requires us to identify and understand causes of change where possible. Although it will be impossible to understand all of the causes of change in the parks, their adequate study is fundamental to the protection of resources.

Research to characterize park resources is frequently long-term and basic. It includes inventories, monitoring, and long-term analyses that involve a range of disciplines such as geology, hydrology, atmospheric sciences, archeology, biochemistry, botany, zoology, and ecology. Comprehensive research examines the structure and function of organisms, populations, communities, ecosystems, and landscapes, as well as soil, groundwater, air, and other elements of the physical and social environment (Romme and Knight, 1982; Knight and Wallace, 1989). Furthermore, many natural resources are influenced by forces that themselves vary through time (such as climate) or that undergo systematic change.

As an absolute minimum, the NPS science program must include an inventory and monitoring of resources to provide a basis for detecting change. An inventory involves enumerating or mapping resources and assessing their status; monitoring involves repeated measurements to detect variations over time. Inventories and monitoring assess the spatial and temporal distributions of resources and patterns of human use.

Inventories and monitoring provide the foundation for analyzing most applied resource management questions, and they can help elucidate the normal limits and variations of systems and establish a baseline for later comparisons of trends. Every element of a system, whether natural, cultural, or human, can change, and all long-term management plans must address the detection of change. Short-term monitoring, for example, is needed to detect changes caused by visitors at campsites, the effects of exotic species, and the impacts of sport fishing in various parks. Longer term inventories and monitoring in support of management include using long-term ecosystem research to assess air quality and long-term population monitoring of wildlife. Such efforts are especially necessary in large areas of relatively pristine wilderness such as the parks designated as Biosphere Reserves. The commitment to inventory and monitor resources must be expanded dramatically to become a major, continuing component of the NPS research program. Effective inventories can involve geographic information systems, remote sensing data, and other technology (including new technologies for information storage, processing, and management) to increase understanding of whole ecological systems.

To be useful, an information system should contain basic data about the location and extent of each parks principal biological, geological, hydrological, aesthetic, cultural, and historic resources. When park managers need additional information critical to carrying out the designated mission of a park, for example, to protect specific archaeological or cultural resources, monitoring data on those resources or human use impacts should be added to the system. The specific requirements for what is to be included in the system and protocols for its measurement should be developed and overseen by senior NPS scientists and resource managers to ensure national consistency, provide clear priorities for the most important needs, and ensure that the programs are of the greatest possible regional and park-specific use. Peer review should be a routine ingredient in these activities.

Research to Support Park Management Goals

> **National Park Service researchers should have more input into the development of resource management plans. Effective interaction between research results and resource management plans cannot take place without both a strong science program and a strong resource management program.**

Research to support management of the parks typically addresses the identification, assessment, and mitigation of threats to park resources. Examples of management-oriented research include studies designed to gain understanding of and minimize damage caused by visitors, exotic species, water-and airborne pollutants, and other external disturbances. Management-oriented research also focuses on protecting scenic values, rare species, and biological diversity. Research might also address the restoration of natural processes and ecosystems, as well as the analysis and mitigation of transboundary problems.

In addition to management-oriented research in the biological and physical sciences, there are equally important issues to be addressed by the social sciences. For example, research should focus on increasing understanding of visitors and their experiences; the social organization and processes that influence visitors' behavior in a park setting; local communities and the social, political, and economic factors that link them to the park; and the interdependence of human and biological systems. There is almost always a direct connection between natural and cultural resources in parks. Because of the complexity of the parks and the interactions between the physical and human dimensions, a broad scientific scope and an interdisciplinary approach are necessary to guide the NPS science program.

Management-oriented research is usually designed to help managers choose among alternatives for action such as those presented in a park's resource management plan. This research is often highly applied and frequently short term (one to three years), but it often demonstrates that longer term studies and monitoring are required to properly address major park management questions. Well-designed short-term studies can provide the foundation for longer term, larger scale research within programs of coordinated studies designed to build accumulated knowledge.

The relationship between research and resource management plans must be interactive. If their understanding of a management issue is limited, scientists and managers might be unable to articulate research needs specifically. As knowledge expands from research, further research questions become clearer; in addition, as management programs are carried out, the validity of the underlying assumptions of resource management plans and the success of management actions themselves can be tested through research. Data properly collected for these purposes will thus allow park managers to evaluate and refine resource management plans as they are updated. This interactive process, achievable only through a consistent, long-term, integrated research program, is necessary if the management of the parks is to become more anticipatory.

Science can support better park management only with communication, understanding, and mutually supportive working relationships between park scientists and park managers. In such relationships, scientists recognize that managers often are compelled to make decisions without the benefit of adequate analysis and will therefore need advice based on the best current scientific information or on the preliminary results of continuing studies. Managers recognize that current research findings can be limited by the lack of baseline data and that this lack of information itself hampers the quick derivation of clear and short-term results.

Most management-oriented scientific studies are designed to be used by managers. Therefore, it is crucial that managers and scientists develop resource management plans cooperatively. This is not routinely done, which severely limits the constructive interaction between research results and resource management plans, and thus weakens both the science program and the resource management program.

Parks for Science

The National Park Service should establish and encourage a strong "parks for science" research program that addresses major scientific questions, particularly within those parks that encompass large undisturbed natural areas. This effort should include NPS scientists and other scientists in independent and cooperative activities. The goal is to facilitate use of the parks for appropriate scientific inquiry on major natural and related social science issues.

As the steward of some of the nation's greatest natural ecosystems and cultural and historical treasures, the NPS manages resources that are critically important to the nation's scientific community. Because the parks contain many areas that are relatively unaltered by human activity, and because there is commitment to their long-term protection, the parks are increasingly important to scientific investigations of larger environmental problems. The parks are invaluable for unraveling the mysteries of natural and human history, evolutionary adaptation, ecosystem dynamics, and other natural processes. They also serve as reservoirs of biotic diversity, as refuges for species threatened by human activity, and as valuable sources of baseline information for comparison with human-altered ecosystems.

One major challenge to the scientific community in general (and park managers as well) is to distinguish anthropogenic change from natural variation in biological and hydrological processes. For example, there is considerable year-to-year variation in the population of many animal species. Some is caused by natural events and cycles; in other cases the causes are attributable to anthropogenic changes in land uses that affect the availability of food and shelter and the quality of habitat. Research in relatively large park areas, where human impacts are less prevalent, provides scientists with some of the best opportunities to study natural variations and the effects of human activity.

The scientific value of park resources in the future is impossible to calculate. Only two decades ago, for instance, the processes that cause acid rain and diminishing stratospheric ozone were unknown. We cannot know what questions will demand attention two decades from now, but it is possible to make educated guesses given enough information. Research on the rates of primary production and decomposition of organic material, the numbers of key species and the general diversity of species, and soil conditions are all essential. Measurements of species over large areas (so natural spatial variation can be evaluated) and over long periods are needed to elucidate trends. Although all parks have been affected by human influences, some dramatically, measurements made where human effects are relatively minimal, such as in parks and other protected areas, serve as a control against which scientists can measure the effects of human activities. The 39 million acres of designated Wilderness and additional areas proposed for wilderness classification within the national park system are especially valuable in this regard (Hendee et al., 1990). The international scientific significance of U.S. national parks is recognized in the designation of more than 30 NPS units as Biosphere Reserves and World Heritage Sites. In terms of scientific value, these sites are among the world's premier natural and historic areas (Table 5-1).

Parks can contribute to the advancement of science and to the understanding of regional and global environmental change. Sometimes, the parks provide truly unique conditions for study. Obviously, the potential for parks to contribute to the basic understanding of natural processes is enormous, yet this potential has not been adequately developed. Support for the idea of parks for science has suffered the same fate as has support for science for the parks—far less has been done than should be expected given the vast potential. Relatively few examples of securely funded, long-term, basic ecological research on questions of national and international importance exist within the national park system.

A parks for science research program should have as a basic tenet encouragement of externally funded research that complements ongoing park research and will aid in generating a useful data base. Although parks for science research often is funded by extramural sources and often is conducted by university researchers, NPS scientists also should be allowed to devote some of their professional time to this pursuit. A basic research component within the NPS science program will aid the professional growth of NPS scientists and will benefit the management-oriented science program.

The establishment of a strong parks for science program will strengthen, not diminish, the importance of management-oriented research. Indeed, given that financial resources will always be limited, it is expected that most NPS funding for science will be devoted to management-oriented research. It also is expected that the results of parks-for-science research and the sharing of information with external researchers will, in fact, often aid park management. But regardless of its management value, parks-for-science research should be en

Table 5-1 NPS Units Recognized for their Natural Resource Values as Part of UNESCO's International Network of Biosphere Reserves, as World Heritage Sites Under the World Heritage Convention, or as Wetlands of International Importance Especially as Waterfowl Habitat Under the Ramsar Convention

Park Unit	Biosphere Reserve	World Heritage	Ramsar Convention
Big Bend NP	X		
Big Thicket N. Preserve	X		
Cape Lookout N. Seashore	X[a]		
Channel Island NP	X[a]		
Congaree Swamp N. Monument	X[a]		
Cumberland Island N. Seashore	X[a]		
Death Valley N. Monument	X[a]		
Denali NP	X[a]		
Everglades NP	X[b]	X	X
Gates of Arctic N. Pres.	X[c]		
Glacier NP	X		
Glacier Bay NP	X[a]		
Golden Gate N. Recreation Area	X[a]		
Grand Canyon NP		X	
Great Smoky Mountains NP	X[a]	X	
Haleakala NP	X[a]		
Hawaii Volcanoes NP	X[a]	X	
Isle Royale NP	X[a]		
Joshua Tree N. Monument	X[a]		
Mammoth Cave NP	X	X	
Noatak N. Preserve	X[a]		
Olympic NP	X	X	
Organ Pipe Cactus N. Monument	X[a]		
Point Reyes N. Seashore	X		
Redwood NP	X	X	
Rocky Mountain NP	X[a]		
Sequoia and Kings Canyon NP	X[a]		
Virgin Island NP	X		
Yellowstone NP	X	X	
Yosemite NP	X	X	
Wrangell-St. Elias NP[d]	X	X	
Number of NPS Units	30	10	1

[a] Part of a biosphere reserve including other administrative units.
[b] Includes Fort Jefferson NM.
[c] Part within Noatak Watershed only.
[d] Part of binational Wrangell-St. Elias NP (US) and Kluane NP (Canada).

couraged because its contributions to society in general are potentially great. Thus appropriate experimentation and research installations should be allowed. This will not jeopardize park resources as long as policies and regulations to guide the selection of permissible research are adhered to strictly. In fact, the designation of special research areas within parks could help ensure their scientific value.

As change throughout the world accelerates, as park data bases are developed, and field research facilities are expanded, the value of parks for science appreciates beyond measure. The national parks have not played a role in regional, national, and international science commensurate with their value.

SEPARATE FUNDING AND AUTONOMY

Organizational Change

The National Park Service should revise its organizational structure to elevate and give substantial organizational and budgetary autonomy to the science program, which should include both the planning of research and the resources required to conduct a comprehensive program of natural and social science research. The program should be led by a person with a commitment to its objectives and a thorough understanding of the scientific process and research procedures.

Many of the deficiencies of the NPS science program have been caused by organizational difficulties, including the balkanization of the science programs in the 10 regions to the extent that there is little consistency or synergy among them. Quality control has been uneven, at best, and research plans and products are not routinely subjected to adequate peer review. Some of the strongest scientists in the external research community do not participate in the NPS science program, administrative processes designed to facilitate research (especially via extramural projects) have been cumbersome, and research policies and procedures have been inconsistent and frequently dependent on the predilections of individu als in key positions. Managers and scientists have not worked cooperatively or with a sufficient understanding of each others' goals and needs. Overriding this litany of difficulties is that too few resources have been available to meet the research needs of the parks.

It is tempting for the committee to systematically propose some solution to each of these problems. However, because the NPS, like all organizations, has a unique culture, specific solutions to each of these problems are best determined from within. Overall, however, it is clear that organizational change and strong leadership are necessary. To develop a strong, independent science program, the NPS should create a separate line of authority for the science program that is generally equivalent to the resource management program. To facilitate the change in direction, the committee recommends the following:

- Science administrators should be appointed at all levels of the organization (in the Washington office, in the regions, and in key parks). They should have program and budget authority equal to that of the administrators of other park functions, such as operations or administration.
- All supervisory scientists in field offices (including cooperative park study units, science centers, and park science programs) should report to a chief scientist at the regional level. In general, scientists in parks should report to scientists, either at the parks or in the regional offices. Scientists would still be expected to work cooperatively with superintendents, resource managers, and other park staff.
- To allow for both science-for-parks and parks-for-science research, increased funding and more organized, multiple year planning will be needed in individual parks, in the regions, and at the Washington office. Within the parks and regions, science programs and activities should be planned in conjunction with the adoption and revision of general management plans and resource management plans. Initiatives of national or international scope—programs on biological diversity, air quality, water quality, the use and enjoyment of natural areas, and long-term effects on ecosystems—should be developed primarily within the Washington of

fice, but they should contain elements that provide for integration with regional and park science programs.

The move toward a more centralized structure need not diminish local or regional flexibility. Administration of research could remain decentralized and at the regional level, but important supervisory and support functions should be performed by a central office, which could provide strong direction on the goals of the science program and how to achieve them. It could facilitate better cooperation, communication, and coordination among regions and thus help NPS researchers deal more effectively with national and common problems. A central office could bring better coordination of baseline inventory and monitoring efforts and better overall consistency and quality control.

Ultimately, the NPS science program will be only as successful as the scientists involved. Currently, the NPS is home to some highly qualified scientists who spend significant time functioning as resource managers. The NPS might acknowledge this current mixed role, as there must be a permanent partnership between resource management and science, but should develop and maintain a separate functional group of resource managers.

The conduct of research is fundamentally different from that of most other NPS functions. It operates on a schedule not determined by the calendar of Congress, but on the calendar of the natural or cultural phenomena being studied. Products from research come with answers frequently surrounded with small or great uncertainties. The design of an experiment and the interpretation of the results often depend on the science process as it is conducted in another discipline or in a different part of the world. At the same time, science-for-parks research must be directed at the needs of the agency's land and resource managers. Thus, the science program is at once closely tied to the fundamental challenges of the resource manager and quite independent of the resource manager's daily needs.

It would be naive to downplay the often-discussed conflict between managers and scientists. It occurs to some degree in all institutions, but the tensions inherent in the work ing relationships between the scientist and the manager can be a constructive force. The two must become allies, because their ultimate objective—the conservation of park resources—is the same even though their motivations, approaches, and responsibilities differ. They must be treated as equals—the manager as the activist focused on real-time decision making and the scientist as the independent problem-solver. Both need relative independence but they also must understand each others' problems and exercise mutual restraint to keep the organization vibrant and responsive.

The current organizational structure is not designed to facilitate multi-park or multi-regional research, although there have been some recent cooperative efforts. Topics such as global climate change and biological diversity are broad and have many underlying principles that transcend individual park boundaries. Regional or biome projects are appropriate in some cases; for example, when studying altered fire regimes in the montane west under conditions of climatic change. It will be necessary to have a strong chief scientist in the Washington office as a national coordinator for inter-regional research.

Management of the science program will require the leadership of a person with a strong commitment to its objectives and a thorough understanding of the scientific process and research procedures. In fact, most committee members felt that it should be stipulated that the manager be a scientist or at least have substantial scientific training. At the park level, there should be some autonomy for the scientific staff. Close interaction among park scientists, resource managers, and superintendents is essential for effective interpretation and implementation of research findings. However, the supervisory functions of the superintendent can unintentionally stifle the independence and objectivity needed for effective science.

Cooperative park study units are a critical feature of the NPS research program. These units must address the need for greater ties between park researchers and academia. They also must provide leadership in addressing problems that affect more than one park. Cooperative park study units should be selected carefully after an objective competition among qualified host institutions.

To improve the NPS science program, changes must be made to strengthen the agency's personnel management system to recruit and retain well-trained scientists. Opportunities to contribute to the solution of important problems; opportunities for advancement commensurate with ability, and opportunities for professional growth, development, and appropriate career advancement are all needed. NPS scientists should be required to participate with their peers inside and outside of the agency in the development of their specialties, thereby creating expanded opportunities for the application of science to park purposes. Continued, but more consistent, use of the peer panel grade evaluation system, including external representation on the panels, is needed to encourage strong science and the professional growth of NPS scientists.

Improving the Budget Environment

The National Park Service science program should receive its funds through an explicit, separate (line item) budget. A strategic increase in funding is needed, especially to create and support the needed long-term inventories and the monitoring of park resources.

Overall, the committee finds much to be admired, much to be added or expanded, and very little to be eliminated from the current NPS science program budget. Some research has resulted from political crises, with funding and direction from Congress for specific problems. Some has been done only because of the energy and enlightened advocacy of individual managers or scientists to obtain the funds or staff needed. For every such example of good research leading to problem solution, however, there are dozens of park units in which the needs are not recognized and the research is not sought because of a lack of awareness, a lack of leadership, or a lack of financial or organizational support.

The most obvious need the committee sees is that of greatly expanded science funding and personnel allocations. If the NPS is to come close to meeting its obligation to pass on significant and relatively unimpaired resources to future generations, then it must be able to conduct serious, compre hensive research, rather than what has been described as "make-do" science. The science program needs a separate budget allocation and tracking system that is on a par with and independent from other elements of the budget such as management of park areas, maintenance, resource management, and visitor protection. The budget should include both base funding and project funding and should provide for short-term and "no year" funding (funding without specific time constraints) because most research projects last for more than one year. It should include funds for long-range monitoring and individual projects, and there should be a reasonable contingency fund for use by the national and regional offices to meet emergency needs.

The Park Service should strive for increased scientific input from external sources. This can be encouraged by a competitive grants program and by working with other agencies, such as the U.S. Forest Service, the U.S. Fish and Wildlife Service, the U.S. Geological Survey, U.S. Bureau of Land Management, and other agencies. The NPS should work with the National Science Foundation and other sources of external support as well.

But more money alone will not improve the science program. A real commitment to change will require a new mandate to encourage research and changes in both the structure and culture of the NPS. Instead of being included in the budget category of Natural Resource Management or Cultural Resource Management, science funding should be separate, as a discrete line-item budget. Activities under the heading of science might include research, inventories, and monitoring; data management and publications; and similar activities. Natural resource management activities might include fire management and natural resource management planning, implementation, and training. The bottom-up process—project identification, assessment and description, and prevention and mitigation—now used to develop resource management plans would still be essential, and full participation would be required from resource managers and scientists, including as needed scientists from outside NPS. Inter-regional, national, and international science activities—especially those of a long-term nature—will require concerted leadership.

To create a viable and effective science program, the funding base must be dependable and not subject to discretionary reallocations. A strategic increase in funding would foster the realization of a valid science program, but it is beyond the scope of this report to specify new amounts of funding or staffing. However, significant increases would be necessary to truly fulfill the potential of science in the parks, as current funding is grossly inadequate even to meet day-today needs. A long-term program of research to inventory, monitor, and gain understanding of park resources requires great commitment. As important as more funds would be, in this era of constrained budgets an equally important first step would be to ensure the independence of the science program and establish a secure institutional commitment to it.

BUILDING CREDIBILITY AND QUALITY

The Role of Chief Scientist

To provide leadership and direction, the NPS should elevate and reinvigorate the position of chief scientist, who must be a person of high stature in the scientific community and have as his or her sole responsibilities advocacy for and administration of the science program. The chief scientist would work from the Washington office and report to the Director of the NPS, provide technical direction to the science and resource management staff at the regions and in the parks, and foster interactions with other research agencies and nongovernment organizations. In addition, the chief scientist should establish a credible program of peer review for NPS science, reaching from the development of research plans through publication of results.

Given the great importance of science to the NPS mission, it is critical that the program be guided by a chief scientist who can garner respect and who has the authority to turn ideas into action. This scientist could bring a future-oriented vision to the NPS science program, serve as a coor dinator for interregional research, and assure consistent quality control throughout the program. Giving greater authority to this position would be a shift toward a more centralized structure, but it need not diminish flexibility. Instead, while administration of research remains decentralized at the regional level, the chief scientist could provide important supervision and support. A central office would bring better coordination of baseline inventories and monitoring efforts and bring better overall consistency and quality control to the program. It could coordinate with a science advisory board in organizing periodic evaluations of research programs in the parks and regions.

The chief scientist should administer national projects and budgets and should meet at least annually with the regional chief scientists to coordinate research programs and projects. The chief scientist also would be important in enhancing cooperation with external scientists, increasing the flow of information among park scientists and between park scientists and external scientists, and providing guidance to increase the professionalism of science in the park system. Finally, the chief scientist would maintain close interaction with other national efforts such as the National Science Foundation's Long-Term Ecological Research Program, the Forest Service's Health Monitoring Program, the Environmental Protection Agency's Environmental Monitoring and Assessment Program, the United Nations Man and the Biosphere Program, and the World Heritage Program.

Encouraging External Science

To help the NPS expand the science program and increase its effectiveness, the Park Service, in cooperation with other agencies, should establish a competitive grants program to encourage more external scientists to conduct research in the national parks. The program should include scientific peer review that involves both NPS scientists and external scientists.

Research to support the NPS mission—whether to gain understanding of resources or to develop management ap proaches—can be funded by the Park Service, outside organizations, interagency cooperative efforts, or the cooperating nonprofit associations found in many parks. It could be carried out by NPS employees or by researchers and students from academic institutions (including land grant and private institutions), research organizations, or other government agencies. Because there will always be insufficient funding, and because the science program will include basic and applied research, the program must involve frequent and close cooperation with the external research community. Such research will fall into both the science-for-parks and parks-for-science categories. Over time, the importance of parks as sites for research in increasingly critical areas such as ecology, biological diversity, climate change, acid precipitation, aquatic systems, and other natural resource-related areas will grow and bring enhanced opportunities for external funding. As the NPS expands its science program and attracts more collaborators, it will have to ensure that its administrative processes are capable of handling research requests, ruling on the admissibility of experimental and manipulative studies, and incorporating data and publications into the NPS's growing scientific record.

The Need for an External Advisory Board

The National Park Service should enlist the services of a high-level science advisory board to provide long-term guidance in planning, evaluating, and setting policy for the science program. This independent advisory board should report to the director annually, and its reports should be available to the public.

Virtually all high-quality science programs are subjected to careful, continuing peer review. This helps ensure the most efficient use of resources and the most beneficial results, and it provides a clear, independent voice of evaluation. A strong review process operates in several capacities: developing research ideas and proposals; providing continuing supervision of activities; and assuring the quality of research results and final products, including efforts to trans late research results into information for policy and management planning. Review also can be useful for the strategic analysis of program direction and organization. Throughout this report there has been a consistent call for peer review of plans and products. This might be done by guiding and organizing, in coordination with the chief scientist, panels to conduct periodic evaluations of the research programs in individual regions and parks. Advisory boards have existed at various times in the past and given guidance to the Park Service (e.g., Advisory Board on National Parks, Historic Sites, Buildings and Monuments, 1971), but such oversight would be particularly valuable now. A great effort will be necessary to change the NPS science program at the strategic level—program directions, principles of operational procedures, and organizational structure—and no single document such as this one can provide all the external input needed to guide that kind of fundamental change. Thus, as a new mandate for science in the NPS is developed and implemented, it will be especially important to work with a science advisory board.

REALIZING THE VISION

To build a science program that fulfills its potential—that meets the needs of resource managers, helps the public understand and enjoy park resources, and contributes to understanding our changing world—the Park Service must give the science program immediate and aggressive attention. Pressures on these national treasures are increasing rapidly. It is shortsighted to fail to organize and support a science program to protect the parks for future generations. And it is a waste of a unique resource if the parks are not used, with proper safeguards, to help address the scientific challenges faced throughout the biosphere. The current Park Service leadership has expressed its recognition of the need for a reinvigorated science program as well as the importance of the parks in a broader scientific context. It is time to translate that recognition into action.

Given a new and clear mandate for science in the parks, the value of science to resource management will become

The National Park Service is entrusted to manage some of the nation's most treasured resources for future generations, and science is an indispensable tool in that process. CREDIT: U.S. Fish and Wildlife Service photo of banded eagle chicks by Craig Kappie.

more evident to all levels of park staff, and support for the program within the ranks will grow. Cross-training among scientific, managerial, and interpretive personnel will enhance mutual understanding and encourage staff to see the value of science. The new environment will attract and retain high-quality researchers, especially given incentives such as support for participation in professional meetings and other activities, encouragement to publish results both in the peer-reviewed open literature and in well-reviewed NPS publications, the acquisition of high-quality equipment and facilities, and the possibility for greater professional recognition that attends the more tangible offerings. NPS scientists would be encouraged to challenge conventional wisdom and current policies and practices—with the single objective of improving the quality of science and management in the national parks.

Increased scientific communication and cooperation with national park leaders in other nations would ensure faster, less expensive resolution of common problems and provide greater protection of the world's natural and cultural resources. An international orientation for worldwide park management and its underlying science is needed now more than ever, given the growing importance of tourism and in the dire consequences of failing to maintain the world's ecosystems (Lubchenco et al., 1991).

The recommendations in this report are sweeping and fundamental; they will require substantial alterations in the philosophic and substantive structure and function of the Park Service. The NPS recognizes the need for a reinvigo-rated science program as well as the importance of parks in the broader scientific mission of the country. But accomplishing the transformation will require special leadership and teamwork. The members of the Committee on Improving the Science and Technology Programs of the National Park Service are optimistic that NPS personnel—renowned for their dedication—will prove able to accept the challenge. Many of the employees with whom the committee has met have expressed significant frustration with current conditions and a sincere willingness to adopt new practices. Numerous external organizations, the news media, decision makers throughout government, and concerned citizens have called for changes in the NPS, especially in its science program. The scientific community —often critical of the NPS program—is broadly supportive of such changes and is willing to assist the agency in revamping its research effort.

Despite the widespread desire to see dramatic improvements in the NPS science program, the challenges are significant. All organizations, including the NPS, suffer some institutional inertia, and not all those in leadership positions wish to face change—no matter how obvious the need. Some changes and expansions will require congressional approval and allocation of additional resources. In addition, because NPS is a government agency, there will be severe scrutiny of the decisions made. Still, the nation cannot afford to wait any longer for the NPS to move toward a new mandate for science. The Park Service is entrusted to manage some of the nation's most treasured resources, and science is an indispensable tool in that process.

References

Advisory Board on National Parks, Historic Sites, Buildings and Monuments. 1971. Inspection of Certain Field Areas of the National Park System. Report to the Secretary of the Interior, Rogers C.B. Morton.

Allen, D.L., and A.S. Leopold. 1977. A Review and Recommendations Relative to the NPS Science Program. Memorandum Report to Director. National Park Service, Washington, D.C. 15 pp.

Allen, D.L., L. Erickson, E.R. Hall, and W.M. Schirra. 1981. A Review and Recommendations on Animal Problems and Related Management Needs in Units of the National Park System. A Report to the Secretary of the Interior James G. Watt. Reprinted by the George Wright Society, Hancock, Mich.

Baron, J. 1991. How Has the National Park Service Gained from Acid Rain Research? Highlights of Natural Resources Management 1990, L. Fox, ed. NPS/ NRPO/NRR-91-03. U.S. Department of the Interior, Natural Resource Publications Office.

Castleberry, D. 1987. Report on the Workshop of National Park Service Regional Chief Scientists , Omaha, Nebraska, Dec. 3–5, 1986. 10 pp.

Coggins, G.C., and C.F. Wilkinson. 1987. Federal Public Land and Resources Law, 2nd ed. Mineola, N.Y.: The Foundation Press. 1066 pp.

Conservation Foundation. 1979. Federal Resource Lands and Their Neighbors. Washington, D.C.: The Conservation Foundation.

Conservation Foundation. 1985. National Parks for a New Generation: Visions, Realities, Prospects. Washington D.C.: The Conservation Foundation.

Dolan, R., B.P. Hayden, and G. Soucie. 1978. Environmental dynamics and resource management in the U.S. National Parks. Environ. Manage. 2:249–258.

Forgey, B. 1990. Forest in the City: Rock Creek Park Turns 100. The Washington Post Magazine, Washington, D.C., Aug. 12.

Franklin, J. 1985. Observation from outside. Park Science 5:19.

GAO (General Accounting Office). 1987. Limited Progress Made in Documenting and Mitigating Threats to the Parks. General Accounting Office, Washington, D.C.

Hendee, J., G. Stenkey, and R. Lucus. 1990. Wilderness Management. International Wilderness Leadership Foundation: North American Press.

Holland, M.M., P.G. Risser, and R.J. Naiman, eds. 1991. Ecotones: The Role of Landscape Boundaries in the Management and Restoration of Changing Environments. Papers presented at a symposium at the annual meeting of the Ecological Society of America, Toronto, Canada, Aug. 8, 1989. New York: Chapman and Hall.

Knight, D.H., and L.L. Wallace. 1989. The Yellowstone USA fires issues in landscape ecology. BioScience 39:700–706.

Leopold, A.S., S.A. Cain, C.M. Cottam, I.N. Gabrielson, and T.L. Kimball. 1963. Wildlife management in the national parks. Trans. N. Amer. Wildl. and Na-tur. Resour. Conf. 28:28–45.

Lubchenco, J., A.M. Olson, L.B. Brubaker, S.R. Carpenter, M.M. Holland, S.P. Hubbell, S.A. Levin, J.A. MacMahon, P.A. Matson, J.M. Melillo, H.A. Mooney, C.H. Peterson, H.R. Pulliam, L.A. Real, P.J. Regal, and P.G. Risser. 1991. The sustainable biosphere initiative: An ecological research agenda. Ecology 72:371–412.

National Audubon Society. 1986. Wildlife and the National Park Service. Pp. 463-494 in Audubon Wildlife Report 1986. New York, N.Y.: The National Audubon Society.

NFWF (National Fish and Wildlife Foundation). 1990. FY 1991 Federal Agency Needs Assessment. National Fish and Wildlife Foundation, Washington, D.C.

NPCA (National Parks and Conservation Association). 1979. NPCA Adjacent Lands Survey: No Park is an Island. National Parks and Conservation Association, Washington, D.C.

NPCA (National Parks and Conservation Association). 1988a. Research in the Parks: An Assessment of Needs, Vol. 2. National Parks and Conservation Association, Washington, D.C.

NPCA (National Parks and Conservation Association). 1988b. Investing in Park Futures: The National Park System Plan—A Blueprint for Tomorrow. National Parks and Conservation Association, Washington, D.C.

NPCA (National Parks and Conservation Association). 1989. National Parks: From Vignettes to a Global View. Commission on Research and Resource Management Policy in the National Park System. National Parks and Conservation Association, Washington, D.C.

NPS (National Park Service). 1978. Management Policies. U.S. Department of the Interior, National Park Service, Washington, D.C.

NPS (National Park Service). 1980. State of the Parks: A 1980 Report to Congress. National Park Service, U.S. Department of the Interior, Washington, D.C.

NPS (National Park Service). 1981. State of the Parks: A Report to the Congress on a Service Strategy for Prevention and Mitigation of Natural and Cultural Resource Management Problems. National Park Service, U.S. Department of the Interior, Washington, D.C.

NPS (National Park Service). 1991. 1990 Inventory of Research Activities in the National Parks. National Park Service, U.S. Department of the Interior, Denver, Colo.

NPS (National Park Service). 1992. National Parks for the 21st Century: The Vail Agenda. Report and Recommendations to the Director of the National Park Service. Steering Committee of the 75th Anniversary Symposium. National Park Service, U.S. Department of the Interior, Washington, D.C.

NRC (National Research Council). 1963. A Report: Advisory Committee to the National Park Service. Washington, D.C.: National Academy Press. 156 pp.

NRC (National Research Council). 1987a. Saving Cape Hatteras Lighthouse from the Sea. Washington, D.C.: National Academy Press. 136 pp.

NRC (National Research Council). 1987b. River and Dam Management: A Review of the Bureau of Reclamation's Glen Canyon Environmental Studies. Washington, D.C.: National Academy Press. 203 pp.

NRC (National Research Council). 1990. Haze in the Grand Canyon: An Evaluation of the Winter Haze Intensive Tracer Experiment. Washington, D.C.: National Academy Press. 97 pp.

Pickett, S.T.A., and J.N. Thompson. 1978. Patch dynamics and the design of nature reserves. Biol. Conserv. 13:27–37.

Romme, W.H., and D.H. Knight. 1982. Landscape diversity: The concept applied to Yellowstone Park. BioScience 32:664–670.

Soulé, M.E., and B.A. Wilcox, eds. 1980. Conservation Biology: An Evolutionary-Ecological Perspective. Sunderland, Mass.: Sinauer Associates, Inc.

Sumner, L. 1983. Biological Research and Management in the National Park Service: A History. The George Wright Forum 3:3–27. 27 pp.

White, P.S., and S.P. Bratton. 1980. After preservation: Philosophical and practical problems of change. Biol. Conserv. 18:241–255.

Wright, H.E., Jr. 1974. Landscape development, forest fires, and wilderness management. Science 186:487–495.

Wright, R.G. 1992. Wildlife Research and Management in the National Parks. Urbana: University of Illinois Press.

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