A Biological Survey for the Nation

Committee on the Formation of the National Biological Survey, National Research Council

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A BIOLOGICAL SURVEY FOR THE NATION

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the National Biological Survey

Commission on the Formation of
the National Biological Survey

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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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Preface

The Department of the Interior has begun the process of forming a new agency, the National Biological Survey (NBS). As described by Secretary of the Interior Bruce Babbitt:

> The National Biological Survey will produce the map we need to avoid the economic and environmental "train wrecks" we see scattered across the country. NBS will provide the scientific knowledge America needs to balance the compatible goals of ecosystem protection and economic progress. Just as the U.S. Geological Survey gave us an understanding of America's geography in 1879, the National Biological Survey will unlock information about how we protect ecosystems and plan for the future.

An important distinction exists between the ordinary use of the word *survey* and its use in *National Biological Survey*. Confusion about the meaning of the word sometimes arises in discussions about the NBS, and it is worthwhile to clarify the difference between the two at the outset. The NBS will be a new administrative entity in the Department of the Interior (DOI). Formed from a reorganization of programs in DOI, it will have responsi

bilities for inventorying, mapping, and monitoring biotic resources; performing basic and applied research on species, groups of species, populations, and ecosystems; and providing the scientific support and technical assistance needed for management and policy decisions in DOI. Thus, it includes far more than the inventorying and mapping functions that the use of the word *survey* might imply.

The idea of a national biological survey has a long history in the United States, beginning with the formation of the Division of Biological Survey in the Department of Agriculture at the end of the last century. After that division was transferred to DOI in 1939 and made part of the U.S. Fish and Wildlife Service, the survey component gradually declined. But with concerns over loss of habitats and species and calls for more effective regional land management, professional organizations, nongovernment organizations, individual scientists, and members of Congress have increasingly called for a new biological survey.

In February 1993, the Secretary of the Interior requested advice from the National Research Council on the formation of the NBS. The National Research Council thereupon assembled a committee that included both scientists and persons with experience in government, industry, and public-interest organizations. The Committee on the Formation of the National Biological Survey conducted its study under the auspices of an ad hoc oversight body, the Commission on the Formation of the National Biological Survey, drawn from the membership of the Commission on Life Sciences and the Commission on Geosciences, Environment, and Resources.

The committee worked from March to September 1993. Its timetable was designed to accommodate the schedule that DOI set for administratively establishing the NBS. The committee was charged with addressing issues related to the scope and direction of the NBS embodied in the following questions:

- What should a biological survey for the nation entail?

- What should the National Biological Survey in the Department of the Interior be, if it is to serve the needs of the department and others?
- How should information relevant to the survey be managed?
- How can existing and new survey-related activities and information be made most useful for policy, management, and scientific purposes within and outside the Department of the Interior?
- How can federal and other entities best collaborate for these purposes?

It is important to note that the charge did not include a study of the question of whether or not the NBS should exist on a detailed evaluation of DOI's specific proposal, but rather the scope and direction of NBS in the context of the larger national picture. In developing answers to those questions, the committee considered a wide range of current and potential elements of a survey appropriate to the Department of the Interior and other locations. Many of the activities of a national biological survey—such as basic and applied research, monitoring, inventory, and information management—are going on, not only in DOI but in other federal agencies, such as the U.S. Forest Service, the National Oceanic and Atmospheric Administration, the Environmental Protection Agency, the National Science Foundation, the National Aeronautics and Space Administration, and the Department of Defense. Many of the activities occur in state agencies, state biological surveys, universities, museums (including the Smithsonian Institution), and private organizations, such as The Nature Conservancy's Heritage Programs, which maintain inventory databases in state offices throughout the country. There are also a number of international efforts, such as the World Conservation Monitoring Center in England, and national efforts, such as the Australian ABRS-ERIN (Australian Biological Resources Study-Environmental Resources Information Network) complex and the biodiversity institutes in Taiwan, Mexico (CONABIO, Comisión

Nacional para el Conocimiento y Uso de la Biodiversidad), and Costa Rica (INBio, Instituto Nacional de Biodiversidad).

During its inquiries and deliberations, the committee discovered a wide range of national needs, a broad distribution of relevant efforts and resources already occurring in federal and nonfederal organizations in a relatively uncoordinated fashion, and a wide range of management needs within the Department of the Interior. These findings, combined with the short time available to examine these programs and needs in preparation for this report, led the committee to conclude that it would be more effective in fulfilling Secretary Babbitt's wish that its work help provide a vision for the National Biological Survey if it approached the first two questions above in the context of the broader needs, opportunities, and activities as they related to the stated goals of the NBS rather than concentrating on the details of its proposed structure or specific research agenda, except to the extent that such an examination seemed essential to deal with the broader issues.

This report proposes a research agenda for the National Biological Survey that is far broader than the existing research effort in the Department of the Interior but that is also focused and has priorities according to likely immediate and long-term user needs. A National Biotic Resources Information System is envisioned to make reliable biological information more accessible to diverse users. The report also describes how the many public and private entities involved in current research on biological resources can work together in a new entity, which the committee has called the National Partnership for Biological Survey, to provide comprehensive information that will be useful for decision-makers at all levels of government and outside government. The recommendations of this committee, if followed, should provide the United States with a framework for making decisions about the management, use, and protection of its biological resources.

While this report represents the work of the committee, it benefited greatly from the support of professional staff from the National Research Council: Eric Fischer, who helped the com

mittee refine the report, and Deborah Stine who contributed to the preparation and administrative organization of the study. Their resumes are included with those of the panel in Appendix B because of their intellectual contributions, which advanced the committee's efforts throughout the study. The report was greatly improved by the diligent work of its editor, Norman Grossblatt. In addition, invaluable support was provided by Paulette Adams, Robin Harp, Karen Plaut, and Helene Mokhiber.

The panel also acknowledges with appreciation presentations made at meetings of the committee by the following persons:

Senator Daniel Akaka, U.S. Senate
Randy Alberte, Department of Defense
Bruce Babbitt, Secretary of the Interior
William Brown, Waste Management Inc.
John Busby, Australian Environmental Resources Information Network
Faith Campbell, National Resources Defense Council
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EXECUTIVE SUMMARY

The idea of a national biological survey has a long history in the United States, beginning with the formation of the Division of Biological Survey in the U.S. Department of Agriculture at the end of the last century. After that division was transferred to the Department of the Interior (DOI) in 1939 and made part of the U.S. Fish and Wildlife Service, the survey component gradually declined.

In recent years, increasing concerns about the nation's biological resources have led to calls for a new biological survey. Secretary of the Interior Bruce Babbitt has recently initiated the process of forming a National Biological Survey (NBS) within DOI. To create the new agency, the Secretary is combining portions of the biological research and survey activities from DOI bureaus.

As identified in the department's FY 1994 budget justification to Congress, the mission of the NBS is "to gather, analyze, and disseminate the information necessary for the wise stewardship of our Nation's natural resources, and to foster an understanding of

our biological systems and the benefits they provide to society. The NBS will act as an independent science bureau without advocating positions on resource management issues and without regulatory or land and water development authorities."

In February 1993, Secretary Babbitt requested advice from the National Research Council on the formation of the NBS. In response, the Committee on the Formation of the National Biological Survey, was formed, consisting of scientists and persons with experience in government, industry, and public-interest organizations. The committee conducted its study from March to September 1993. This timetable was designed to ensure that DOI received timely advice on its activities.

The committee was charged with addressing scientific, functional, information, and coordination issues related to the scope and direction of the NBS in the context of the larger national picture. It is important to note that the charge included neither an examination of whether or not the NBS should be established nor a detailed evaluation of DOI's specific proposal. In addressing its charge, the committee discovered a wide range of national needs, a broad distribution of relevant efforts and resources already occurring in federal and nonfederal organizations in a relatively uncoordinated fashion, and a wide range of management needs within the Department of the Interior. These findings, combined with the short timeframe, led the committee to conclude that it would be most effective in fulfilling its charge if it focused on the broader needs, opportunities, and activities as they related to the stated goals of the NBS rather than concentrating on the details of its structure or specific research agenda, except to the extent that such an examination seemed essential to deal with the broader issues.

This report proposes a research agenda for the National Biological Survey that is far broader than the existing research effort in the Department of the Interior but that is also focused according to likely immediate and long-term user needs. A National Biotic Resources Information System is envisioned to make reliable

biological information more accessible to diverse users. The report also describes how the many public and private entities involved in current research on biological resources can work together in a new entity, which the committee has called the National Partnership for Biological Survey, to provide comprehensive information that will be useful for decision-makers at all levels of government and outside government.

WHAT NEEDS WILL A BIOLOGICAL SURVEY FOR THE NATION ADDRESS?

A biological survey for the nation will provide information that is critical for addressing a number of issues:

- *Finding ways to preserve the nation's biological heritage.* Achieving this goal requires extensive information on the current status and trends in distribution and abundance of species and on relationships among species, and an understanding of the ecological processes on which they depend.
- *Managing biological resources in a sustainable manner.* Sustainable use depends on accurate knowledge of the identity, distributions, and ecology of the species being used and those with which they interact.
- *Maintaining essential ecological services, such as water supply, flood and erosion control, and climate amelioration.* We need to understand how natural ecological services operate and to what extent they depend on the biological richness and diversity of ecosystems.
- *Understanding the impact of human settlement patterns (metropolitan growth, renewable land use, and nonrenewable-resource extraction) on biological resources.* The impact of daily human activity has had and will continue to have a great effect on the nation's biota.
- *Maintaining contributions of our nation's biota to the aesthet#*

ic quality of life. We need to know how species and ecosystems contribute to our quality of life and how patterns of human use affect those contributions.

- *Understanding the effects of climate change.* To anticipate the nature and intensity of ecological changes that might be induced by natural or anthropogenic climate change, we need information on how past climate change affected species and biological communities.
- *Deriving new economic wealth from biological resources.* Only a small fraction of species have been tested for potentially valuable chemicals, foodstuffs, or materials, and ecological information on the nature of the natural products of wild species is fragmentary.
- *Restoring degraded environments.* Restoring environments that are degraded by erosion, depletion, pollution, or the invasion of nonnative species will require accurate information on the ecological and physical processes affected by degradation and knowledge of which species can best establish themselves on degraded sites.

Some common weaknesses exist in the availability of information to address those issues. In some instances, data have been collected but are not organized in useful ways. In many cases, data are unavailable, have not been collected over a sufficiently long time for trends to be separated from short-term variations, have been collected only in a few localities, or have not been recorded in a format that can be used to make decisions about the management, use, and conservation of the nation's biological resources.

Many national and local agencies have responsibilities for understanding and managing the nation's biological resources, but there is no effective cross-institutional framework for identifying and conducting research of the highest priority, coordinating research activities, or making information available in a coherent

and usable way to the many agencies and other organizations that need it.

HOW CAN A BIOLOGICAL SURVEY FOR THE NATION BE CREATED?

The National Biological Survey is a critical step toward assembling a comprehensive assessment of the nation's biological resources, but it cannot by itself come close to meeting the full range of needs and objectives in scientific research, inventory, and information management that a biological survey for the nation must fulfill. The NBS should therefore have a dual mission: to meet the scientific research and information needs of DOI for management of the lands within its jurisdiction and species for which it has responsibility (and geographic areas that affect either of the above) and to provide national leadership and vision for this comprehensive assessment. To achieve the best possible results, this assessment must be a coordinated national effort at all organizational and jurisdictional levels. This joint enterprise can be called the National Partnership for Biological Survey. The committee therefore recommends the following:

The United States, under the leadership of the Department of the Interior, should establish a National Partnership for Biological Survey (NPBS). This will be a new national, multisector, cooperative program of federal, state, and local agencies; museums; academic institutions; and private organizations. Its purpose will be to collect, house, assess, and provide access to the scientific information needed to understand the current state of the nation's biological resources (status), how that status is changing (trends), and the causes of the changes.

The mandate and mission of DOI make it the logical agency to

lead the development and implementation of the National Partnership. The department has broad research and management responsibilities for the biological resources of the nation and strong links to key nonfederal partners, and by initiating the formation of the National Biological Survey, it has already indicated its willingness to take on a leadership role.

Although the National Partnership does not yet exist formally, many of its elements do.

- *The Department of the Interior (DOI)* is the nation's largest land manager and the steward of many of the wild living resources of the United States. It also has a historically strong partnership with the states.
- *The National Biological Survey (NBS)* will provide scientific research and information within DOI to help manage the lands and species for which the department has responsibility.
- *Other federal agencies* should participate. Major partners should include the Department of Agriculture (USDA), especially the Forest Service, the Soil Conservation Service, and the Agricultural Research Service; the National Oceanic and Atmospheric Administration (NOAA) in the Department of Commerce; the Department of Defense, including the U.S. Army Corps of Engineers; the Environmental Protection Agency; and the National Science Foundation.
- All fifty *states* have natural resource agencies charged with the management of the state's fish and wildlife resources. Many states have their own biological surveys. Natural Heritage Data Centers, coordinated nationally by The Nature Conservancy (TNC), exist in every state.
- *The Smithsonian Institution* is a national leader in the development of specimen-based databases and houses extensive collections of organisms. It also hosts the Biological Survey Unit staff of the U.S. Fish and Wildlife Service and biologists from NOAA and USDA.
- *Museums* are the major depositories of the biological specimens and associated data that constitute a primary resource for the

NPBS. They are involved in specimen-gathering, identification, collections management, research, data development and analysis, and information dissemination.

- *Universities* have advanced programs in research and training in the scientific disciplines that the National Partnership will require.
- *Nongovernmental organizations* include some major landholders, managing land for the conservation of biological diversity. Several have established databases on biological resources.
- *Cooperative programs* and existing national networks deal with large components of the North American biota.
- *Native American groups* in the United States use and often manage lands that contain over 20 million acres of habitats that harbor endangered species, old growth forests, rare communities, and unique ecosystems.
- *Puerto Rico, U.S. territories, and possessions* contain important biological resources under federal and local jurisdiction.
- *Private landholders and user groups* should contribute to and benefit from the NPBS. Private landholders own most of the land in the United States. The associations representing the private-sector—focused on such groups as land developers, home builders, and the agriculture, forestry, mining, and grazing industries—should find that information from the NPBS will add greater certainty to future land-use planning.
- Thousands of *individual scientists* perform critical research and generate and possess detailed knowledge necessary for the success of the NPBS.
- *Foreign biological sources* have knowledge and expertise that is especially important in areas contiguous to U.S. holdings. No one country can house the best, or only, specialists on all groups of organisms. DOI and other agencies have special international responsibilities relevant to the Partnership under various laws, treaties, and agreements.

The major missing elements required to create an effective National Partnership are some key programmatic components and

mechanisms for horizontal and vertical integration and coordination of the ongoing independent efforts. The recommendations below are intended to help provide these missing elements. Some are directed specifically to the National Biological Survey and some to the broader Partnership. The latter class also applies to NBS in its proposed role as a leader of the NPBS. The committee recognizes that various factors may affect the specific form that the Partnership eventually takes, but believes that the functions and needs it identified are relevant to any attempt to create an effective biological survey for the nation.

WHAT ARE THE NECESSARY FUNCTIONAL CAPABILITIES OF THE NATIONAL PARTNERSHIP?

To carry out its responsibilities, the Partnership, including NBS, must have several specific functional capabilities. It must be

- *Able to conduct credible science.* The fundamental purpose of the NPBS is to provide a rational and objective scientific basis for meaningful stewardship of the nation's biological resources. The scientific credibility and reputation of the Partnership are therefore of utmost importance.
- *Able to stimulate and coordinate appropriate research.* The National Partnership should be broadly based scientifically. It should also be broadly connected, both nationally and internationally, and its programs should be designed to gather information that will be of maximum use in guiding further activities.
- *Organized for program continuity.* Data on status and trends of the nation's biological resources become increasingly valuable as the length of the record increases. Interruptions would seriously reduce the value of these data.

- *User friendly and adapted to a variety of users.* Users need timely, accurate, and easily interpreted information that will vary widely in scope and purpose. The NPBS will need to facilitate access to information in a variety of forms for many different users and uses.

The National Partnership will provide new information and much more powerful tools for managing, using, and preserving biological resources. It will provide a stronger information base on biological resources, an organized framework for collaboration and priority-setting, and economies of scale and more efficient use of research resources.

HOW WILL THE NATIONAL PARTNERSHIP STRENGTHEN THE INFORMATION BASE FOR PLANNING AND OPERATIONAL DECISIONS?

Performing Research

One of the most important uses of the scientific information gathered by the National Partnership is to assist decision-makers in addressing existing issues about biological resources and in anticipating future ones. The National Partnership should develop a strong, scientifically credible research program designed to meet this goal.

The research of the Partnership should identify changes in biological resources and determine why those changes are happening. It should identify trends in a timely manner so that actions can be taken while multiple options are available, determine how local actions influence events elsewhere, reduce the chances of taking costly remedial actions unnecessarily, evaluate the effectiveness of management decisions, and direct attention to areas

where problems are most likely to develop in the near future, such as urban expansion zones, estuaries, rivers, and zones of intensive resource extraction.

Key scientific objectives of the National Partnership for Biological Survey should include the following:

- Determining what specimens and data representing the U.S. biota exist in the nation's institutional collections.
- Discovering, describing, classifying, and mapping U.S. species of selected taxa.
- Establishing taxonomic specialists, collections, and databases for large and important taxa.
- Studying the biology of selected species of importance.
- Developing classification systems for ecological units and a set of core ecosystem attributes and protocols.
- Developing predictive models to facilitate sustainable management.
- Performing research on the restoration of degraded environments.
- Performing research to develop biological protocols for pollution and to identify useful biological indicators of ecological trends.
- Establishing collaborative pilot projects for interdisciplinary research on biological resources in selected regions of the United States. These projects should target areas that are changing rapidly because of human activity, have high biodiversity, have diverse co-occurring ecosystems of different types, or are unique ecologically.

The committee believes that the scientific activities and programs of the NBS should focus both on its responsibilities as the main biological research agency within the Department of the Interior and on its proposed role as the lead agency for the National Partnership. The large amounts of land managed by DOI, along with the department's other responsibilities with regard to

the nation's biota, make NBS especially important in providing key elements of a program to assess the status and trends of biological resources. The committee therefore recommends the following:

> **NBS should perform research needed for the management of lands within the jurisdiction of DOI and species for which it has responsibility. It should also ensure, both through its own scientific activities and its proposed role of national leadership, that needed research is performed to fulfill the central purpose envisioned for the National Partnership—to generate the information required to understand the current status of the nation's biological resources, how that status is changing, and the causes of the changes.**

The committee believes that DOI should work to ensure that needed research is done by NBS or other entities no matter what specific form the Partnership eventually takes. To fulfill its scientific mission, the NBS will need additional staff in a number of scientific disciplines. It should perform a systematic assessment of needs based on existing staff capabilities and program requirements and develop and implement a plan to hire needed experts. This should be the activity of highest priority for the application of additional budget and staffing resources. Agencies whose participation is essential to the success of the Partnership, such as the National Science Foundation, should receive increased funding so that the Partnership can take full advantage of the nation's relevant scientific expertise. Funding increases will also be needed for other appropriate agencies.

Making Information Useful

One of the challenges for the Partnership is to communicate research results effectively to resource managers, planners,

legislators, and regulators. These users have questions whose answers are not obvious in existing research products. The NBS and others involved in the Partnership should consult with users to find ways of disseminating information so that it can be applied most effectively.

There is an urgent need to organize existing information and make it more readily available and to coordinate future data collection and exchange. The committee therefore recommends that

Under the leadership of NBS, the Partnership should develop a National Biotic Resource Information System. This should be a distributed federation of databases designed to make existing information more accessible and to establish mechanisms for efficient, coordinated collection and dissemination of new information.

An effective National Biotic Resource Information System will require substantial cultural and institutional changes to build stronger bridges among the broad spectrum of producers and users of biological data. The NBS should take the lead in promoting standards for biological-survey data and for meeting the key requirements for an effective distributed database. It should collaborate with other federal initiatives to develop national and global environmental databases and should also support database development by states, museums, and universities. The NBS will need to commit adequate resources to ensure that its diverse user community receives timely dissemination of reliable, high-quality data and information presented in a variety of formats.

The National Partnership should establish well-coordinated efforts to develop standard sets of spatial data. For example, sufficiently detailed, computerized maps of actual vegetation do not exist for much of the United States. To remedy these deficiencies, the NPBS should participate in the National Spatial Data Infrastructure; promote greater awareness and use of spatial data

and technologies; increase efforts to locate field data spatially; adopt, where appropriate, existing standards for mapping and spatial data handling; and increase the role of biologists in efforts to develop standards for spatial data.

To meet the growing needs of all sectors of society for biodiversity data and information, the NPBS should have a strong capability for publication and product communication—increased online access to data, reports, and bibliographies; publication of selected data sets on CD-ROM and other media; and expanded publication of synthetic documents. The NPBS should produce appropriate paper publications such as instructional materials, range and habitat maps, atlases of distribution and trends in regional biodiversity, floras and faunas, field guides and manuals, taxonomic monographs, and summaries of surveys and trends. The most important paper publications will be peer-reviewed scientific articles and reports.

Software tools must be responsive and readily accessible to all users. The NPBS should expand efforts to develop tools for data visualization and analysis, for data reformatting and conversion, for trend analysis of monitoring data, for spatial interpolation of sighting and collection data, and for Geographic Information System (GIS) habitat modeling.

HOW WILL THE NATIONAL PARTNERSHIP PROVIDE AN ORGANIZED FRAMEWORK FOR COLLABORATION AMONG ITS PARTICIPANTS?

Organization and Coordination of the NPBS

Coordination among its various participants is a key to the success of the Partnership. Because it will be a national program that cuts across political, jurisdictional, and geographic bound

aries, it will need a mechanism through which all sectors involved can advocate, justify, and discuss proposed programs and activities that will affect them. Because the scope and activities of the National Partnership are quite broad, and because of the extensive amount of intergovernmental and nongovernmental coordination required, the committee believes that no existing model for national coordination is readily adaptable to the National Partnership. A unique and innovative process is probably needed. It therefore recommends the following:

Formal mechanisms should be established for coordination among the entities with responsibilities for the National Partnership for Biological Survey. The mechanisms should collectively exhibit the five characteristics described below.

The coordination mechanisms should

- Provide for high-level, balanced input from diverse participants and users into the development and implementation of the Partnership.
- Take full advantage of the federated structure of American government, in particular the states.
- Have a clear lead organization with primary responsibility and authority for fostering coordination.
- Provide for continuity of involvement by participants and users.
- Be designed to encourage active, voluntary participation.

Coordination among nonfederal participants might be accomplished via a standing body of appropriate representatives. The link to federal programs could be provided through the Secretary of the Interior. In the committee's view, what is needed is a high-level forum for the discussion, development, and implementation of policies and priorities for all nonfederal stakeholders in the National Partnership, not merely an advisory body. The forum could identify and recommend national (not solely federal)

policies and priorities for biological-resource assessment (not management decisions) and make recommendations for all segments of the Partnership, both federal and nonfederal. It could also review NPBS programs for their appropriateness to policies and priorities and recommend appropriate changes. Recommendations for programs would be passed to the appropriate entity for action and feedback. Each representative would work directly within the sector of the community (e.g., museums, etc.) that he or she represents to implement policies and priorities.

An effective mechanism for federal coordination might be an interdepartmental committee on biological survey. Such a committee could be chaired by the Secretary of the Interior and include the heads of key federal departments and agencies involved in the Partnership. The mechanism should provide cross-agency coordination of federal policies and participation in the Partnership and it should identify federal-agency priorities for the conduct of biological research and resource assessments. The interagency committee would be both a forum for high-level policy discussion and coordination and a framework for increased day-to-day interaction at the working level.

Appropriate mechanisms also need to be established to obtain scientific advice for the Partnership and to ensure proper data management. These mechanisms would identify priorities for research and protocols for surveys and inventories; establish procedures for quality assurance in research and data management, including the development of database standards; plan the development of the NPBS data network; and develop recommendations for ensuring access to data by public and private users. One way to obtain the necessary advice and guidance would be to establish committees in science and data management.

Coordination within DOI

The director of the NBS must be an acknowledged and respected professional leader in the biological-science community

and should be selected in a way that helps to ensure the scientific independence of the agency. A chief scientist should be similarly appointed and should be free of management responsibilities other than for the development of scientific programs.

Much of the work of the NBS will serve needs within DOI. For example, in many instances, a DOI land manager might require on-site scientific expertise. Land-management bureaus should retain a small cadre of scientific expertise to address unique site-specific and short-term biological resources issues and to facilitate interaction between the bureaus and the NBS.

The secretary should establish an office in each state to facilitate joint NBS activities and to provide a communication channel among state agencies, private and individual participants, and federal agencies. This may be the most important consideration for ensuring that the NBS achieves liaison with all possible contributors.

Because a state organizational structure for the NBS is recommended, neither the NPBS or the NBS needs alternative geographical bases. Nonetheless, collection, analysis, and dissemination of data might, for some purposes, be categorized by ecological criteria that do not necessarily correspond with any political boundaries, such as watersheds, vegetation zones, or wildlife migration routes.

HOW WILL THE NPBS PROVIDE AN ORGANIZED STRUCTURE WITH STATED PRIORITIES FOR ACQUIRING NEEDED INFORMATION ABOUT BIOLOGICAL RESOURCES?

The NPBS research program should be well-balanced between the conduct of new fundamental research designed to advance science and the conduct of more practical research focused on near-term problem-solving. A robust national biological research program must encompass the entire spectrum. Because the NPBS

must address many scientific needs and because the resulting information has many uses, no single criterion can be used to establish priorities.

A strength of the NPBS is that multiple criteria for setting priorities can be brought together under its coordinating framework. Priorities should be based on the degree to which proposed research advances the following goals:

- Evaluation of biological resources that are demonstrably or potentially important but for which relatively little information exists.
- Information required for the maintenance of biological diversity and the long-term sustainability of ecological systems.
- Understanding of the status and trends of biological resources that are changing rapidly, are rare, or are threatened by factors such as land use, natural patterns or harvesting activities, or natural changes in the environment.
- Information about biological resources that are identified as important according to legal mandates or because of their current or potential economic value.
- Understanding of ecological processes that provide services, such as control of nutrient and soil loss, degradation of pollutants, and maintenance of biological diversity.
- Conduct of studies whereby relatively small investments will yield large returns in understanding.
- Information that will guide the remediation and restoration of damaged or degraded ecological systems.

HOW WILL THE NATIONAL PARTNERSHIP PROVIDE IMPROVED PROGRAMMATIC EFFICIENCIES AND ECONOMIES OF SCALE?

Through its coordinating mechanisms and ability to set priorities, the National Partnership can provide increased efficiency in

the use of scientific resources. Redundancies can be avoided or eliminated. Full use can be made of resources. Collaboration among public and private organizations can permit the development of projects that would be far too large or difficult for a single organization. Investments made now to improve the knowledge base should pay off in the future by lessening the risk of costly political conflict and the need for expensive environmental repair efforts.

Research

Extensive biological research and inventory programs exist in several federal agencies. The proposed coordination mechanisms will permit better evaluation, prioritization and, where appropriate, reprogramming of current spending on programs relevant to the goals of the Partnership. Where necessary, the NBS should develop cooperative agreements. Effective leveraging of the other federal programs will necessitate some funding increases in the NBS budget to support these activities. Such increases in investment by the NBS will be more cost-effective than undertaking large new programs.

Information Management

Much of the information generated by the Partnership will be exchanged over computer networks through a distributed federation of databases, which will be more cost-effective and efficient than a large centralized database. A federated approach that takes full advantage of advances in information technology will permit rapid, easy access to a wide array of databases distributed around the country. To facilitate the sharing of data among participants, the NBS should establish a facility for archiving and distributing regional and national data sets and for meeting the goals of DOI's

new National Biological Status and Trends Program, which will be part of NBS.

NPBS data management should ensure that its databases coevolve with the major federal environmental and socioeconomic databases to minimize redundancy, to avoid conflicting terminology and classification systems, and to maintain consistent data standards and formats.

HOW SHOULD THE NATIONAL PARTNERSHIP BE IMPLEMENTED?

Implementation of both the NBS and the Partnership should be phased in according to a well-planned strategy that provides for early results. The strategy should identify specific near-term, intermediate-term, and longer-term priorities. Otherwise, too many tasks might be initiated at one time, programs might be started before clear goals have been established, and results might therefore fall short of needs and expectations. The committee therefore recommends as follows:

Development of the National Partnership and the National Biological Survey should be guided by a single strategic implementation plan developed under the leadership of the Department of the Interior with the full participation of NPBS partners. Some proposed key elements of the plan are listed below.

Near-Term Priorities (Immediately to within 1 Year)

NBS

- Appoint key leaders

- Phase in personnel transfers
- Assess existing national biological databases
- Identify priorities for additional information
- Assess collections
- Establish register of taxonomic specialists
- Develop national research plan
- Initiate regional collaborative pilot projects
- Establish data-management office headed by senior official

NPBS

- Establish national coordination mechanisms
- Develop FY 1995 budget initiative for DOI, NSF, and other agencies involved
- Develop strategic plan for information management
- Develop national research plan
- Initiate regional collaborative pilot projects

Intermediate-Term Priorities (within 3 Years)

NBS

- Broaden mix of scientific disciplines
- Establish or expand research programs in environmental indicators
- Establish or expand research programs in inventories of areas rich in biological diversity, unique ecosystems, and potential candidate areas for restoration
- Develop series of manuals, monographs and atlases and system of ecological classifications based on attributes
- Establish moderate-size data-management facility

NPBS

- Develop multiyear authorization
- Establish national data network

Long-Term Priorities (within 5 Years)

NBS

- Develop strong capability in ecological analysis
- Broaden scientific priorities to include research efforts in restoration biology
- Expand inventories
- Develop predictive models
- Fill information gaps

NPBS

- Develop programs to deploy new information technology
- Evaluate data-management programs.

Although priorities might change over time, the committee believes that phasing the steps outlined above according to a well-planned strategy will lead to a successful NBS and National Partnership. Establishing the priorities outlined here will help both the NBS and the NPBS to provide quickly the kinds of results that are essential if they are to show their value to the nation.

WHAT ARE THE LIMITS TO THE NATIONAL PARTNERSHIP?

The National Partnership has the potential to serve the nation well as it grapples with increasingly contentious and challenging issues in managing its biological resources. Yet, the very richness and diversity of our biological resources mean that decisions will often need to be made from incomplete information. Even when sufficient information is available, government must respond to public concerns that might influence decisions in a direction different from that indicated by scientific findings.

The NPBS will provide a much stronger information base from which to make decisions about the nation's biological resources, but hard choices and conflicts will remain. The National Partnership will be most useful in preventing costly environmental confrontations if it has a paramount scientific function, maintains a long-term commitment to scientific excellence, and is well-integrated across its membership.

A BIOLOGICAL SURVEY FOR THE NATION

1

THE VALUE OF A BIOLOGICAL SURVEY FOR THE NATION

We Americans are increasingly aware of how much our well-being depends on the diversity of living organisms and the integrity of ecological communities. We depend directly on other species for new and improved sources of food, fiber, construction materials, and medicines. In addition, much of our economic base is related to income from all those resources and from tourism and recreation. For example, recreational hunting and fishing are enjoyed by tens of millions of Americans each year and create a major demand for the effective management of habitats that contain game species and other wildlife.

Natural diversity also has many indirect values. It is the source of genes from wild organisms that can be incorporated into domesticated species to improve production and to provide resistance to diseases and pests. Biodiversity is the foundation of biotechnology, an important and growing economic activity.

The nation's ecosystems provide such valuable environmental services as controlling floods, conserving and forming soils, assimilating pollutants, and moderating local climates. Loss of

ecological habitats has caused problems in each of these areas. In addition to those explicit ecological services, natural resources provide important recreational, aesthetic, and spiritual values to our culture.

Recognizing the value of its biological resources, this country has promulgated laws and policies to protect plants and animals from extinction. It has also demonstrated a strong commitment to wise, responsible, scientifically based stewardship of its biological resources through regulatory programs, acquisition of public lands, and an array of private conservation efforts. (As used in this report, the term biological resources refers to living organisms, their products, and the ecosystems in which they occur that are actually or potentially useful materially, ecologically, scientifically, or aesthetically or that are protected under law, treaty, or other legal instrument.)

Despite those endeavors, the nation's biological diversity is in decline, and there are many unanswered questions about how it should be managed to support sustainably all the goods and services on which we depend. For example, off Florida's Key Largo, coral reef area decreased in abundance by 30% in the last 20 years (Wilson, 1992). In the United States alone, over 760 species of fishes, crayfish, and fresh-water mussels (44% of all the species in these groups) are considered to be at risk (Stein, 1992); only 70 (24%) of the 297 species of freshwater mussels in the United States are considered to have stable populations (Williams et al., 1993). A national survey of endangered species of plants conducted in 1988 revealed that over 780 native taxa (of a total of some 20,000 species) are facing possible extinction by the end of the 1990s (Falk, 1991). Additional taxa are added to the list annually as new threats are discovered and the decline of populations continues.

Nationally, 775 species of plants and animals have been listed as threatened or endangered, and there is an enormous backlog of candidate species that have been nominated for listing. Recovery programs have been developed for only about half the listed

species and have been implemented for fewer. It should be clear that the nation is facing a decline in its living natural resources and, more important, that the current legal and institutional structures are inadequate to protect these resources.

Human activities are widely recognized to be a major contributor to the decline. The rapid and continuing growth in the land occupied by our metropolitan areas and our patterns of resource development and use are both putting pressure on the country's ecological systems. The broad extent of the pressure and its specific effects are poorly understood.

Declines in the quantity and quality of the nation's biological resources are due in part to a lack of basic knowledge of its biota, ignorance of trends, and inefficient use of existing information. We do not know how our alteration and degradation of ecosystems affect their ability to provide in a sustainable way the goods and services on which our society depends, nor do we understand the impacts of human activities on these ecosystems. We do not even know, for many groups of organisms, how many species occur in the United States and where they live. In many of these cases, and even among many species that are known, we have little information about their ecological relationships.

Such a lack of information is critical because we continually make important, and often irreversible, decisions concerning these resources. The societal consequences to society of these deficiencies are certain to increase in the future. The constantly growing pressures of human society on the environment guarantee that maintaining the functional integrity of ecological systems will become ever more difficult. (By functional integrity we mean the capacity of communities to maintain their productivity, cycling of nutrients, and species composition in the face of environmental stresses. A community has lost its functional integrity when it is no longer capable of maintaining those functional attributes.) The consequences of loss of or harm to natural resources are costly to both the public and private sectors.

Frustration with the current process is now shared among

natural-resource users and managers, scientists, and the public at large. No clear national agenda or strategy exists for integrating the many programs directed at understanding our biological resources.

Recognizing the need for change and a better means of informing its own decision-making efforts, the Department of the Interior (DOI) is in the process of reorganizing to form a new agency, the National Biological Survey (NBS). The NBS will not be a survey in the everyday sense of the word, although it will include strong survey-like elements. The purpose of this Committee of the National Research Council (NRC), entitled the Committee on the Formation of the National Biological Survey, is to provide guidance as to the scope and direction of the NBS in the context of both national needs and those within DOI.

As identified in its FY 1994 budget justification to Congress, the mission of this new agency is "to gather, analyze, and disseminate the information necessary for the wise stewardship of our Nation's natural resources, and to foster an understanding of our biological systems and the benefits they provide to society. The NBS will act as an independent science bureau [within DOI] without advocating positions on resource management issues and without regulatory or land and water development authorities."

To create the NBS, the Secretary of the Interior has proposed combining substantial portions of the biological research and survey activities in three DOI bureaus—the Fish and Wildlife Service (FWS), the National Park Service (NPS), and the Bureau of Land Management (BLM)—with smaller portions of five other departments—the Minerals Management Service, the Office of Surface Mining Reclamation and Enforcement, the Bureau of Reclamation, the U.S. Geological Survey (USGS), and the Bureau of Mines.

The committee believes that the National Biological Survey will be a critical first step toward assembling a comprehensive assessment of the nation's biological resources. However, to achieve the best possible results, there must be a coordinated national

effort that draws on existing programs and strengths at all organizational and jurisdictional levels. The work of the NBS must be integrated with the continuing efforts of other relevant federal agencies, state surveys, museums, academic institutions, and other entities. This joint, integrated enterprise can be called the National Partnership for Biological Survey (NPBS). This National Partnership would be a new national, multisector program to facilitate the collection, housing, assessment, and use of scientific information needed to understand the current and historical state of the nation's biological resources, how that state is changing and projected to change, and the natural and human-induced causes of the changes. The NPBS would provide a substantial amount of new information and much more powerful opportunities for analysis than those available now. It would provide the scientific information that is needed to develop appropriate strategies for managing our nation's biological resources (including mitigation and restoration), their use, and their preservation.

Although the Partnership will necessarily be a highly collaborative undertaking, it will require clear leadership to be coordinated effectively. With the formation of the National Biological Survey, the committee believes that the most logical federal leader is DOI. The mission and mandates of the department encompass broad research and management responsibilities for the natural resources of the nation. DOI also has strong links to key nonfederal partners, including the states and universities. By initiating the formation of the National Biological Survey, the department has implicitly indicated its willingness to take on this role. After examining various alternative possibilities, the committee concluded that no other federal office or agency possesses all the necessary characteristics. The regulatory focus of such agencies as the Environmental Protection Agency (EPA) can create problems in an attempt to lead the kinds of long-term research efforts that the National Partnership will need to perform (NRC 1985, 1993b). Other agencies are either more narrowly focused on specific components of the nation's biological resources—e.g., the Na

tional Oceanic and Atmospheric Administration focuses on marine environments, and the U.S. Department of Agriculture focuses on forests and agricultural systems—or do not have management responsibilities or as strong ties to key users as does DOI.

Many of the elements of the National Partnership already exist. Thousands of scientists are working on relevant projects and programs scattered throughout federal, state, and local agencies; academe; museums; nongovernment organizations; and the private sector. But major elements are missing and must be supplied if an effective National Partnership is to be created. In addition to some key additional programmatic components, the NPBS will need effective mechanisms for horizontal and vertical integration and coordination. This report will identify key needs that the new National Partnership should address and recommend ways to supply the missing elements. Some of the recommendations in this report are directed specifically to the National Biological Survey and some to the National Partnership. The latter class also applies to NBS in its proposed role as leader of the NPBS. The committee recognizes that various factors may affect the specific form that the Partnership eventually takes but believes that the functions and needs identified in its findings and recommendations are relevant to any attempt to create a biological survey for the nation.

Recommendation 1-1: The United States, under the leadership of the Department of the Interior, should establish a National Partnership for Biological Survey. This will be a new national, multisector, cooperative program of federal, state, and local agencies; museums; academic institutions; and private organizations. The purpose will be to collect, house, assess, and provide access to the scientific information needed to understand the status of the nation's biological resources, the trends in the changes of that status, and the causes of those changes.

PURPOSE OF THE NATIONAL PARTNERSHIP FOR BIOLOGICAL SURVEY

Some common weaknesses exist in the availability of information to address the issues discussed above and later in this chapter. In some instances, data have been collected but are not organized in useful ways. In many cases, data are unavailable, have not been collected over a sufficiently long time for trends to be separated from short-term variations, have been collected only in a few localities, or have not been recorded in a format that can be used to make decisions about the management, use, and conservation of the nation's biological resources.

Many national and local agencies and organizations have responsibilities for understanding and managing the nation's biological resources, but there is no effective cross-institutional framework for identifying and conducting research of the highest priority, coordinating among current and future research activities, or making information available in a coherent and usable way to the many agencies and other organizations that have responsibilities for protecting, restoring, and managing biological resources.

The National Partnership for Biological Survey, designed to remedy these deficiencies and weaknesses, would have the abilities to generate new information; to manage, analyze, and interpret the information through the development and use of organized databases; and to communicate information in appropriate and readily understood formats to a wide variety of users. The purpose of the National Partnership is to develop the scientific basis for effective protection, restoration, use, and management of the nation's biological resources. More specifically, its objectives are to document and assess past and present status and trends of the nation's biota and ecological systems, to predict future trends, to analyze and interpret available data on biological resources, and to provide information to those responsible for managing, utilizing, and conserving those resources.

PARTICIPANTS IN THE NATIONAL PARTNERSHIP FOR BIOLOGICAL SURVEY

The institutions and other elements described below are obvious contributors to the goals and objectives of the NPBS. The group is heterogeneous, and participants will vary in the nature and extent of their participation. Many already produce relevant information. Others have responsibility for major components of the nation's biological resources and, in the opinion of the committee, should benefit from developing or participating in programs and other activities that contribute to information about these resources.

- *Department of the Interior.* DOI is the nation's largest land manager and the steward of many of the wild living resources of the United States. It also has wide-ranging hands-on responsibility for its trust lands and a historically strong partnership with the states. Elements within DOI that have important land-management responsibilities include BLM, NPS, and FWS. The USGS will be especially important with respect to the kinds of interdisciplinary research that will be critical for the success of the National Partnership (see Box 1.1). Other bureaus have regulatory responsibilities and pertinent expertise. All will need to interact closely with the NBS and will be involved with the National Partnership as users or participants.
- *National Biological Survey.* The NBS will provide scientific research and information to help DOI manage the lands within its bureaus and manage species for which it has legal responsibility (as well as lands that affect either of the above); it is also the appropriate agency to assume leadership and vision for the NPBS. In name and intent, the NBS should be a catalyst for the National Partnership, providing a forum for efforts to coordinate the actions of the participants in the NPBS.
- *Other federal agencies.* Several other federal agencies conduct programs and activities that will be important elements of

BOX 1.1: THREE EXAMPLES OF THE IMPORTANCE OF GEOLOGICAL INFORMATION

Geologic Habitat of the Mexican Spotted Owl in Santa Fe National Forest, New Mexico

Some 113,000 acres were surveyed for Mexican Spotted Owls in the Jemez and Cuba Ranger Districts of Santa Fe National Forest. A total of 18 territories were found. All core areas and roosting and nesting locations are in canyons with steep cliffs. All nests were in cliffs in narrow canyons. No nests or roosts were on mesa tops in either district. Foraging habitat is diverse, ranging from mixed conifer with heavy overstory to open, nonforested areas in an old forest-fire burn in the Jemez District. Nest sites, especially in the Jemez District and the eastern portion of the Cuba District, are in steep canyons exposing a volcano-stratigraphic unit identified by the U.S. Geological Survey (USGS) as the Otowi member of the Bandelier Tuff. The Otowi member is 600 ft thick and is a nonwelded to densely welded ash flow (incandescent avalanche) deposit, characteristically containing abundant accidental pumice and lithic fragments. As mapped by USGS, it includes 0-30 ft of basal, bedded, air-fall pumice. The steep canyons, whose walls consist of Otowi, provide shelter, owing to deep pockets formed in the canyon walls from the weathering out of large pumice fragments. The deep pockets provide a cool nest in summer, warmth in the winter, and protection from severe rain and snow storms. The single exception to the Otowi outcrop association is a spotted owl territory in the Cuba District in the Golondrino Diversity unit. Owls there also nest in steep-walled canyons, but the cliffs are composed of sandstone with deep joints (fissures). In the 1992 nesting season, a pair of the owls nested in a tree adjacent to the canyon walls. These cliffs and canyons in the Jemez and Cuba Ranger Districts can be classified as important habitat. The mesa tops beyond a quarter of a mile on either side of the canyons can be classified as potential foraging habitat.

Geologic Habitat of the California Desert Tortoise

To comply with the Endangered Species Act, Department of Defense officials issued a contract to a consulting firm to determine the popula

tion of desert tortoises on one of its bases in the Mojave Desert. Field biologists went about the time-consuming task of trying to develop and implement an effective method to count the tortoises. The fact that they tend to burrow to escape the searing desert heat made the task difficult. After many frustrating months, one of the biologists crossed paths with a geologist who was studying earthquakes and environmental hazards in the region. The geologist was using satellite images and geologic maps covering the tortoise area. The biologists immediately noticed a spatial correlation between concentrations of tortoises and what they termed "the green splotches on the image." The geologist explained that "the green splotches" represented a particular rock type (a unique metamorphic rock) that weathered to soil more rapidly in the desert climate than outcrops of all the other rocks that surround it. The geologist hypothesized that the tortoise had defined its habitat on the basis of geology, reasoning that the need to burrow had caused the animals to seek out readily "diggable" substrates. Given this insight, the biologists went about the task of mapping tortoise habitat in other areas of the military base on the basis of the images' "green splotches," thus saving substantial time and cost (R. Dokka, Louisiana State University, Baton Rouge, pers. commun., Sept. 1, 1993).

Geologic Habitat of the Red Hills Salamander

The Red Hills salamander (*Phaeognathus hubrichti*) is a plethodontid salamander whose entire range is confined to a small area of southern Alabama (Dodd, 1991). The salamander is federally listed as threatened and prefers forested, steep-sloped ravines, and bluff faces for its habitat. International Paper's Forest Environmental Quality Guidelines for managing its habitat (adopted in March 1977) cover almost 30,000 acres of forest located within the salamander's historic range and require periodic population surveys.

During the company's soil survey of its southern ownership, soil scientists examined this area in detail because of its unique geological characteristics and the presence of this species. As the survey proceeded, the scientists were able consistently to predict where salamander burrows would occur on the basis of geologic formation and slope with

in the Red Hills physiographic province. This province consists of hilly terrain of Eocene age that comprises two principal formations, the Tallahatta and Hatchetigbee. The Red Hills salamander is found predominantly in the Tallahatta Formation, which consists of claystone, gray thin-bedded siltstone, and various yellowish gray sands and clays. When the species is observed in the Hatchetigbee Formation, outcroppings of the Tallahatta occur in close proximity.

In early 1992, a population survey was conducted in conjunction with the Alabama Natural Heritage Program (J. McGlincy, W. Dennis, S. Hindman, and S.G. Haines, International Paper Co., Bainbridge, GA, unpublished material, June 3, 1993). The survey was designed to focus on topography and geology identified in the soil survey as most likely to be occupied by the salamander but also included a representative sample of nontypical habitat. Ninety-two percent of survey sites occupied by the salamander occurred on the Tallahatta/Hatchetigbee formations with slopes of 30% or greater.

Soils underlain by or containing siltstone outcrops are the primary habitat determinant. Such sites are typically forested with mature hardwood or mixed hardwood-pine stands that occur on steep slopes. The siltstone, which is moist and easy to burrow through, and the microclimate created by the overstory provide the moist environment required for the salamander's survival.

The integration of population, soil, geologic formation, slope, and vegetative data permits a more refined characterization of preferred habitat for the Red Hills salamander and its occurrence on company lands. This ensures that the habitat is adequately protected during the course of regular forestry activities.

the NPBS. Among them are the Forest Service and Soil Conservation Service in the U. S. Department of Agriculture (USDA), where the Agricultural Research Service likewise has important capabilities in the taxonomy and inventory of many noxious and pest species and their relatives; the National Oceanic and Atmospheric Administration (NOAA) in the Department of Commerce, which has several units and programs concerned with marine and

- coastal organisms and ecosystems; the U.S. Army Corps of Engineers, which issues permits for the development of wetlands and coastal areas, constructs major public-works projects, and has extensive capabilities in freshwater biology; EPA, which has broad environmental responsibilities; the National Aeronautics and Space Administration, which is the lead agency in earth remote sensing, and is the largest sponsor of national and international global-change research; and the National Science Foundation, which provides grants for research into the systematics, ecology, and evolution of the nation's biological resources, making possible much of the research that takes place in universities and freestanding research institutions throughout the United States, and which also runs the Long Term Ecological Research (LTER) program. EPA's Environmental Monitoring and Assessment Program (EMAP—see Box 1.2) and the National Biological Survey are complementary programs with different but related missions. Although it is beyond the scope of this report to compare the two programs in detail, they clearly need to work together. An examination of EMAP is being conducted by another NRC committee which has issued an interim report (NRC, 1992).

In addition, the Department of Defense manages extensive land holdings through all four of the uniformed services, and each carries out activities pertinent to the National Biological Survey, pursuant to compliance with federal, state, and local laws and regulations and in connection with the long-term management of their lands.

- *States.* All 50 states have natural-resource agencies responsible for the management of their fish and wildlife resources. Those agencies have a statutory mandate to protect, preserve, enhance, and manage some or all of the wildlife resources of the state for their esthetic, educational, scientific, economic, and recreational value. The state wildlife agencies have inventory and monitoring programs with substantial databases on many species.

  About 20% of the states have biological surveys of long-estab

lished (1836) to recent (1993) origin. The state surveys often have broad missions and comprehensive research and monitoring capabilities that are directly pertinent to the goals and objectives of the NPBS. State natural heritage data centers, coordinated nationally by The Nature Conservancy, exist in every state, although the organizational placement of the program varies from state to state. This network provides detailed information on endangered, threatened, and selected rare species, and an ecologically based inventory of areas of special importance are found in the state databases. (See Boxes 2.3, 2.4, and 3.2 for examples of how that information is used.)

BOX 1.2: ENVIRONMENTAL MONITORING AND ASSESSMENT PROGRAM (EMAP)

The Environmental Protection Agency (EPA) has led the development of a large program designed to monitor the nation's natural resources, the Environmental Monitoring and Assessment Program (EMAP). The EMAP has several components, including a nationwide grid for systematic collection of indicators of the status and trends of natural resources and several pilot projects for selected terrestrial and marine ecosystems. Several other federal agencies have participated in the EMAP as it has evolved over the last 5 years.

Because the EMAP will provide information on the conditions of natural resources, it will enrich the national database available to decision-makers and the scientific community. Thus, the NBS will not subsume or manage the EMAP, but will recognize that this program, like many others at all jurisdictional levels, will collect and make available information that will contribute to the goals of the NPBS. The NPBS will provide an organizational framework for assisting in the distribution of EMAP-derived information and for relating this information to other sources of data on the status and trends of biological resources. DOI and EPA should work to ensure that the NBS and the EMAP are properly coordinated.

- *The Smithsonian Institution.* The Smithsonian Institution has proposed the establishment of a National Biodiversity Center to

help build its capabilities for dealing with biodiversity around the world, including the United States. The institution has devoted much effort to the development of specimen-based databases and is a national leader in this field. It hosts the Biological Survey Unit staff of FWS, and the National Marine Fisheries Service taxonomy groups, and systematists at USDA. The National Museum of Natural History houses extensive collections of organisms from the United States. The institution has the potential to become a major contributor to the NPBS, especially if it is successful in achieving the goals it has established for itself.

- *Museums.* Museums generally, as collection stewards, are the major depositories of the biological specimens and associated data that constitute a primary source for the NPBS. Large nongovernment museums—such as the Missouri Botanical Garden, American Museum of Natural History, Field Museum of Natural History, Bishop Museum, New York Botanical Garden, Academy of Natural Sciences of Philadelphia, and California Academy of Sciences—are comparable with the Smithsonian Institution in the size and importance of their holdings and must be enlisted in the NPBS effort. Other large museums, such as the Florida Museum of Natural History, are affiliated with universities; they and such holders of extensive collections as the University of Michigan, University of Texas, Ohio State University, Cornell University, Harvard University, University of Kansas, and University of California are important not only because of the size and quality of their holdings, but because of the special and crucial role that they play, in their university settings, in training scientists for efforts like the NPBS. Museums and their scientific staffs are involved in specimen-gathering, identification, collection management, research, data development and analysis, and information dissemination. They not only will be the repositories of the specimens gathered during the course of pursuing the objectives of the NPBS, but should participate directly in planning the research effort and other activities.
- *Universities.* Institutions of higher learning are a major

source of research on the nation's biological resources. Many are already involved in collaborative efforts, such as DOI's Cooperative Research Units and USDA's agricultural research programs. They are also the chief source of training in the scientific disciplines and methods that are crucial to an effective National Partnership.

- *Nongovernment organizations.* Some private organizations, such as The Nature Conservancy and the National Audubon Society, are major landholders, managing land for the conservation of biological diversity. In addition, The Nature Conservancy has established a large-scale database in connection with its Heritage Program, which deals with endangered, threatened, and rare species throughout the United States. Organizations with a similar purpose, which also operate databases, include the International Joint Commission on the Great Lakes and those dealing with important river basins and other habitats, such as the Delaware River Basin. The Center for Biological Conservation was established in 1993 by the Massachusetts Audubon Society to address the problems of species extinction in New England. The formation and funding of such organizations, which have an obvious role to play in the NPBS, are to be encouraged.
- *Cooperative programs.* Existing national and international networks and cooperative programs dealing with large components of the North American biota should be parts of the NPBS. Examples include the following: The Biodiversity Research Consortium—which brings together FWS, the Forest Service, USGS, The Nature Conservancy, and other groups—was organized by the EPA research laboratory in Portland, Oregon, to develop the use of research information for effective biodiversity management on a regional basis. Flora of North America draws together current knowledge of the relationships, characteristics, and distributions of North American plants through collaboration among taxonomic and floristic specialists in universities, museums, and government and private agencies; it makes this information available on paper and in database form to a broad array of

users. The Center for Plant Conservation, a consortium of botanical gardens, maintains an extensive database and acts directly to conserve threatened and endangered plants in the United States. Partners In Flight is described elsewhere in this report (see Box 4.1). The Freshwater Imperative is an effort to promote interdisciplinary and institutional cooperation to address issues and needs related to our understanding of fresh-water systems in the context of environmental change; it is represented by a coalition of scientists from government, academe, and the private sector. CARICOMP (the Caribbean Coastal Marine Productivity Program) is an international cooperative network of 20 marine laboratories in and near the Caribbean basin dedicated to monitoring the status of coral reefs and associated environments throughout the region.

- *Native American groups.* Native American lands in the United States contain over 20 million acres of habitats, some with unique geological, archeological, and biological resources. Many Native Americans are highly knowledgeable about these resources and continue to depend on them for survival. The lands, including those held in trust under DOI, harbor endangered species, old-growth forests, rare communities, and unique ecosystems that receive various degrees of management or protection. Data on those resources will be an important part of the information to be gathered by the Partnership, and the participation of Native American groups is therefore necessary.
- *Puerto Rico and U.S. territories and possessions.* Important biological resources exist in Puerto Rico, trust territories, and other lands and waters under U.S. jurisdiction. Those resources—under a mix of federal and local jurisdiction—should be accorded a high priority in the NPBS.
- *Private landholders and user groups.* Private landholders have a great role to play in the full development of the NPBS; collectively, they own most of the land of the United States (Figure 1.1). Ideally, they should contribute to and derive much benefit from the NPBS in relation to the sustainable use of their

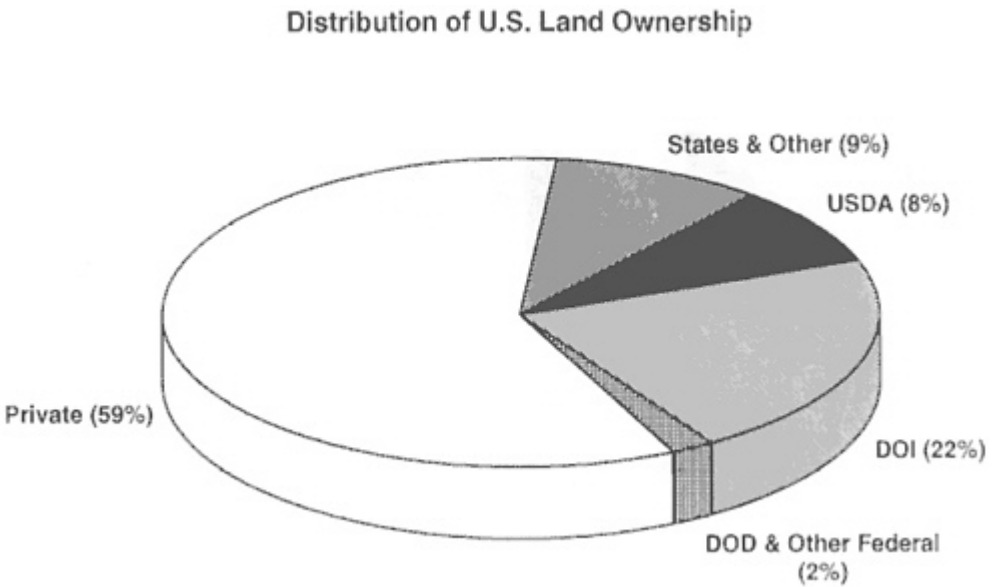


Figure 1.1
Most of the 2.3 billion acres of land in the United States is owned privately. Sources: Federal—National Fish and Wildlife Foundation; Private, State, and Other—U.S. Department of Agriculture

lands. Many large industrial landholders already collect relevant information. The associations representing the private sector—focused on such groups as land-developers, home-builders, and the forestry, mining, farming, and grazing industries—should find that the information available as a result of the operation of the NPBS will add greater certainty to planning for resource development and land use. A chief role for them in the Partnership will be to help to coordinate the relevant activities of their members.

- *Individual scientists.* Much of the critical research and detailed knowledge necessary for the success of the NPBS has traditionally been performed, generated, or held by individual researchers. Those researchers might be professionals or informed amateurs; their participation is vital to the success of the NPBS. They will need to be fully engaged in the process, regardless of their institutional affiliation. Their involvement should be sought, in part, through the wide array of scientific professional societies—such as the Botanical Society of America, the Ecological Society of America, the Society for Conservation Biology, the Wildlife Society, and the American Fisheries Society—and organized volunteer groups, such as the various Audubon Societies and the Izaak Walton League.
- *Foreign biological entities.* Specialists best able to deal with particular groups of organisms in the United States often reside in foreign countries, and their assistance in pursuing the goals of the NPBS should be sought vigorously. No country can house the best or only specialists on all groups of organisms. In addition, special cooperation of the biological surveys of Canada and Mexico and the specialists resident there and in other areas next to United States holdings—such as Russia for the Arctic Sea Region, other Caribbean basin and Central American nations for Puerto Rico and the Virgin Islands, and the nations of the South Pacific for the U.S. possessions and trust territories there—are of special importance. National and state or provincial agencies,

universities, and nongovernment organizations in all those and other countries can contribute to the goals of the NPBS.

MAJOR ISSUES TO BE ADDRESSED BY THE NATIONAL PARTNERSHIP FOR BIOLOGICAL SURVEY

Major policy issues that can be addressed with the formation of the National Partnership are reviewed on the following pages of this chapter. Dealing with each of them effectively requires better, more consistent, and more readily available scientific information about the organisms and ecological systems that occur within our national boundaries.

Preserving the Nation's Biota

The United States is committed to attempting to preserve its biological heritage. The national policy, as embodied in the Endangered Species Act, is to prevent species from becoming extinct. The FWS implements the Endangered Species Act and manages a diverse national wildlife refuge system. The Forest Service is mandated to manage its lands to preserve viable populations of native species over major portions of their ranges, and NPS is charged with conserving the wildlife on its lands. NOAA has similar obligations for all marine species in national waters. All federal agencies are obliged by the National Environmental Policy Act to assess the impacts of their actions on the survival of the organisms that occur on their lands.

Fulfilling those commitments requires accurate and extensive information on the evolutionary relationships among species (Vane-Wright et al., 1991; Nixon and Wheeler, 1992), their

biology, and the status and trends of their distributions and abundance. But such information is often not readily available, and for many groups of organisms (e.g., fungi, mites, nematodes, and marine invertebrates), most species have not yet been described and named, even within the borders of the United States.

For many taxa, sampling methods are poorly developed. Life-history traits and ecological requirements of most species are poorly understood, even among the better-known groups. Our knowledge of microbial diversity is extremely limited. Although the determination of gene sequences has made assessment more feasible than in the past, the application of these methods remains in its infancy.

Because the biological information available is often sparse or of poor quality, threats to the viability of species are often not recognized until the situation is serious and options are limited and expensive. Therefore, many of the remedial actions undertaken are late, costly, and inadequate. The meagerness of information also makes it difficult to determine what land can be altered for economically beneficial purposes with the least threat to biological diversity.

Sustainable Use of Biological Resources

Biological resources—such as food, fiber, and medicines—will be renewable for present and future generations only if they are used within scientifically determined limits. Sustainable use depends on accurate knowledge of the identity, distribution, and life-history characteristics of the species being used and those with which they interact, as well as knowledge of the ecological processes on which their existence depends. It is also important to understand the biological impact of human activities, such as the expansion of metropolitan areas and the extraction of nonrenewable resources. With more complete information, optimum harvest levels and methods can be established on a sound scientif

ic basis, as is done successfully with some sport species. Those necessary data are well established for few species; for most, they are virtually absent.

Maintenance of Essential Ecological Services

Natural environmental processes purify water, maintain air quality, regulate hydrological cycles and flooding, and buffer the carbon dioxide in the atmosphere. Those ecological services can be replaced by technology only in part and only at great economic and social costs. We need to understand these essential services and the exact ways in which they depend on the richness, diversity, and integrity of ecological systems, both natural and altered, and on the individual species that make them up. Such information will also greatly improve our ability to restore essential ecological services in degraded areas. Reliable indicators of functional well-being are not available for most ecological systems, so we typically cannot predict how or when ecological services will be jeopardized by either human activities or natural processes.

Reducing Undesirable Effects across Ecosystems

Human activities in one location can produce undesirable environmental effects elsewhere. For example, the use of fertilizers and pesticides on land can pollute wetlands, rivers, ponds, streams, and coastal marine environments downstream. That pollution can cause a decline in commercially, recreationally, and ecologically important species or in ecological services. Likewise, low-density metropolitan land use in the United States could contribute to the decrease in the numbers of neotropical migratory birds in their wintering habitat. Management and conservation of species and ecological services require greater understanding of

the extent and consequences of functional links among ecosystems.

Management of Land and Water Habitats and Resources

Knowledge of the distribution and abundance of organisms and of their ecological requirements and interactions is essential for scientific prediction of the consequences of different patterns of habitat loss or alteration caused by humans. However, such knowledge is commonly available for only a small fraction of the vertebrate and plant species of a region and for a much smaller fraction of species in other ecologically critical groups like fungi and many invertebrates. Moreover, in many natural and managed communities, ecological relationships among even common species are often insufficiently known. And there is little broad understanding of the collective and specific impact of humans on biological resources, whether that impact results from metropolitan growth, renewable-resource uses, nonrenewable-resources extraction, or other sources. If management decisions are based on detailed information for only a few highly visible species, then costly and irreversible mistakes that adversely affect the production of ecological goods and services are likely to occur.

Maintaining the Aesthetic Quality of Life

In a world populated only by people and selected species of plants and animals that survive in degraded or developed environments, not only would goods and services from our biological resources be reduced, but the aesthetic experiences now provided by them would be drastically impoverished. Contact with nature provides a valuable antidote to the intense pace of modern urban life and is eagerly sought by an increasing number of people. Preserving ample opportunities for a variety of high-quality

aesthetic experiences requires not only preserving species and habitats, but also determining how individual species and ecological diversity contribute to the quality of these experiences and how the impacts of people attempting to satisfy their aesthetic needs influences that quality.

Anticipating Climate Change

Although the rate and extent of future climate change cannot be predicted in detail, substantial change has occurred in past centuries and millenia, and future change, whether or not it is triggered or exacerbated by human activities, would have enormous economic impact. Therefore, it is prudent to understand the biological implications of various levels of change. Ecological productivity and the locations and species composition of ecological communities are among the things likely to be affected. To anticipate the nature and intensity of ecological changes that might be induced by climate change, information is needed on how ranges of species shifted in response to past climate change, the extent to which the species compositions of communities changed, and which species became extinct during times of rapid climate alteration.

Information is also needed on the effects of increased atmospheric concentrations of carbon dioxide and other greenhouse gases on productivity, plant competition, and vulnerability of plants to pests and pathogens. Much is known about the responses of young plants to altered atmospheric concentrations of carbon dioxide, but too few experiments have been performed in the field under different ecological conditions, and only relatively short-term information is available for a limited number of ecosystems.

Prospecting for Biological Resources

People depend heavily on other species for food, chemicals,

fiber, structural materials, and energy. Most medicines, including the 20 with the largest worldwide sales, either are obtained directly from organisms or are synthetic versions of molecules first discovered in nature. For most of the world's people, medicines are substances taken directly from nature.

Even so, enormous potential wealth might remain untapped. About 100 species of plants, of a total of about 250,000, provide virtually all the calories we consume, either directly or indirectly (Prescott-Allen and Prescott-Allen, 1990).

Our ability to splice genes from one organism into another has enormous, largely unrealized potential to increase the nation's pool of economically important taxa. Methods still need to be developed to identify organisms with the greatest economic potential as either sources or recipients of genetic material. The application of biotechnology to marine systems is also of great potential importance (Colwell, 1983). In general, "biodiversity prospecting," which depends on an organized and readily retrievable body of information about organisms, is a rapidly developing field that will benefit greatly from the operations of the National Partnership (for a recent review, see Reid et al., 1993).

Restoring Degraded Environments

Many environments have been seriously degraded by human activities. Soils have been eroded and contaminated with toxic chemicals, species have been exterminated or seriously reduced in abundance, and exotic species have invaded and modified native ecosystems and reduced their ability to function in ways that continue to provide environmental services. Restoring degraded terrestrial environments to their former productivity will require accurate information on crucial factors, such as soil-forming processes, effective methods to decontaminate soils, and knowledge of which species can best establish themselves on degraded sites and alter them to favor the growth and productivity of other

species. In addition, improved methods are necessary for monitoring biological communities to assess the degree of pollution of particular areas. The degradation of coastal marine ecosystems is a widespread and growing problem, but our knowledge of requirements for restoring degraded marine systems is even poorer than for terrestrial ones.

DESIRED CHARACTERISTICS OF THE NATIONAL PARTNERSHIP FOR BIOLOGICAL SURVEY

The National Partnership could be effectively organized in many ways. Regardless of the structure, several general principles should guide the organization and management of all the work of the NPBS, and especially that of the National Biological Survey, if it is to play the leadership role recommended by this committee.

Ability to Conduct Credible Science

The work of participants in the National Partnership must be scientifically credible if its information is to be used widely and with assurance in decision-making and in developing a stronger information base for the management of biological resources. The National Partnership must be

- *Science-driven and guided by highly qualified scientists.* Unless its programs are designed, executed, and evaluated by highly qualified scientists, the information generated by the NPBS will not be credible. Indeed, the hallmark of the Partnership must be the uniformly high quality of its science. Effective management of the nation's biological resources—including protection, use,

and restoration—depends on high-quality research and the judicious use of the best scientific information.

Although the quality of the science must be driven by the standards and criteria of the best research practices, the type and scope of research in the NPBS will be driven by a new partnership of scientists and users. This new model explicitly recognizes that the National Partnership will provide a framework for organizing high-priority research in an integrated fashion across traditional disciplines. Moreover, because the research will be used to enhance knowledge about the status and trends of biological resources for the purpose of managing them wisely, strong interaction is essential between the scientists who produce the information and those who use it.

Ability to Conduct and Stimulate Appropriate Research

The NPBS will conduct and stimulate basic scientific research on the patterns and processes of species diversity and on ecological systems. Such research has proved to be a powerful approach to discovering fundamental biological interrelationships. From such knowledge, predictions and generalizations can be made about the protection, restoration, and management of these ecological resources. The research program of the NPBS will focus both on understanding biological resources and on stimulating and coordinating research that holds special promise for yielding results that can serve important management interests. To meet this need for a comprehensive research base, the National Partnership should

- *Be broadly based scientifically.* The scales on which information from NPBS will be applied will range from individual species to whole regions and from short-term to long-term. The data will need to address a broad range of issues, as described above. The range of information gathered and interpreted must

be equally broad. This Partnership will require expertise in evolutionary biology, population genetics, systematics, toxicology, ecology, and other biological disciplines, supplemented with skills in the physical and social sciences, statistical design and evaluation, and data management. However, the great strength of the NPBS is that these traditional disciplines will be brought together to focus on the nation's biological resources in synergistic and synthetic ways. For example, NPBS must have the expertise necessary to organize existing information and stimulate research regarding human settlement patterns as they relate to the status and trends of the nation's biological resources. These patterns include the growth of metropolitan areas (where over 75% of the population live), the use of renewable resources, and nonrenewable resource extraction.

- *Be broadly connected internationally.* The National Partnership must have the expertise necessary to design and conduct research, interpret results and share them with decision-makers, and coordinate research both within the borders of the United States and, as appropriate, elsewhere in the world. The NPBS must be able to identify gaps in knowledge, expertise, and research approaches, and it must seek to rectify those deficiencies either directly or through the resources and mandates of other organizations. Because the geographic distribution of many species extends beyond our borders, strong links must be established with the biological surveys of Canada, Mexico, Central America, and the Caribbean basin. The scientific, management, and conservation expertise of other bordering nations, such as Russia (for the area surrounding the Arctic Ocean in particular) and the nations of the South Pacific, should also be involved. The many species of vertebrates (especially birds, fishes, and turtles) that regularly migrate beyond our borders likewise need to be considered throughout the areas where they range. To understand the historical origin, diversification, and relationships among our nation's species, comparative research must be done in the context of the worldwide groups to which they belong.
- *Set priorities adaptively.* The need for information is great

and there are many potential users of it. NPBS must have a strategy for its development. That strategy must set priorities among science activities, and it must adapt to new information as it becomes available and to newly identified needs for information. Priorities for the NPBS must not be set discipline by discipline, but rather on the basis of a need to synthesize information required for protecting, restoring, and managing the nation's biological resources. Assessing the current status of knowledge, identifying the most serious deficiencies, and determining how best to gather information that will be of maximum use in guiding further activities should be a central goal of the National Partnership. Because of the many uncertainties and gaps in our current understanding, the work of the Partnership needs to be planned to reduce major uncertainties rapidly and to modify priorities and permit users to change management strategies easily in response to what is learned (Holling, 1978; Walters, 1986). Investment in such an adaptive approach should permit substantial savings in the long term by reducing the risk of costly management errors.

Organization for Program Continuity

Distinguishing important trends from normal variability in the dynamics of biological resources requires long-term, broadly based information. Therefore, the NPBS must have stability in the direction and financial support of its research programs and the expectation of long-term continuity. Data on the status and trends of the nation's biological resources become increasingly valuable as the length of the record increases. Interruptions in the development and maintenance of databases would seriously reduce their value for nearly every purpose to which they might be put.

Ability to Provide Useful Information

The success of the National Partnership will depend in part on

its ability to communicate useful information in a timely manner. Therefore, the information products of NPBS need to be user-friendly and adapted to a variety of users. The Partnership will gather and manage very large quantities of data. In raw form, those data will be difficult for many clients to use properly and effectively, because the data will require analysis and synthesis and because the form in which information is needed will probably be highly problem-specific. Users will need data that vary widely in geographic scope, temporal domain, habitat types, and taxonomic groups. They will use the information for many purposes, including detecting patterns and processes in ecological systems and individual species, detecting the status and trends of biological resources, assessing economic and biological effects of alternative land-use decisions, and making decisions about the protection, restoration, and management of resources. As a leader and catalyst for the National Partnership, the NBS especially will need to find various ways to make information available to many users and for many different uses.

BENEFITS OF THE NATIONAL PARTNERSHIP FOR BIOLOGICAL SURVEY

This brief overview has indicated how information about the nation's biological resources—to the extent that it is relatively complete, up to date, scientifically accurate, and readily available—can be used to benefit the nation. Information about the species that live within our boundaries and across our borders, their historical relationships, and their life histories will form an essential foundation for their effective management and the management of the ecological systems of which they are a part. Information on the structure and dynamics of the many ecological systems that provide important services is essential for our future prosperity. Information on the ways in which those services and material goods depend on individual species, biological diversity, the locations and sizes of particular ecological systems, and their

sensitivity to natural and human-caused changes will support land-management decisions and aid preparations for dealing with potential climate change.

We have concluded that the proposed National Partnership for Biological Survey can make major contributions to our ability to develop and use such information effectively. The benefits that will accrue from the formation of the National Partnership can be emphasized most effectively by discussing them in relation to five points, which in essence constitute a summary of the ways in which the Partnership will be able to address the important issues that have just been outlined. They include some of the most important ways in which the steps recommended here will lead to improvement in our ability to maintain and use sustainably the biological resources that occur within our borders.

An effective National Partnership for Biological Survey would

Provide a better and more efficient information base from which to make planning and operational decisions, thereby strengthening the quality of such decisions and improving the management of biological resources.

The NPBS will identify, develop, and coordinate biological information from many sources, making these sources readily available to decision-makers. The information will remain in many localities and under the custodianship of numerous individuals and organizations. However, under the auspices of the NPBS, it will be cataloged and made accessible in a consistent format. Moreover, as new information is acquired and made available, it will be identified as part of the information base.

Provide, for the first time, an organized framework for collaboration among federal, regional, state, and local organizations, both public and private, where much of the information resides and where many of the decisions are made about biological resources.

The National Partnership will be coordinated and supported at the federal level, with the National Biological Survey playing a key role, but it will include a comprehensive structure that involves public and private organizations at all jurisdictional levels. Thus, information will be exchanged in a network fashion among many entities, and each one can contribute to and use it. In essence, NPBS is a national effort that happens to be coordinated at the federal level.

Provide, for the first time, an organized structure with stated priorities for inventorying and monitoring national biological resources, for acquiring information on the status and trends of these resources, and for understanding the causes of changes in them.

The purpose of the National Partnership is to develop the scientific basis for effective management, use, and conservation of the nation's biological resources. Prerequisites for accomplishing that purpose are to understand the location, status, and trends of the resources; to comprehend their features better; and to assess how human activities and natural processes cause changes in them. In many cases, existing information can be identified and organized to serve these purposes—for example, by the efficient use of museum resources. In other instances, new information must be collected, analyzed, and made available. Not all necessary information can be collected immediately, and the NPBS will need to set comprehensive priorities for organizing existing information and for collecting new data.

Provide improved programmatic efficiencies and economies of scale through better coordination than is now possible with public and private organizations.

Many public and private organizations collect, analyze, and use biological information for making decisions about the management, use, protection, and restoration of biological resources.

Because there is inefficient coordination among these programs, there is likely to be unnecessary duplication, as well as gaps in the necessary knowledge. In addition, much information gathered for individual programs, such as environmental impact statements, is filed and then effectively "lost" for all other purposes. The NPBS will provide a framework for developing a continuing assessment of the availability and quality of information and for efficiently collecting, analyzing, and distributing new and existing information.

Provide an extensive and common information base that will be used to anticipate and lessen potential conflicts about biological resources.

Many decisions about the management, use, and preservation of natural resources are made in response to court cases or to avoid incipient crises. Many of those decisions are expensive in both money and political cost. These problems can be reduced both in number and degree of confrontation with the kind of common, extensive, scientifically credible information base that the National Partnership will develop.

THE LIMITS TO THE NATIONAL PARTNERSHIP FOR BIOLOGICAL SURVEY

The National Partnership for Biological Survey will serve the nation well as it grapples with increasingly contentious and challenging issues in protecting, restoring, and managing its biological resources. Nonetheless, the very richness in biological resources that the Partnership seeks to describe and understand means that decisions will always be supported by incomplete information. Current information is spotty at best. But even with much more research and coordination, decisions will always be based on incomplete information because it is impossible to know

everything about any species or ecosystem. Moreover, values and economic interests other than scientific ones inevitably influence resource management decisions. Although the National Partnership would improve the scientific basis for decision-making, hard choices and conflicts will remain.

In the United States, much biological information is collected, analyzed, and interpreted locally and regionally, and the inclusion of this information will be an important strength of the Partnership. Most environmental decisions are made at state and local levels. Therefore, local, state, and regional nongovernment programs must constitute a vital part of the Partnership. This comprehensive structure of the NPBS will broaden and deepen the information base that supports decisions about biological resources. However, decisions at all levels will be made within the context of human value systems and political processes.

There is a risk that the label National Partnership For Biological Survey would simply be applied to existing science programs in the federal government and elsewhere. But the proposed NPBS has a very specific focus on knowing species diversity and the distribution of biological resources, understanding the patterns and processes that determine their locations and dynamics, measuring the status and trends of these resources, assessing economic and biological effects of alternative land-use decisions, and providing this information to users who must make decisions about the protection, restoration, and management of these resources.

2

SCIENCE IN THE SERVICE OF BIOLOGICAL SURVEY

It follows from the considerations in Chapter 1 that a continuing assessment of the biological resources (species, communities, and ecosystems) of the United States will ultimately benefit the nation in many ways. The body of information that will be developed by the National Partnership for Biological Survey will help the country to meet many objectives and address such issues as the preservation of biota, the maintenance of ecosystems, and the sustainable use of biological resources.

One of the most important uses of the scientific information gathered by the National Partnership will be to assist decision-makers in addressing existing biological resource issues and anticipating future ones. The research activities discussed in this chapter are essential for gathering scientifically reliable information to support the decision-making process. Decisions based on inadequate, unreliable, or incorrect information can be unwise and costly. The chapter first reviews general criteria for setting priorities and then discusses strategies for conducting research on the species of plants, animals, fungi, and microorganisms of the

United States; the communities and ecosystems in which they occur; and the trends that affect the distribution and abundance of populations of individual species and of communities and ecosystems. As in all work of the National Partnership, success will require the extensive cooperation of scientists of many disciplines and from many institutions. Later chapters address the information needs of users and mechanisms to coordinate and manage the work of the Partnership.

Three themes will be emphasized here and in later chapters. First, priorities must be set for much research on biological resources in a new way that is more directly responsive to our nation's needs for better conservation, management, and sustainable use of those resources. Second, inventory, monitoring, and other research activities must expand beyond traditional, disciplinary lines to encompass well-designed, large-scale, interdisciplinary research initiatives on selected taxa, ecosystems, and geographic regions. Third, new interdisciplinary research initiatives must be explicitly designed to investigate functional relationships across different levels of biological organization, different spatial scales, and different temporal scales; the research needs to range from microsites to ecoregions, from individuals to higher taxonomic groups united by a common history, and from days and weeks to geological epochs. These initiatives will need to involve geological, hydrological, atmospheric, social, and other sciences as well as various areas of biology. The need for interdisciplinary environmental research has also been recognized by other NRC committees (NRC, 1990, 1993b).

SETTING PRIORITIES

There will always be more scientific questions to be addressed and more environmental concerns to be met than available human and financial resources can support. Therefore, priorities must be set.

No single criterion can be used to establish these priorities. Many scientific needs exist within the National Partnership and among its clients, and the information produced and managed by the NPBS will have many uses. But one of the strengths of the Partnership is that multiple criteria for setting priorities can be brought together. Potential priorities can be comprehensively evaluated, and individual agencies and organizations can take specific responsibility for addressing them.

Priorities for the National Partnership should be based on the degree to which proposed research advances one or more of the following goals:

- Understanding the status and trends of biological resources that are changing rapidly, are rare, or are threatened by such factors as metropolitan growth, renewable land use, nonrenewable-resource extraction, and natural changes in the environment.
- Learning about biological resources that are identified as important by legal mandates or for economic reasons, such as their status as possible sources of new products.
- Performing research that will guide the remediation and restoration of damaged or degraded ecological systems.
- Evaluating biological resources (species, groups of evolutionarily related species, communities, ecological systems, and landscapes) that are clearly important for science and society but for which relatively little information exists.
- Doing studies that might lead to the maintenance or enhancement of biological diversity and to the long-term sustainability and functional integrity of ecological systems.
- Understanding ecological processes that provide services, such as control of nutrient and soil loss, assimilation and degradation of pollutants, and maintenance of biological diversity.
- Converting small investments of human and financial resources to relatively large returns in understanding of the status and trends of biological resources.

Several general considerations are important in developing priorities. An examination of existing records concerning the past geographic occurrence and condition of species and ecological systems provides a context in which to measure their current status and trends. The same is true for the examination of past management experiences or studies, especially if the information has been gathered in a standard way and is documented (NRC, 1986). For example, the projects for which environmental impact statements are written are potentially valuable experiments, but they are usually treated as one-time sets of observations, rather than as predictions of the consequences of planned manipulations. As a result, there is usually no monitoring to determine the effects of the projects. Such information would be of special importance in remediation and restoration, and those projects are often the only way to generate such information. Finally, priorities should be chosen to enable the National Partnership to carry out its work efficiently and cost-effectively.

The committee believes that the scientific activities and programs of the NBS should focus both on its responsibilities as the main biological research agency within the Department of the Interior and on its proposed role as the lead agency for the National Partnership. The large amounts of land managed by DOI (Fig. 1.1), along with the department's other responsibilities with regard to the nation's biota, make NBS especially important in providing key elements of a program to assess the status and trends of biological resources. The committee therefore recommends the following:

Recommendation 2-1: NBS should perform research needed for the management of lands within the jurisdiction of DOI and species for which it has responsibility. It should also ensure, both through its own scientific activities and its proposed role of national leadership, that needed research is performed to fulfill the central purpose envisioned for the National Partnership—to generate the information required to

understand the current status of the nation's biological resources, how that status is changing, and the causes of the changes.

Given the wide range of national needs identified in Chapter 1, the broad distribution of relevant research efforts in federal and nonfederal organizations, the wide range of management needs within the Department of the Interior, and the short time available to examine these programs and needs in preparation for this report, the committee believed that it would be most helpful by focusing its attention on research needs at the level of the National Partnership rather than concentrating on specific recommendations for NBS research activities. For this reason, most of the recommendations in this chapter apply to the Partnership as a whole and not specifically to the NBS or other participants. However, the committee recognizes that many factors will influence the formal creation of the proposed National Partnership and believes that DOI should work to ensure that needed research is done by NBS or other entities no matter what specific form the Partnership eventually takes. The recommendations below provide a general framework to help members of the National Partnership to develop their research programs, but more detailed examination, based on this framework, of research needs and priorities of key participants, including the NBS, could be usefully performed by an independent group of experts.

SCIENTIFIC RESEARCH ON THE STATUS OF BIOLOGICAL RESOURCES

If the National Partnership for Biological Survey is to realize its purpose, it must greatly strengthen our understanding of the distributions and the factors that govern the distributions of species and higher taxa, communities, ecosystems, landscapes, and marine realms of the United States. To achieve that goal, the

work of the Partnership should meet the following objectives in assessing the status of the nation's biological resources:

- *To determine the identities and distributions of species that live in the United States.* Discovering, describing, and classifying these species will make possible the accurate and efficient identifications needed for many purposes by decision-makers, scientists, and other users. Species need to be understood in the context of their groups, and that understanding necessitates broad, comparative studies of the species in these groups and access to large, representative collections. For species whose geographic ranges extend beyond the United States, information is needed about their distributions in other countries.
- *To use knowledge of relationships among species to produce predictive classifications.* A classification that accurately reflects the relationships among species should improve our ability to predict which species are likely to have particular properties, even if they have not yet been studied in detail (Wheeler, 1990).
- *To determine the physical and biological factors that govern the distributions of species.* Management and conservation decisions affecting particular species are problematic in the absence of information about such basic aspects of their biology.
- *To understand the population biology of species selected for intensive study, management, or conservation.* Detailed understanding of the biology of populations will permit predictions about the consequences of decisions that lead to expansion or contraction of the geographic ranges of species.
- *To determine the types and locations of communities and ecosystems in the United States.* Management strategies that deal explicitly with ecological units require accurate distributional information for these units.
- *To determine the factors that govern the distributions of communities and ecosystems.* Unless the factors that shape and limit the distribution of individual communities are known, decisions intended to manage them sustainably might prove ineffectual.

- *To understand the effects of human settlement patterns (metropolitan growth, renewable land use, and nonrenewable-resource use) on species, communities, and ecosystems.* Much of the current decrease in biological diversity in the United States is concentrated at the rapidly expanding urban-rural interface. Research is needed on the effects of suburbanization on biological resources, and on ways of reducing or mitigating these effects, and on the levels at which settlement can coexist with viable ecosystems.

What Species Occur in the United States? Where Do They Occur? How are They Related?

We need to know what species live in the United States, where they live, and how they are related to one another in an evolutionary sense. Modern classifications reflect patterns of common ancestry and can be helpful in predicting the occurrence of properties of poorly known organisms. Although no substitute for research on individual species, they are thus vital tools in the search for and management of biological resources and provide a frame of reference for biological research. For example, botanists can use classifications to decide where to search for chemicals of potential value to industry and medicine, and entomologists can use them to predict which parasites hold promise for the control of agricultural pests.

The United States has unparalleled taxonomic research capabilities in its public and private museums, botanical gardens, universities, and government agencies. In general, taxonomic research has not been focused specifically on the goals that the NPBS will fulfill, but the Flora of North America, Moths of North America, Birds of North America, similar current projects, and state biological surveys are important examples of the kind of taxonomic research that the National Partnership should perform. Australia (see Box 2.1) and Costa Rica have established national organi

BOX 2.1: ENVIRONMENTAL RESOURCES INFORMATION NETWORK: AUSTRALIA'S RESPONSE TO THE NEED FOR ACCESS TO NATIONAL BIOLOGICAL SURVEY DATA

Australia has pioneered a two-pronged approach to surveying and monitoring its flora and fauna. Within the Australian National Parks and Wildlife Service, the Biodiversity Directorate administers the Australian Biological Resources Study (ABRS), the purpose of which is to collect and document information on the biota of Australia. The Environmental Resources Information Network (ERIN) Directorate is responsible for developing an information-management system and for assembling data on the flora and fauna and analyzing them for management purposes.

ABRS maintains editorial centers for its flora and fauna series and provides grants to taxonomic specialists to undertake the research necessary to classify and describe the plants, animals, and microorganisms of Australia. The grants address the highest-priority needs and are in the form of binding contractual agreements that specify products and a delivery schedule. This scheme ensures that careful scientific work will be done in a timely manner and that scientific attention is focused where it is most needed.

ERIN's mission is to provide geographically related environmental information of an extent, quality, and availability required for planning and decision-making. ERIN contracts with taxonomic specialists and uses data from the flora and fauna series to create its backbone of taxonomic information. It contracts with institutions that maintain biological collections to computerize data on the identities and places of collection of those specimens. This information is brought together with information on physical properties of the continent—climate, topography, soils, etc.—and with information on vegetation, ownership, and conservation status through geographic information systems (GISs). ERIN has developed computer programs that can predict how a species' distribution might change if average temperature increases or decreases; its programs can show correlations among species distributions; and its system can model expected impact on a species' distribution and population viability if part of its habitat is lost, for instance, through development. Individual institutions and specialist groups take responsibility, as custodians, for the quality and reliability of data made available to ERIN. Data standards have been established cooperatively between ERIN and the custodians to facilitate data transfer and sharing.

ERIN has several large-scale data-analysis projects. One is the Landcover Project, which aims to collate data on the distribution of species that make up the dominant groups of plants in the Australian landscape. Another project is the Murray-Darling Basin Project, which is reviewing the availability of environmental data for the area, defining the major ecosystems of the basin and assessing the relationship between the ecosystems and conservation reserves, and developing a strategic plan for the conservation of the ecosystems. A third project is the National Marine Information System, a comprehensive computerized marine-science information base that will include significant data on all aspects of Australian marine environments, including fisheries, mineral resources, ocean currents and climate, and the distribution of marine life around the Australian coastline.

By bringing together the expert knowledge of its biologists, the information held in its rich museum collections, and the innovative and focused use of data-management, analytical, and mapping computer programs, the Australian National Parks and Wildlife Service has assembled a powerful and far-reaching tool for understanding and managing its natural resources.

zations to study and document biodiversity. Their experiences suggest that even small investments in taxonomic research can yield results of importance to decision-makers.

Recommendation 2-2: The National Partnership should determine what specimens and data representing the U.S. biota exist in the nation's institutional collections, both public and private.

Specimen collections are useful for many purposes (see Box 2.2). The large holdings in the United States should be studied and assessed, and the resulting information should be synthesized and made available. By taking stock of the information already available, scientists will be able to find the gaps in our knowledge and take steps to fill them. Some groups of organisms are poorly represented in collections and poorly understood. Examples

BOX 2.2: COLLECTIONS

Within public and private institutional collections in the United States are millions of specimens that document two centuries of exploration of our country and contain a rich trove of information about our flora and fauna. Such specimens are usually parts of organisms (a branch of a tree, a blood sample from a bird), entire animals or plants, or a number of individuals from a population. They are accompanied by information about where and when they were collected, what the place was like, and what other organisms were present. The specimens and their associated data give insight into the ideas of the researchers who have studied them. Collections of specimens are a critical component of the NPBS. In all but a few well-known taxa, identifications of species must be based on voucher specimens, without which frequent misidentifications are certain to be made. Faulty management decisions are likely to result from incorrect identifications. Collections are the repository for most of what we know about species diversity and are constantly pressed into use for new and often unexpected purposes. The tissues and organs of collected organisms may contain valuable information about the environment at the times they were collected. For example:

- Specimens collected 100 years ago can give an indication of what kinds of plants and animals lived at the place of collection then, what the soil, water, or climate was like, etc. By comparing historical and current collections, it is possible to monitor change in conditions. For instance, the decline in fresh-water mollusks in Pennsylvania was demonstrable only because of the existence of specimens collected over many decades from diverse sites.
- Knowledge of the concentrations of mercury occurring naturally in fish ruled out pollution as the source of the mercury, because the specimens were collected before pollution began.
- Many specimens have been studied by specialists over the years and provide documentation for their own research. As researchers try to identify newly collected samples, they can use these vouchers to determine how well new samples fit within the range of variation for a given species as it was understood by earlier specialists. Vouchers are kept for samples used in chemical, ecological, or other kinds of studies so that later researchers can confirm the identity of the samples used.

- Specimens for a given species, genus, or family that have been collected from throughout the geographical area where the group occurs make it possible to compare variation in characteristics of that group from place to place or over time. Plant breeders can search for specimens of a given species with some desired characteristic, such as larger tubers or earlier flowering times, and learn where plants with that characteristic grow and under what conditions.
- Samples of organisms are preserved so as to retain the most information possible. Often, they are simply air-dried; sometimes, they are liquid-preserved or frozen. It is possible to analyze the chemical contents of the specimens; with new techniques, the DNA of century-old and irreplaceable specimens can be probed. Changes in the chemical components of habitats can sometimes be monitored, as well. For instance, collections of egg shells of birds were useful in learning about the effects of DDT.

Natural history collections contain information that is invaluable to our understanding of biodiversity, its history, its current status, and its future. They are an essential resource for the study and management of the biodiversity of our nation.

include mites, nematodes, many groups of fungi, and marine invertebrates. For bacteria, DNA or RNA probes might reveal the extent of diversity, but these organisms are poorly known. Collections of bacteria in culture are indispensable for the further understanding of the group. Even for such well-known groups as plants and vertebrates, there are geographic gaps in our knowledge, and the available records might not have been gathered recently enough to indicate the present status of individual species.

Precise knowledge of what materials and data already exist will facilitate the timely provision of information to those who need it and will help scientists to identify gaps that warrant research. Tens of millions of specimens and facts have been accumulated through more than two centuries of exploration of the biological

diversity of the United States. However, because of the immensity of the country's collections and how they are dispersed, management of this information was impractical before the existence of modern computer technologies. The NPBS, with the NBS taking the lead, should assess, as rapidly and completely as possible, what we now know about the distribution of species in the country on the basis of records of collections. It should also determine the importance of this information for current and future research efforts.

Recommendation 2-3: The NPBS should discover, describe, classify, and map U.S. species of selected taxa.

The National Partnership should go beyond an inventory of information and collections and take decisive and forward-looking actions to fill important gaps already known to exist in our knowledge of U.S. biological resources. Taxa should be chosen on the basis of their economic, societal, or scientific importance and the length of time required to complete the task. Among those appropriate for immediate study are terrestrial, fresh-water, and marine vertebrates (all classes); plants (bryophytes and vascular plants); macrofungi; and selected fresh-water, marine, and terrestrial invertebrates (mollusks, crustaceans, mosquitoes, beetles, butterflies, moths, spiders, and ticks). Special attention should be given to taxa that occur in the areas where regional collaborative pilot projects are established (see Recommendation 2-13).

More complete species inventories and classifications for selected taxa will support environmental research of both immediate and long-term priority. For example, vertebrate, plant, fungus, and arthropod surveys in old-growth forests of the Pacific Northwest would improve the scientific basis for policies related to resource use and conservation. In such inventory work, special attention should be given to preserving specimens for DNA, protein, and other analyses that are particularly useful for evaluating relationships but are not usually possible with older specimens.

The Department of the Interior should initiate studies that pertain to its missions, including vertebrates, plants, fungi, and arthropods. The U.S. Department of Agriculture (USDA) should sponsor research through the Forest Service on taxa that occur in forest lands, committing an appropriate portion of its resources to address private-forest issues, and it should substantially increase support for its systematics-research laboratories (especially those studying fungi and insects). The National Oceanic and Atmospheric Administration (NOAA) should extend its research efforts to include noncommercial marine fishes and increase its survey, inventory, and taxonomic research efforts on marine invertebrate groups. The National Institutes of Health, the Department of Defense, USDA, and the Department of Energy should conduct or sponsor research on mosquitoes, ticks, and other vectors of disease and on potential sources of medicines, feedstocks, biomaterials, and foods.

Recommendation 2-4: Taxonomic specialists, collections, and databases should be established for large and important taxa for which research resources are inadequate, including taxa that live in terrestrial environments (e.g., fungi, nematodes, and arthropods), marine environments (e.g., polychaetes, crustaceans, and mollusks), and freshwater environments (e.g., protists, mollusks, and other invertebrates).

The United States needs to have specialists in all major and important taxa and on taxa for which no experts exist throughout the world. Species of many large and ecologically or economically important groups are unknown or currently unidentifiable because of a lack of relevant expertise. Clearly, an adequate scientific research program must include the training of specialists, support of surveys and taxonomic research, and the building of comprehensive collections of diverse taxa.

Our lack of knowledge of microorganisms and invertebrates, which are estimated to make up as much as 88% of all species, seriously hampers our ability to understand and manage ecosys

tems. Fungi and arthropods associated with nutrient cycling in forests, for example, are only poorly known. For many parks and other protected areas, such groups as fungi and lichens, for which there are few available specialists, are little known or understood. Organisms that prey on or infect insects hold promise for cost-effective and environmentally benign control of insect pests, but the relevant parasitic wasps, nematodes, fungi, and protozoans have been little studied. Important proposals have been made to address this deficiency on a global scale (e.g., Hawksworth and Ritchie, 1993), and our national programs ought to be integrated with such efforts and constructed so to support them.

Our lack of information on marine habitats is also critical. Of the 70 phyla of living organisms, 43 are either exclusively marine (20) or partially marine (23), but gaps in our taxonomic knowledge of many groups of marine organisms are numerous and broad (Ray, 1988).

For fungi, algae, and bacteria, which are critical in the functioning of ecosystems, organizations that maintain living collections, such as the American Type Culture Collection, should be supported. The functioning of the multi-billion-dollar biotechnology effort in the United States alone demands the maintenance of such facilities and underscores the need to add to their collections rationally and aggressively. From a scientific point of view, this approach constitutes the only way to gain an adequate, comparative, verifiable understanding of the groups involved. In a more general sense, the living collections of botanical gardens, zoos, and insectaria are comparable, and such groups as the Center for Plant Conservation, which assembles genetically adequate samples of the threatened and endangered plants of the United States, ought also to be encouraged and supported.

Why Do Species Occur Where They Do?

Surveys of species distribution, abundance, and population

structures provide only part of the information necessary for managing the nation's biotic resources. An understanding of ecological requirements of species is also needed for their management, protection, and restoration, as well as for developing models that can be used to predict their likely distributions and responses to environmental changes. We need basic knowledge of the natural history of species, their patterns of genetic variation, habitat requirements, interactions among widely separated populations, life-history characteristics, feeding habits, reproductive biology, interactions with pollinators, predators and competitors, and vulnerability to anthropogenic disturbance and habitat fragmentation.

Because detailed biological information would be desirable for hundreds of thousands of species, adopting criteria for determining the order in which species are chosen for study is crucial. Species can be selected on the basis of whether they might be ecological indicators; are important to the functioning of ecosystems; represent distinct phylogenetic (evolutionary) lineages; represent taxa that are believed to be declining; have potential or demonstrated economic, scientific, or societal worth; or are at the margins of their geographic distributions. For example, although details of projected climate change due to carbon dioxide emissions cannot be predicted, monitoring populations at the extremes of their distributions might permit early detection of the effects of potential climate change. A high priority should therefore be placed on establishing baseline data on the current status of indicator taxa at range extremes.

The National Biological Survey should perform research on ecological requirements for taxa from ecosystems of current national concern (e.g., Pacific Northwest old-growth forests or coastal estuaries) and from diverse, biologically significant ecosystems (e.g., native forests of Hawaii or unique areas within our national parks, such as the Great Smoky Mountains National Park). USDA should lead research on taxa that fall within its mission, such as agriculturally important insect and plant pests, such beneficial species as pathogenic nematodes and predatory

insects, and introduced species; the national forests should be of primary concern. NOAA should target both marine fishes and little-known marine invertebrates for detailed study; for example, the recent decline of Caribbean reef corals, including those in U.S. waters, might be largely the result of the catastrophic decline in a single species of sea urchin (Lessios, 1988). The U.S. Geological Survey should provide leadership in researching the histories of species and ecosystems as interpreted from the fossil and geological record. Taxonomists and ecologists should participate in the selection of species, and priority should be given to team research.

Recommendation 2-5: Identify and thoroughly study the biology of selected species that have significant economic, scientific, or aesthetic value or play a key role in a threatened biogeographic area or ecological habitat.

Because informed management decisions depend on detailed understanding of the biological habits and requirements of species, it is important to identify species relevant to environmental issues of high priority and initiate the process of accumulating fundamental knowledge about them. For example, the population biology of threatened and endangered species is obviously a subject of high interest (Falk and Holsinger, 1991). Targeted research on selected species should inform the NPBS about future needs, as well as urgent existing problems. Special attention should be given to key species in the pilot project areas described under Recommendation 2-13.

What Communities and Ecosystems Occur in the United States? Where Do They Occur?

Recommendation 2-6: The NPBS should develop classifica-

tion systems for ecological units—such as communities, ecosystems, and landscapes—that will provide consistent terminology for recognizing, mapping and monitoring trends in the distribution and status of those units. The NPBS should also move rapidly to define a set of core ecosystem attributes and protocols for sampling, measuring, and recording those attributes. NBS should play a major direct role in these efforts.

Classification systems for communities, ecosystems, and landscapes are needed for recognizing and mapping them and for communicating information about their status, distributions, and trends. There are currently no broadly accepted classification schemes for such ecological units above the level of species, and no single classification system is likely to serve all management purposes. Community classifications for terrestrial, fresh-water, and marine habitats have been established by The Nature Conservancy and have proved useful for setting conservation priorities. However, classification schemes for aquatic systems are generally poorly developed and rarely applied.

Ecological classifications are extremely important for the management of biological resources on an ecosystem and regional basis, and they need to be developed as fully as possible according to broadly based criteria. The same criteria can be used to design specific classification systems for particular purposes.

With the advent of better technologies for handling spatial data, classification and mapping are no longer limited by such a priori constraints as the need to limit a map to four colors. Instead, geographic phenomena can be described with a set of attributes that can be selectively weighted and combined for a posteriori classification and mapping. For example, specific terrestrial units within a region can be described in a database according to their geology, geomorphology, vegetation height, canopy leaf type, vertical stratification, and canopy floristic composition. Regional vegetation or ecosystem patterns can then be remapped in many ways on the basis of different classification rules.

That approach obviates a single, general-purpose classification system and can serve a wide range of users. Because the basis for classification is more value-neutral than with traditional systems, resulting information will have a stronger scientific basis. Thus, although we need standard ecosystem classification schemes for monitoring and reporting purposes, the databases from which the classifications are generated should record preclassified ecosystem data. To that end, the National Partnership should give high priority to defining a set of core attributes for characterizing vegetation, habitats, and ecosystems and then establishing standard methods for measuring and recording those attributes (see, for example, Bolton, 1991; DiCastri et al., 1992). Eventually, this approach will lead to national and international databases that can be analyzed to uncover patterns in ecosystem structure and composition and to evolve more functional classification systems.

Useful classification systems will permit clear delineation of all included ecological units. They should serve as a predictive base for anticipating interactions among ecosystems and their physical environments. The ecological units recognized should correspond to the distribution of constituent species whose protection is likely to afford protection to the entire community. A hierarchical structure of such classification systems is likely to prove useful, even though effective conservation and management strategies would normally deal with subordinate levels within the system (Bourgeon, 1988; Orians, 1993).

Why are Ecosystems Found Where They are?

Recommendation 2-7: The National Partnership, with the direct involvement of NBS, should stimulate research to understand and develop a predictive theory of *keystone linkages* and *keystone species* and should work toward developing predictive models that facilitate sustainable management of communities and ecosystems in the United States.

Valuable though ecological classification systems might be, they contain little information about why ecosystems are found where they are. The members and kinds of species living together in ecological assemblages are determined by both local and regional processes, including current and historical interactions between organisms and the physical environment. Individual species have specific ranges of tolerance of physical environmental conditions, but the actual range of environments occupied is reduced by interactions with other species. Competition, predation, and parasitism happen only among organisms living in the same area, but the kinds and numbers of individuals available to interact depend on regional-scale processes. For example, a small isolated community is likely to receive many immigrants that belong to species living in adjacent but different communities, whereas most immigrants to portions of large, extensive communities come from other parts of the same ones. Interactions with humans occur at all spatial scales. The result of all these interactions is a recognizable, but not identical, assemblage of species that occupies a particular zone of environmental conditions.

The interactions that structure ecological assemblages range from strong to weak. Ecologists refer to very strong interactions as *keystone linkages* and to species that exert the strongest influences on the composition and functioning of the assemblages of which they are a part as *keystone species*. Keystone linkages and species are often identified empirically after the fact. Ecological theory cannot yet predict where keystone features will be found, although experience shows that some higher taxa, such as large echinoderms in the ocean, typically play a keystone role. Developing a predictive capability is important because it would enable direction of attention to elements and interactions whose maintenance is critical to the continued and undiminished production of important ecosystem services.

Recommendation 2-8: The NPBS should encourage research on restoration of degraded environments.

Terrestrial and aquatic ecosystems of the United States have been degraded by human activity. Although restoration has been attempted often, it has rarely been successful (NRC, 1992). Understanding why communities and ecosystems are found where they are and how they interact with adjacent assemblages is also necessary as a foundation for methods of restoring degraded and damaged ecosystems. To restore a community, we must know what the community was like before it was degraded, how many and what kinds of organisms are likely to arrive in the area without human assistance, and what conditions are necessary if arriving individuals are likely to colonize successfully.

Research is needed on restoration methods that will work in the highly varied terrestrial and aquatic environments of the United States. Successful restoration also depends on historical analyses that permit an assessment of the types of ecosystems that can persist in an area.

Efforts in restoration biology can take advantage of the large-scale "experiments" represented by major development projects that are required to file environmental impact statements (EISs). The EIS amounts to a prediction of the extent and kind of impact a project will ultimately have on the local environment. Scientists can learn much from this process if EISs are done in such a way as to establish a baseline and if appropriate follow-up monitoring is done to learn the eventual ecological impact. Properly done, such "experimentation" can reveal what kinds of projects have more or fewer environmental impacts than expected. It might not be practical to treat all EISs this way, at least initially; but specific case studies can be chosen to represent common classes of environmental problems for which knowledge of the success or failure of specific management decisions could inform future approaches.

Recommendation 2-9: The NPBS should identify target areas for restoration. As a pilot project, NBS should lead the Partnership in an assessment of the rivers of the United States

to identify those most appropriate for restoration according to biological indicators. The effort should be coordinated with current work of the Corps of Engineers, the U.S. Fish and Wildlife Service, the Environmental Protection Agency (EPA), and the U.S. Forest Service.

An important role for the NPBS would be to identify target areas for restoration. As an example, consider the flowing waters of the United States, which have been highly affected by human activity. We lack an inventory of the rivers of the United States that would permit setting priorities for restoration of rivers or river segments (NRC, 1992). There is a need for a national river inventory that would place the nation's rivers in three categories: healthy, degraded, or highly degraded. Rivers characterized as "degraded" should be selected for aggressive restoration efforts. Mildly degraded rivers could be improved with a modest investment. Within that class, restoration priorities can be based on potentially valuable species, recreational value of the ecosystem, or other criteria. A similar inventory could prove useful for targeting restoration efforts in other types of ecosystems.

Recommendation 2-10: Current chemical assessments of pollution sites (terrestrial, fresh-water, and marine) should be augmented by NPBS research to develop biological assessment protocols.

The detection and characterization of polluted sites (fresh-water, marine, and terrestrial) by EPA and other agencies now rely almost exclusively on chemical assessments of habitats. Among the many species that have such habitats are many that might serve as biological indicators of pollution. Research should be done to identify such indicator species and learn enough about their biology to make it possible to recognize warning signs of particular kinds of pollution. Pollution assessment through such biological approaches is potentially more cost-effective, quicker,

and more useful than chemical methods. The indicators should also prove useful for tracking the remediation of basic pollution problems.

Interactions among Ecosystems

The survival of species and the maintenance of essential ecological services commonly depend on patterns of species migration and transport of materials among ecosystems over an enormous range of spatial scales. Thus, local changes in one ecosystem might have major consequences far beyond their immediate range of obvious impact. Examples include the suspected reduction of North American songbirds due to tropical and temperate habitat destruction and fragmentation effects, including lower productivity and survival (Terborgh, 1989); decreases in salmon due to migration restrictions, nonpoint pollution, and sedimentation; and decreases in aquatic species due to point and nonpoint pollution, sedimentation, introduction of exotic species, changes in hydrology, and loss of wetlands (Thorne-Miller and Catena, 1991). Most such examples involve either outright habitat destruction that interrupts the movements, breeding, or seasonal survival of widely ranging species; increases in the natural flux of materials from terrestrial "source" to aquatic "sink" habitats; or unexpected impacts on one habitat as a direct result of modifications made in another. In any case, effects can be highly specific, as in the interruption of the life cycle of symbionts that depend on particular hosts, or much more general, as exemplified by the dramatic alteration of the entire Lake Erie ecosystem by the accumulation of nutrients. Impacts can move from one terrestrial habitat to another, from terrestrial to aquatic habitats, or from fresh-water to marine habitats. The pesticide DDT, for example, applied to agroecosystems, became concentrated as it moved up terrestrial and aquatic food chains (Carson, 1962).

Many harmful ecosystem interactions can be restricted to a

single watershed or forest, but most are broader in scope and transcend local or even regional political boundaries. The National Partnership can play a critical coordinating role in the identification of important shifts in ecosystem interactions and the gathering of existing and new information on the magnitude of habitat alteration or the material flux responsible. These activities should lead to the identification of a small number of critical model systems for intensive study. The systems should be included in the group of projects referred to in Recommendation 2-13. Important candidate systems that are already the focus of considerable local and federal attention include the effects of agriculture and land development on fresh-water and marine ecosystems in South Florida (see Box 2.3), and the loss of flyway habitat of migrating birds (see Box 4.1)

DETECTING TRENDS IN BIOLOGICAL RESOURCES

The purpose of studying trends is to identify biological resources that are changing in quality and quantity and to determine why they are changing. The resources whose changes are of interest include species and their constituent populations, evolutionarily related groups of species, ecological communities, and ecosystems.

The importance of identifying trends in the condition of resources and determining the causes of changes is highlighted by the increasing evidence of rapid declines in important groups of organisms. For example, a rapid decline in populations of at least half the species of mushrooms has been documented in Europe (Arnolds, 1988, 1991; Gulden et al., 1992). Those fungi are fundamental to healthy ecosystems because they form intimate associations with plant roots, and the associations increase the rate at which the roots absorb nutrients from the soil and make it possible for plants to survive in the particular ecosystems where

BOX 2.3: SOUTH FLORIDA AND THE EVERGLADES

The South Florida landscape is dominated by a series of closely linked wetlands and aquatic ecosystems that extend from the Kissimmee River and Lake Okeechobee in the North through the Everglades and Florida Bay to the Florida Keys in the South. The Everglades is the largest wetland ecosystem in the contiguous 48 states and has been the subject of intense controversy about the ecological effects of drastically reduced and altered patterns of water drainage and increased nutrient inputs from North to South due to flood control, agriculture, and human settlement.

Attempts to assess status and trends of terrestrial and marine biota in South Florida have been hampered by ignorance of the biology of many species, especially invertebrates and lower plants, which have been ignored except by a few systematists. For example, the endangered Florida Snail Kite is almost exclusively dependent for its food on one species of freshwater mollusk, the apple snail. A real-estate developer would never plan a human community without serious consideration of the location of supermarkets. Yet, agencies have been forced to make major decisions about habitat protection for the Snail Kite with very little knowledge about its sole source of food (National Audubon Society, 1992).

Failure to monitor components of adjacent ecosystems (e.g., wading birds in the Everglades, phytoplankton in Florida Bay, and reef corals in the Keys) has delayed understanding of their close interdependence. This failure has greatly increased the probable costs for environmental restoration over what would have been required if the necessary scientific assessments had been made sooner.

There is also no well-established regional infrastructure to bring together status and trends data on organisms and conditions in disparate environments. Moreover, much existing information is effectively unavailable for lack of local resources and personnel to access and interpret crucial remote sensing data, as for algal abundance and productivity in Florida Bay.

The management authority for different biota, habitats, and water resources is fragmented—scattered among federal, state, and county agencies that work under different and sometimes conflicting missions and mandates. For example, the U.S. Army Corps of Engineers and the South Florida Water Management District share responsibilities for

water-resource management. The U.S. Fish and Wildlife Service, the National Park Service, the National Oceanic and Atmospheric Administration, the Florida Bay and Biscayne Bay State Parks, the Florida Game and Freshwater Fish Commission, and the Florida Department of Environmental Protection all have jurisdiction over various marine and terrestrial protected areas and wildlife in the region. Counties and state agencies share jurisdiction over land-use planning, zoning, development, and resource use. Much ecologically important land is owned privately. While some is managed for conservation, most is used for agriculture or human settlement.

South Florida is by no means unique in this fragmentation of authority, which interferes with the abilities of agencies and the private sector to address a common set of environmental problems and needs. Closer coordination is clearly needed.

Important local initiatives have begun. Secretary Babbitt recently announced an agreement among major parties to reduce harmful nutrients and improve water flow to the Everglades. This initiative and subsequent actions would be greatly assisted by the proposed National Partnership for Biological Survey. For example, cooperative studies involving the National Biological Survey, the Corps of Engineers, the South Florida Water Management District, and universities could use existing water-control structures to determine how Everglades ecological communities respond to different water-supply regimes. Such knowledge is essential for effective restoration and sustainable use of this great wetland.

they occur. The causes of the decline are not fully known, but both air pollution and acid rain are suspected contributors. Determining the causes is made more difficult by the decrease in the number of taxonomists and ecologists studying fungi and by lack of sufficient attention paid in the past to the distributions of fungi.

The trends portion of a status and trends program should have the following objectives:

- *To identify trends in a timely manner so that corrective actions can be taken while multiple options are available.* Typically, the later a corrective action is taken, the fewer and more expensive are the ones that remain. Generally, an ounce of prevention is worth a pound of environmental restoration.
- *To learn how local actions, both individually and collectively, influence processes and products elsewhere.* Spatial interconnectedness is important. As projects study selected ecosystems in detail, potential impacts of ecosystems and their components on one another should also be monitored.
- *To reduce uncertainty about risks so that expensive remedial actions are not undertaken unnecessarily.* Faced with great uncertainty about risks, decision-makers are likely to take action to avoid any risk because they cannot afford to remain passive when the possibility of great risk cannot be ruled out. The more accurate the available information, the more appropriate and cost-effective the steps taken will be.
- *To evaluate the effectiveness of management decisions.* One of the requisites of adaptive management is that options that are chosen should be evaluated by monitoring the changes in the managed resource, and the management plan then revised accordingly.
- *To direct attention to areas where problems are most likely to develop in the near future.* Among such areas are urban expansion zones, estuaries, rivers, and zones of intensive resource management and extraction.

Data Useful for Determining Trends and Their Causes

Trends in the status of biological resources cannot be identified or understood unless a solid database on the identification and distribution of the resources is available. Collections and related literature are a primary source of information on the past status of

species and ecosystems. The information they contain needs to be computerized and made efficiently and rapidly available. Sampling procedures need to be set up to ensure that records of selected taxa and ecosystems are kept up to date. Historical information on several time scales is needed:

- *Within recorded history.* Data on the distributions and status of natural resources within historical time are provided by specimens in museums and herbaria, photographs, written records, archival aircraft and satellite imagery, and oral histories. Such information is especially valuable because it is potentially more complete than information from the more distant past, because the causes of changes are likely to be human actions similar to those operating today, and because it can help predict what resource status is potentially achievable if the adverse effects of human actions are sufficiently reduced in the future.
- *Within postglacial times.* Paleoclimatologists and paleoecologists are able to reconstruct climates during the last glacial period and the period during which the glaciers retreated to approximately their current positions. They can also reconstruct shifts in the distributions of organisms and ecological communities that accompanied climatic changes. Those long-term records reveal that the ranges of species shifted at varying rates and that species assemblages differed strikingly from any found today. If climate change occurs, whether naturally or as a result of human activity, information about ecological responses to past change will be useful for managing ecological communities in the face of future shifts.
- *Over geological times spans.* Although data on long-term, evolutionary changes in the earth's biota are inevitably less complete than data from the more recent past, they provide valuable insights into the evolution of the groups of species found today, how they achieved their current distributions, and what happened when organisms from different geographic regions interacted with one another for the first time. For example, when

> North America and South America were joined by the formation of the Panamanian land bridge about 3 million years ago, many species of mammals crossed that bridge in both directions. At first, there was in increase in the number of mammalian species in South America, but over time many groups of South American mammals became extinct, probably as a result of competition with and predation by North American mammals (Marshall, 1985).

Given that human activities are resulting in massive exchanges of species between continents, extinctions and ecological adjustments of biotas will continue to increase in intensity in the future. For example, invasion of alien species is the major cause of extinctions in the Hawaiian Islands today (see Box 2.4) and has had substantial effects on many mainland ecosystems (Mooney and Drake, 1986). Detecting invasions of exotic species and minimizing the impacts of their colonization of the United States is an important use that decision-makers will make of information from the National Partnership.

Data on Current Trends

Because the dominant organisms in many ecological systems, such as trees and corals, are long-lived, many important changes in ecological communities and ecosystems are too slow for us to sense directly (Jackson, 1992). Our abilities to interpret slowly operating cause-effect relationships are even poorer. Therefore, processes acting over decades are hidden and reside in what has been called the invisible present (Magnuson, 1989). In the invisible present, change can be occurring but undetected because of confounding factors. Only long-term sustained monitoring and research can reveal these slow but important changes.

Recommendation 2-11: The National Partnership should identify and monitor the status and trends of organisms sensitive to climatic and pollution factors, such as amphibians,

mollusks, songbirds, reef corals and other marine invertebrates, and fungi.

Changes in distributions and abundance of species are important indicators of impending problems. They can direct attention to areas where improved understanding of the causes of changes will be especially useful to decision-makers. Species whose ranges and abundance are increasing provide signals as valuable as those from species whose distributions and abundance are decreasing. Studies at the margins of ranges of species are particularly important for understanding the patterns of adaptation of those species to extreme conditions and their likely response to change.

Recommendation 2-12: The NPBS should perform research to identify the most useful biological indicators of ecological trends.

Because the goods and services that the nation receives from ecological communities depend, in part, on their functional integrity, indicators of functional-integrity are important to develop and monitor. Whereas ecologists can identify general indicators, much work needs to be done to determine which attributes are most usefully measured in particular ecological communities and for particular management purposes (Karr, 1987). Some indicators will have direct relevance to policy or management objectives (e.g., responsible use of an economically valuable species whose viability depends on specific functional properties of an ecosystem). Others will serve primarily as signals to direct general attention to a region or type of ecological community. All indicators should be judged against standards of repeatability and precision so that changes and trends can be unambiguously detected.

Before a monitoring and assessment program is established, considerable investment is needed to identify the most useful indicators. Procedures for doing so include workshops, seminars,

BOX 2.4: HAWAII AND THE PACIFIC ISLANDS: AN URGENT CONSERVATION PRIORITY

Strikingly different from the continental United States are the island systems of the Pacific Ocean for which the United States has current or historical responsibility. These comprise some 2,300 islands in eight political jurisdictions extending over an area much larger than that of the 48 states. In these islands, there are more endemic organisms per unit of land area than anywhere else in the United States and possibly more than anywhere else on earth. Over three-quarters of the bird and plant extinctions in the United States have occurred in Hawaii, where 34% of the country's endangered plant species and 40% of the nation's endangered bird species are found; another 30 bird species in Micronesia are proposed for federal listing. Thus, the Pacific is a priority for preserving biodiversity, with its rapidly changing political and economic situations—and time is running out. These island habitats and their associated marine communities can be dealt with effectively only through well-coordinated field research focusing on species inventories, adequate ecological information, and especially the role of alien-species invasion in island communities. In dealing with Hawaii, the unincorporated U.S. territories, American Samoa and Western Samoa, the Commonwealth of the Northern Mariana Islands, the Republic of Palau, the Federated States of Micronesia, and the Republic of the Marshall Islands, the organization of a separate office within the NBS and of special attention within the NPBS seems indispensable.

In Hawaii, making up only 0.2% of the land area of the United States, there are more than 10,000 unique species of plants, animals, fungi, and microorganisms—more than 90% of all the native species there. Starting with the arrival of the Polynesians 1,500 years ago and accelerating after the arrival of Europeans nearly 300 years ago, humans have already destroyed 90% of the dry forests, 61% of the mesic forests, 42% of the wet forests, and 3% of the subalpine forests of these ecologically diverse islands. Yet biodiversity is of critical importance to the future of Hawaii, in relation to land development, tourism, the preservation of unique species and for many other reasons. The integrated approach of the NPBS can powerfully influence the course of development and the future of biodiversity there.

Nonnative species are a special threat in Hawaii and throughout the Pacific. Their populations should be monitored closely through a coop

and, where necessary, pilot projects. Retrospective analyses might help to identify indicators that would have been especially useful in the recent past if they had been used systematically. The NBS should be directly involved in this research.

erative effort of the federal, state, local, and nongovernment agencies involved. Controlling these alien species is of critical importance for the preservation of native communities, to protect agriculture, and to retain options for the future. For example, banana poka (*Passiflora mollissima*) has already smothered over 70,000 acres of native forest on two islands and threatens to spread rapidly over additional forested areas. The brown tree snake (*Boiga irregularis*) introduced on Guam has brought about the extinction of nine of the 11 species of native land birds since 1975. Hawaii is invaded successfully by at least 20 new nonnative invertebrates each year, with as many as 39 recorded for a single year (Nature Conservancy of Hawaii, 1992). Some of these species are destructive to native species, others are injurious to agriculture, and still others cause problems for human health.

Cooperation among a number of different entities—including several departments of the state government; conservation groups led by The Nature Conservancy; the University of Hawaii's Center for Conservation, Research, and Training and other units; botanical gardens linked by the Center for Plant Conservation; and the Bishop Museum—appears to offer a promising direction for developing appropriate strategies for the management of biodiversity in Hawaii in the context of regional development. The recent adoption of a State Natural Area Partnership program, which will provide 2:1 matching funds to private landowners for long-term stewardship on their lands, is of special importance nationally and would doubtless work well in other areas. The development of a State Secretariat for Conservation, housed at and partly funded by the University of Hawaii, is another promising effort to contribute to the integration of conservation efforts in Hawaii. The kind of partnership among federal agencies that is envisioned in the NPBS could complete the picture and make the single area that represents one of our most critical conservation priorities a model for the rest of the country.

REGIONAL COLLABORATIVE PROJECTS

Recommendation 2-13: The NPBS should establish pilot projects in key selected regions of the United States, in which terrestrial, fresh-water, and marine communities and their interactions will be identified, characterized, mapped, and monitored.

Our nation's biological resources are so great that management strategies aimed at single species are often impractical or ineffective in preserving or restoring them. Therefore, effective management requires that assessments of status extend from individual species to the ecosystems in which they live and that these assessments include an understanding of key mechanisms and the processes that regulate them. A more detailed knowledge of what makes ecosystems work as they do and how they are being affected by human activities that fragment and degrade them will help us to deal with the increasingly complex legal questions pertaining to land use and water management.

To develop this cross-scale and multidisciplinary information, the NBS should work with other members of the National Partnership to choose a series of pilot projects targeted at areas that are changing rapidly because of different types of human activity (for example, metropolitan development, agricultural expansion, and resource extraction); areas of high biodiversity; areas in which diverse fresh-water, terrestrial, and marine ecosystems interact closely; and areas that are ecologically unique. A series of workshops should be conducted to determine which areas to select and how to design the projects.

The projects should be designed to produce detailed ecological understanding of a range of ecosystems for comparison with other studies as starting points for long-term monitoring and as the first pieces in a national network that should ultimately include all major kinds of ecosystems. Equally important, these projects can serve to develop and refine methods for conducting future re

search more efficiently and effectively. Some of these sites would be ideal places to conduct all-taxa biological inventories (Yoon, 1993).

These projects should not be limited to taxonomic and ecological research. Evolutionary changes often accompany environmental ones and merit careful analysis. For example, the evolution of resistance to chemical pesticide has often occurred within a few generations or years (Georghiou, 1972). The genetic structure of salmon populations can change rapidly and markedly in a few generations in response to the rearing and releasing of hatchery fish (Gross, 1991). On a longer time scale, understanding the changes that have occurred in North American environments through geological time provides a baseline for comparison of the current status and trends. The projects should also involve other disciplines as appropriate, such as geology, hydrology, atmospheric science, and the social sciences.

If the sites of the studies are well chosen, the projects can be especially useful in producing the kinds of scientific information that is needed to manage ecosystems effectively. They can also provide important opportunities for cost-effective collaboration among participants and for implementing an adaptive approach to priority-setting and management. Such an approach could be especially useful in areas like southern Florida, where many agencies and other organizations have separate or overlapping jurisdictions in one watershed and can operate under different or conflicting mandates (Box 2.3). In many cases, the studies might be able to take advantage of existing research and management programs (e.g., in reserves or long-term research areas) run under the auspices of various participants.

3

MEETING THE INFORMATION NEEDS OF NPBS CLIENTS

One of the most important uses of the scientific information gathered by the National Partnership for Biological Survey is to assist decision-makers in addressing existing issues and in anticipating future ones related to biological resources. Recommendations made in the previous chapter for setting priorities for research and data-gathering emphasize factors relating to both near-term and long-term resource management. The research activities outlined in Chapter 2 are essential for gathering scientifically reliable information on which credible and reliable decisions can be made with a high level of confidence. Decisions based on inadequate, unreliable or incorrect information might be unwise and costly.

To respond effectively to information needs at all levels (local, regional, national, and international), NPBS and National Biological Survey (NBS) data and information policies and programs must move from problems to solutions. To do so, the National Partnership must address the following questions:

- Who are the current and potential users of the kinds of information that the NPBS will produce, and how can their needs be met? In particular, how can research findings be communicated to decision-makers in ways that foster understanding and promote appropriate interpretation and use?
- How should NPBS information be collected and managed to serve modeling and prediction efforts in support of biological-resource management?
- How can the NPBS make the best use of the rapidly evolving technology and systems in information management?
- How should information collection and management be coordinated among NPBS participants?

Those questions should be addressed as soon as possible to produce a detailed information model describing the flow of information from collection and analysis to dissemination and use. The model should address general conceptual issues, such as designing stronger linkages between scientific information and decision-making, identifying key environmental variables and relevant spatial and temporal scales, and assigning clear institutional responsibilities to minimize redundancy. It should also deal with technical issues, such as data format, data-exchange protocols, quality assurance and control, and hardware and software requirements.

This chapter highlights some central issues for linking scientific information to decision-making and offers recommendations on the quality, availability, and dissemination of information.

INFORMATION NEEDS

The National Partnership will have to provide information on biological resources in an easily interpretable form and in a timely manner to a wide array of resource managers, city planners, conservationists, scientists, and others. Its databases will have to

be able to answer standard questions about plants, animals, and microorganisms, such as "Where does this species occur?" and questions that require more complicated data analysis, such as "What species occur in a given vegetation type, and which of them occur in other vegetation types as well?" Answers to those kinds of questions should be available simply, quickly, and conveniently, to anyone who needs them.

Mechanisms must be developed to provide reliable answers to complex user queries that require new analysis and interpretation of existing data. Resource-management decisions are themselves sources of information about biological processes, and data accumulated from them should be incorporated in databases and made available to be used in future decision-making.

Some specific needs for NPBS data are the following:

- Public agencies need better biological data to guide acquisition of land and water rights for reserves; set priorities for research, management, and restoration programs; zone local land use and regulate use of public and private lands; locate and design public-works projects; and coordinate resource management both domestically and across international borders.
- The private sector needs better information on the distribution of legally protected resources; on the impacts of metropolitan growth on ecological resources, renewable land use and nonrenewable natural resources and ways to reduce those impacts; on the distribution of species of potential economic value; and on the biological impacts of pollutants.
- Decision-makers need readily available information on status and trends to alert them to issues that require legislative or regulatory attention and to assess the effectiveness of current programs.
- Research scientists need improved access to biological data to help direct and design their research.
- The public needs information on local organisms and habitats, on the ecological role of humans in the environment, and on regional and national trends.

Despite increasing management attention to ecosystem patterns and processes, much planning and development is still based on single species. In the absence of abundance or trend data for most species, inferences about status and about conservation risk must be drawn from incomplete distribution data and habitat models. Box 3.1 illustrates how spatial data can be integrated to model distribution and management status, in this case for the orange-throated whiptail lizard (*Cnemidophorus hyperythrus*). The example highlights several important points:

- Species distributions are almost never known with certainty. Rather, they are modeled by integrating information from such widely disparate sources as biogeographic atlases, museum collections, habitat-relationship information, and habitat maps derived from environmental data and remote sensing imagery. Users of distribution information must be clearly informed as to who produced it, how the results were obtained, the information scale, potential biases, and inaccuracies. This knowledge of information quality is needed to ensure appropriate use of the information. Even for an easily observed and relatively well-known species, existing collection and sighting data are likely to be dated or biased. Computerization of existing data must be weighted in a way that recognizes the differences in precision of different records.
- For conservation and management, knowing where a species occurs is less useful than knowing what processes allow the species to persist in some areas and not others. This requires observation, experimentation, and modeling to develop good life-history information and an understanding of ultimate controls on species' distributions and abundances. For both practical and scientific reasons, we are unlikely to have this knowledge in detail for most species in the near future. Until it is available, we will have to depend largely on the best available survey and monitoring data, correlative analyses, and scientific judgment.
- Hierarchical integration and spatial display of existing

distribution and habitat information is a powerful tool for revealing information content and sampling biases in the data and for setting priorities among taxa and areas for research and management. Integration also helps to highlight possible spatial interactions among neighboring regions and ecosystems.

Only a small fraction of existing biological data and information is now used in planning and decision-making. These activities require information that differs in kind and formats from what is typically generated by systematists and field biologists, (see below), and the results of academic and agency research are communicated poorly to decision-makers (NRC, 1993b). Managers complain that relevant information is scarce, hard to find, and scattered among many institutions. Furthermore, available information is often out of date and not applicable to local problems. Regional planners are stymied by the uneven geographic coverage of existing data and by the difficulty of integrating information produced by different agencies at different times with different methods of sampling, classification, and mapping.

There is wide agreement on the urgent need to organize existing biological information and make it more readily available and to coordinate future data collection and exchange (e.g., NRC, 1993a, b). This is a substantial task, and neither its importance nor its difficulty should be underestimated. Data on a wide array of topics, ranging from species distributions to socioeconomic activity, and from many disciplines and sources must be integrated. Only a tiny fraction of these data is now readily accessible for integration. Existing data are unevenly documented and do not constitute a representative sample of all the nation's biological resources.

Despite the size of the task, a national biological information system is clearly attainable. Although they are far smaller than what is proposed in this report, the experiences of ERIN in Australia (see Box 2.1), INBio (the National Biodiversity Institute) in Costa Rica, and a number of U.S. state initiatives show

BOX 3.1: THE UTILITY AND LIMITATION OF SPECIES DISTRIBUTION DATA

The accompanying diagram and figures show how disparate spatial data can be integrated in a GIS to represent the distribution and conservation status of a species. The process is illustrated for the orange-throated whiptail (*Cnemidophorus hyperythrus*), a lizard native to coastal Southern California and Baja California. The species is considered threatened in California because it depends on coastal sage scrub, a habitat that has been severely reduced and fragmented by urban development. Together with the California Gnatcatcher and the Cactus Wren, the whiptail now serves as a "target species" for ongoing multispecies conservation planning efforts in the region (Hollander et al., in press).

Distribution data for the whiptail are exceptionally good because it is easy to observe, occurs in accessible areas, and has been sampled intensively during the course of recent environmental impact studies. Available information includes life-history notes, a coarse map of range limits, and a table of habitat preferences, which are provided by the California Wildlife Habitat Relationships (WHR) System (Zeiner et al. 1990); remotely sensed Thematic Mapper imagery of Orange, Riverside, and San Diego Counties (Panel A); digital maps of land ownership (Panel B); museum collection data and sightings spanning the past century (Panel C); and maps of suitable habitats as defined by vegetation in the WHR System and mapped at two different scales with 1990 Thematic Mapper satellite imagery (map boundaries from the California Gap Analysis) and 1991 aerial photography (regions with small crosshatching in Panel D were mapped as part of San Diego Counties Multispecies Conservation Plan-MSCP). The processing steps necessary to produce Panel D—which is a composite of field sighting data, habitat maps within the range limits of the species, and the location of existing nature reserves—are shown in the accompanying flow chart.

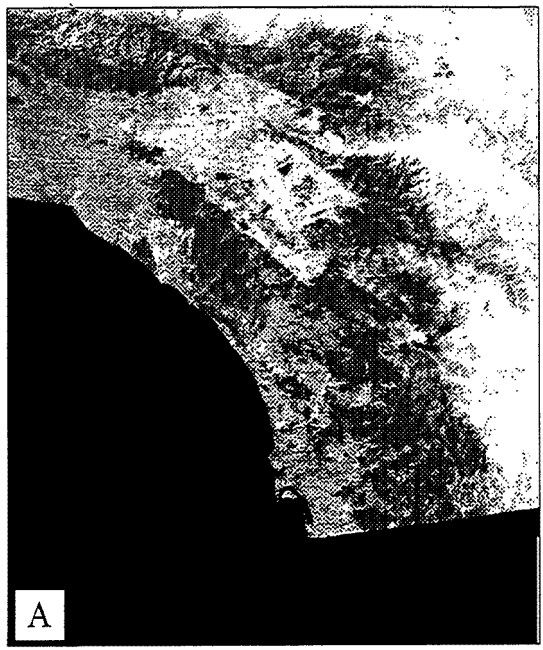
This example illustrates both the utility and limitations of existing information for mapping species distributions and assessing their conser

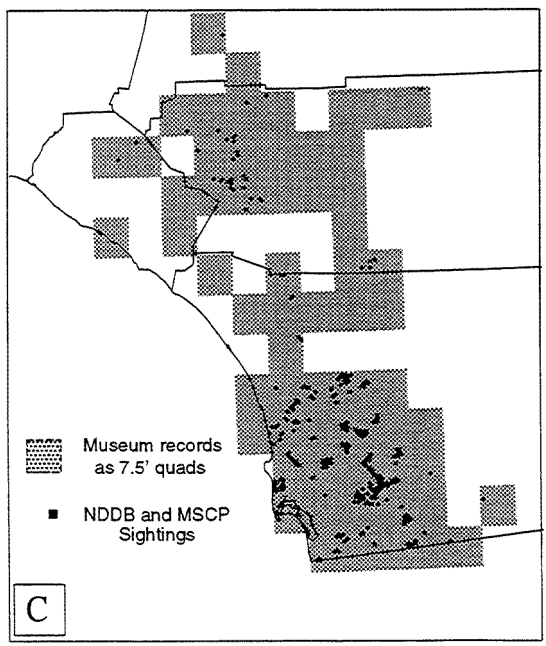
vation status. Specifically, existing museum collection data vary in date and locational precision. In this case, 349 museum specimens could be mapped with certainty only to the nearest USGS 7.5-minute quadrangle, providing a crude representation of the range of the species.

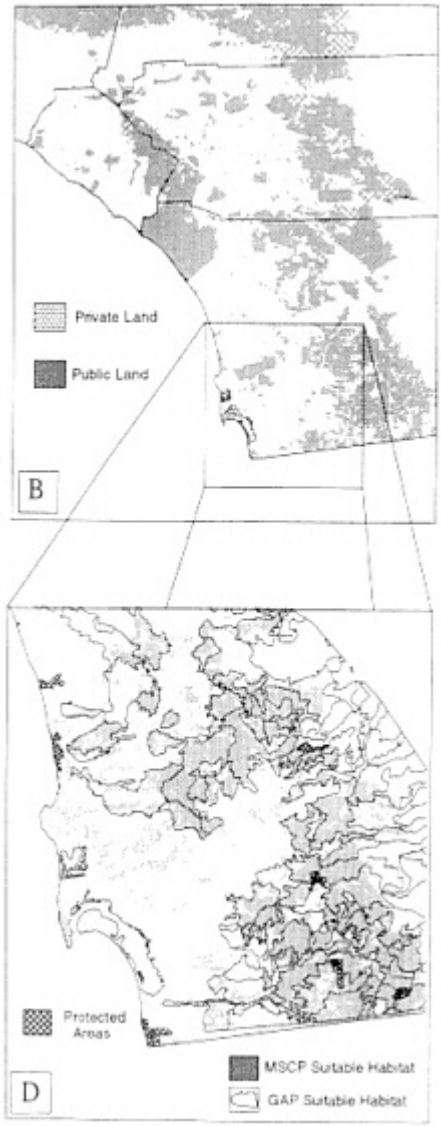
Sighting data are both very dynamic and potentially very biased. Most observations of the lizard were collected after 1985 for projects requiring environmental impact reports. These sightings are clustered at the margins of urban and agricultural areas in San Diego County, where most development is occurring.

Habitat mapping and GIS modeling provide a means of extrapolating the potential distribution of the species. In this instance, we have highlighted areas within the range limits of the species that support vegetation classified as suitable habitat by a statewide habitat relationships system. The potential distribution is somewhat different, depending on whether 1:24,000 or 1:100,000 scale vegetation maps are used. Even the very general pattern predicted by WHR and vegetation data is suspect, because the small amount of life-history information available for the species suggests that it is limited more by its major food item, a termite, than by vegetation.

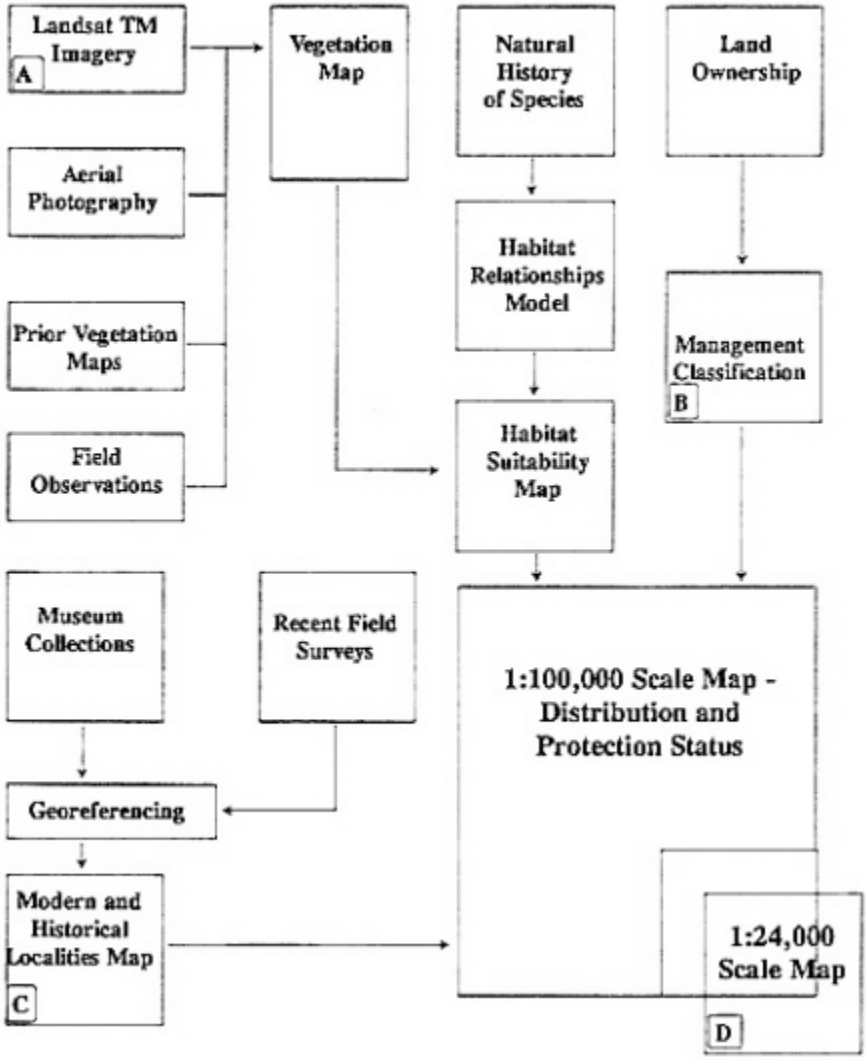
Compiling the information in Panels A-D took considerable time, effort, and technology, yet it provides only a sketch of the species distribution, to say nothing of abundance or trends. Most other species will be even more challenging than the whiptail, which is readily observable and has received a great deal of attention. However, with GIS relational modeling and display, the distribution of a species can be inferred by extrapolating along several lines of evidence. Different data sets can be compared and contrasted, helping to reveal biases and uncertainties. Further study of the species can be productively focused on poorly surveyed areas, and existing habitat models can be refined on the basis of patterns of agreement and disagreement between predicted and observed distributions.







Processing Flow in Species Distribution Mapping



that biological data collection, exchange, and integration are both practical and cost-effective. Nevertheless, an effective National Partnership will require substantial cultural and institutional changes to build stronger bridges among the broad spectrum of producers and users of biological data.

Recommendation 3-1: Under the leadership of the NBS, the National Partnership should develop a National Biotic Resource Information System. This should be a distributed federation of databases designed to make existing information more accessible and to establish mechanisms for efficient, coordinated collection and dissemination of new data and information. The NBS should take the lead in promoting standards for sampling, measurement, data recording, and data transfer. It should support continuing state efforts to develop regional and statewide environmental databases and should work closely with and support database development in museums, universities, and other appropriate organizations. It should also participate in interagency initiatives to coordinate collection and management of biodiversity data by the federal government.

The Need for Spatial Data

Until recently, most research biologists have received little training in cartography or spatial analysis. They might have consulted maps or even prepared them as part of their investigations, but most biologists view mapping as peripheral to their research. Most ecological field research has been conducted on small geographic scales, and collections and field plots have rarely been precisely located spatially (i.e., "georeferenced"). In contrast, maps are a mainstay of planners and decision makers, who must locate and quantify resources and site projects over large planning areas.

That difference in perspectives has contributed to the separation of research and management and has reduced the usefulness of much existing biological information for management purposes. However, the separation is rapidly disappearing as ecologists and conservation biologists pay increased attention to spatial heterogeneity at landscape and regional levels and to the role of spatial pattern in ecosystem functioning, species persistence, and the maintenance of biological diversity.

New technologies have revolutionized mapping over the last 20 years. They include aircraft-and satellite-borne remote sensors, global positioning systems for satellite-based location and navigation, and spatial-data handling tools, such as geographic information systems (GISs), visualization, and spatial-decision support systems. Maps, once primarily a vehicle for communicating research results, are now themselves used as data to derive new information. Furthermore, many spatial data are now acquired and stored in what has been referred to as "value-neutral" form (e.g., as actual measurements, rather than categories or assessments). While creating new opportunities for spatial analysis, these advances place a new burden on producers of spatial data for fuller documentation of data sources, data content, accuracy, scale, appropriate use, and other characteristics. This documentation is called "metadata"—e.g., data about data.

Those scientific and technological advances have led to rapid growth and evolution of a National Spatial Data Infrastructure (NSDI) that is leading to a far more accurate and detailed representation of earth features and phenomena (NRC, 1993a). Biologists lag well behind physical scientists in establishing coordinated efforts to develop standard spatial-data sets. For example, detailed maps of vegetation do not exist for the United States, nor for many of its regions. We lack even reliable range maps for most organisms, including many vertebrates and plants. The NPBS will need to remedy these deficiencies to take full advantage of current and future capabilities in spatial mapping.

Recommendation 3-2: Under the leadership of the NBS, the National Partnership should recognize and participate actively in the evolving National Spatial Data Infrastructure. It should promote greater awareness and use of existing spatial data and technologies; increase efforts to locate field data spatially; adopt, where appropriate, existing standards for mapping and spatial-data handling; and increase the involvement of biologists in federal efforts to develop spatial-data and metadata standards.

Specific Needs Include

- Increased training of biologists in modern spatial analytical theory and spatial statistics (Levin, 1993).
- Fuller use of existing spatial data and technologies, such as global positioning systems, remote sensing, and GISs for biological survey and monitoring, specifically to achieve fuller coordination of ground sampling and mapping activities through carefully designed, multistage mapping and monitoring schemes. This will require a new level of interaction between traditional field biologists and systematists, landscape ecologists, and earth-system scientists and increased federal and state support for application of remote sensing to biological survey and monitoring, especially by the National Aeronautics and Space Administration (NASA) and the Department of the Interior.
- Increased standardization of collection and documentation of spatial biological data, including development of a detailed model for biodiversity data (i.e., defining biodiversity variables and their possible transformations, functional relationships, computer representations, and documentation) and then establishment, adoption, and implementation of data and metadata standards for describing, classifying, and mapping biological features, as described by the Interior Geographic Data Committee (1992).

COORDINATION AND MANAGEMENT OF DATA AND INFORMATION

A Federated Database Approach

Biological information is produced and maintained by diverse federal, state, and local agencies and private organizations. Collectively, this is a vast effort, and no organization or centralized facility could effectively compile, maintain, and distribute all relevant information. A more realistic goal is to link existing and new biological databases into a distributed federation of NPBS databases. Such a linkage must occur both physically over networks and logically through the use of appropriate software and data standards.

Many pieces of a distributed biological database are already in place or under development, notably taxonomic databases (such as the Flora of North America), conservation databases (such as the Natural Heritage and Gap Analysis databases), monitoring data (such as the National Science Foundation's [NSF] Long Term Ecological Research [LTER] sites and the Breeding Bird Survey), and the databases maintained by statewide natural history surveys (such as those in Illinois and Kansas).

Consistency and documentation of data content, quality, performance, and exchange are essential for ensuring the usability of scientific data. Data that are to be useful decades after they are collected have special documentation requirements (Bowser, 1986). The integration of existing biological databases is seriously impeded by the lack of data standards. To be effective, the development of new standards must build from heterogeneous sources and be phased to allow existing data to be transferred to a more uniform database environment.

Recommendation 3-3: The NPBS should develop and adopt appropriate standards for data quality assurance and quality

control and metadata content. The standards should be established by federal agencies in close collaboration with states and the private sector and should build on current efforts, such as those of the Federal Geographic Data Committee, the Interior Geographic Data Committee, the Interagency Task Force on Water Quality Monitoring, the Freshwater Imperative, the Interagency Working Group on Data Management for Global Change, and Systematics Agenda 2000.

Environmental and socioeconomic databases are evolving rapidly through numerous state efforts, as well as such federal initiatives as the U.S. Global Change Data and Information System (GCDIS); the NSF LTER network; the NASA Earth Observing System Data and Information System (EOSDIS); the Environmental Protection Agency (EPA) Environmental Monitoring and Assessment Program (EMAP); EPA's revised water-quality information system, STORET; the Census Bureau's Topologically Integrated Geographic Encoding and Referencing system; the National Oceanic and Atmospheric Administration's climatological, meteorological, and oceanographic databases; the U.S. Geological Survey National Mapping Division and National Water Quality Information System; and the Department of Energy's Carbon Dioxide Information Analysis Center database. Those are some of the major building blocks of the National Spatial Data Infrastructure referred to above. They have developed independently of most biological databases, notably the museum collections and state biological surveys.

Recommendation 3-4: The NPBS should develop its databases in conjunction with the major federal environmental and socioeconomic databases to minimize redundancy, to avoid conflicting terminology and classification systems, and to maintain consistent data standards and formats.

Limits to Federation

Much of the information generated and managed by the NPBS will be housed in and exchanged over computer networks. Many producers and consumers of NPBS data do not yet have network access, but most will have it soon. Already, 5-10 million people in 50 countries are linked via Internet.

Free sharing of data raises issues of proprietorship and appropriate use. Some individuals and institutions distribute primary data only after they have had time to conduct their own analyses and publish the results. Even more important, integrating data can require a commitment of time and resources far beyond what most institutions can afford.

Recommendation 3-5: Full and open sharing of biological data on a timely basis should be an objective of NPBS data management, and adequate funds should be made available to meet this objective. The objective should apply foremost to data acquired with public funds. Conventions and protocols for sharing of primary data should be developed cooperatively among NPBS participants. Under NBS leadership, the NPBS should move quickly to produce a data and information policy for establishment, maintenance, and distribution of long-term national and international biological data and derived information.

Learning from Others

The human-genome project has been described as the first truly "big-science" project in biology. It has as its primary product, huge databases of complex genetic information. The National Center for Atmospheric Research stores and manipulates large volumes of data that can readily be visually browsed and retrieved across Internet. The four national supercomputers supported by

NSF manage large amounts of astronomical data. When fully functional, NASA's EOSDIS will process at least 30,000 digital images per day while managing or linking to a wide range of biological and geophysical databases.

Recommendation 3-6: NPBS data managers should consult with the Human Genome Project, EOSDIS information scientists, the National Center for Atmospheric Research, the NSF supercomputer centers, and other large database programs to take advantage of the lessons and products from these efforts to manage large volumes of biological and geophysical data and to expedite the development of an effective, distributed database environment.

Custodianship

Data quality assurance and control are best achieved through the clear assignment of custodianship for subsets of the data to appropriate experts or organizations. Curators must be appointed with the responsibility for overseeing the long-term quality, currency, and consistency of the data. That will help to transform databases from passive collections of information into something more similar to the scientific literature, which relies upon an active set of editors and reviewers to ensure its quality. To support the custodians, tools must be developed to encourage those who contribute to databases but do not have curatorial obligations to take responsibility for the quality of their submissions. Examples of custodial tools include standardized submission formats and intelligent software for screening submitted data.

Recommendation 3-7: NPBS data managers should develop mechanisms to ensure the clear assignment of custodial relationships for data sets and to develop appropriate support tools for the custodians.

Data Archiving

The utility of data on status and trends will increase with the length of the record. A National Biotic Resources Information System will be most useful if it can archive biological data for many years or even centuries. A highly distributed system with many different custodians, as proposed here, is potentially vulnerable to loss of a dataset if the custodianship falters. Mechanisms should be developed to ensure that the data archives of NPBS custodians are preserved beyond the life span of individuals and institutions. For example, regional and national sites might have to be designated as repositories for data for which custodians cease to exist.

Recommendation 3-8: NPBS data managers should identify a small network of organizations to form the core of a national biological archive for data that merit preservation but have no active custodian. The NPBS should also develop clear guidelines for documentation, storage, and retrieval of these data.

Functional Requirements for NPBS Data Management

To be effective and useful, distributed databases must meet a number of functional requirements, among which the key ones are the following:

- *Network interfaces.* Distributed databases work best when the data are available through standard interfaces over networks, such as Internet. Effective interfaces between databases can be developed only if all the databases have a standard means of allowing other computer programs to interact with them. Public-domain programs that are now appearing—such as GOPHER, MOSAIC, WAIS, and WWW—make it possible to provide integrated access into multiple databases easily and inexpensively.

- *Distributed queries.* A user of NPBS information should be able to query multiple databases. Success depends on the degree of consistency among databases regarding taxonomic conventions, use of terms, geographic addressing schemes, data-management systems, and analytical software. Users should not be required to know all synonyms and geographic transformations, nor should they be expected to maintain many functionally equivalent software packages. Meeting the goal of a fully distributed database will require adoption of standard names and terms (or system-supported synonyms) and vendor-independent data representations.
- *Queries on different scales and levels of organization.* Users of NPBS information systems will want to query the systems at different conceptual levels. For example, how many cricetine rodent species live in Ingham County? In Michigan? In the United States? What are the status and trends of fish populations of the Upper Peninsula of Michigan? Which of these populations are endangered? Supporting those different queries will require that the survey information system support hierarchical classifications so that questions can be posed and answered easily at different taxonomic or geographical levels. Because the classifications will change over time, they must be implemented in a manner that allows easy modification.
- *Vertical and horizontal integration of spatial data.* Relevant information on biological resources must flow to local and county decision-makers and resource managers. Information must also support larger-scale analyses to place local actions in perspective and to address regional and national management issues and those which span administrative boundaries. Meeting these needs will sometimes require vertical integration—combining information about a place from many scales (e.g., species collection points, 1:24,000 vegetation maps, and 1:100,000 soil maps); information must be brought to a common scale of representation for analysis. Alternatively, information might be available on one scale but from different sources for different parts of the area being examined; this information requires horizontal integration—information pieced together with a common classification system and

definitions. In other words, information must be managed to support vertical integration (across space and time scales) and horizontal integration (across space and time on a fixed scale).

- *Flexible system design.* Modern hardware and software systems have useful lives of at most a few years. Therefore, NPBS databases must be designed in a way that will facilitate their transfer across multiple future computer platforms. That is best achieved by using, where possible, commercially available products that adhere to extant standards. Custom software can be difficult, sometimes impossible, to transport to new systems. The National Institute of Standards and Technology has substantial expertise in this regard and should be consulted in the planning of the NPBS data system.

Recommendation 3-9: NPBS data managers should meet the key functional requirements for an effective distributed database. Among them are standard interfaces, an ability to query multiple databases easily and across taxonomic and geographic scales, and easy transport of the data to new computer platforms as they are developed.

INFORMATION MANAGEMENT IN NBS

Consolidation and Coordination of DOI Survey and Monitoring Data

DOI has proposed initiating a National Biological Status and Trends (NBST) program at the NBS. It will be a coordinated monitoring program based on existing activities in DOI, including the National Wetlands Inventory, the Waterfowl Inventory, the Park Service Inventory and Monitoring Program, the Gap Analysis Program, the Breeding Bird Survey, the Global Change Research Program, Biomonitoring of Environmental Status and Trends, and the Great Lakes Fisheries Assessment. DOI proposes

to initiate the program by consolidating databases, designing a statistically valid monitoring network capable of biennially assessing biological status and trends, developing standardized data collection and management protocols, and establishing rigorous quality-assurance and quality-control procedures.

The committee believes that such an effort is central to the NBS and strongly endorses the concept, but the program's scope should evolve as the NBS and other DOI survey and monitoring activities are extended to other taxonomic groups, ecosystem types, and geographic areas, as discussed in Chapter 2. The NBST program should include the management, archiving, and analysis of DOI survey and monitoring data of national extent or significance. At the same time, the NBST program must be coordinated with other important monitoring programs outside DOI. Continuing efforts like the joint Fish and Wildlife Service-Smithsonian initiative, Standard Methods for Measuring Biological Diversity, should be accompanied by similar initiatives concerned with management, exchange, and integration of biological survey and monitoring data, such as The Nature Conservancy's Heritage Program, and broadly based projects, such as the Flora of North America. The integrated management schemes being developed for southern Florida (see Box 2.3) and California (see Box 3.2) constitute excellent regional examples of the need for infrastructure sufficient to bring together status and trends data of organisms and conditions in disparate environments.

Recommendation 3-10: The NBS should establish a National Biological Status and Trends (NBST) program that builds from existing DOI survey and monitoring programs eventually to include a broader range of taxonomic groups, ecosystem types, and geographic areas. At the outset, staff should be appointed and mechanisms developed to ensure that the NBST program is effectively linked to related federal survey and monitoring initiatives and to other pertinent databases.

BOX 3.2: NEW APPROACHES TO INFORMATION MANAGEMENT AND CONSERVATION PLANNING IN CALIFORNIA

California's biodiversity is extraordinary for its richness (e.g., 5,862 flowering plant species, or one-fourth of all flowering plant species in the conterminous United States) and a high level of endemism (e.g., 24% of all flowering plant species). Unfortunately, this biodiversity has been seriously threatened by human activities, and the state leads the nation in federally listed threatened and endangered species.

As with other states, there is no single repository for data on California's biodiversity. The data are scattered across many institutions, and general standards have not been established for data collection, classification, or transfer or for database design. The state of California is now moving rapidly toward coordinated collection and management of biodiversity data. In 1991, a Biodiversity Memorandum of Understanding was signed by major federal and state agencies, with the intent of promoting interagency cooperation in conserving biodiversity across administrative boundaries. A California Council on Biological Diversity, established to promote this new approach, was charged to

- Develop cooperative biological inventory projects.
- Identify and agree to more consistent management of riparian and other sensitive areas.
- Share management expertise.
- Share funding to accomplish conservation projects.
- Develop mitigation and trading banks to allow flexibility for development and conservation projects.
- Work with researchers to ensure necessary advancement in knowledge and technology.

To meet those goals, the council has divided the state into 10 "bioregions" that are defined mainly by physiographic and biogeographic features. A new process, Natural Community Conservation Planning (NCCP), has as its objective active conservation of native plants and animals and their habitats through an expanded system of natural reserves.

An NCCP pilot project in the threatened coastal sage-scrub natural community of southern California has recently been completed; it exemplifies the kind of effort required to implement proactive conservation strategies in areas under intense population and economic pressure. Applying GIS modeling to available socioeconomic and ecological data, a scientific review panel defined core and satellite habitat areas on the basis of the extent and quality of coastal sage-scrub vegetation and identified three target species—the California Gnatcatcher, the Cactus Wren, and the orange-throated whiptail lizard (Box 3.1)—to help efforts to plan and design reserves. The panel also attempted to define the extent and location of allowable development of remaining habitats. Finally, a research agenda was proposed to help resolve unanswered questions bearing on conservation of the community and its component biodiversity. It addressed six basic subjects: biogeographic inventory and mapping, monitoring of trends in selected taxa, dispersal characteristics and corridor-use patterns of target and other animal species, demography and population viability analysis, survey and autecology of sensitive plants and animals, and genetic studies.

The NCCP project in southern California underscores several user needs that the NBS must meet if it is to be effective: the need for better organization of and access to highly dispersed biological data; the need for information at all levels of biological organization, ranging from genes to communities; the need for distribution and monitoring data on species and habitats at both local and regional scales; the need to account for socioeconomic pressures and trends; and the critical need for information on spatial characteristics such, as species' dispersal traits and effects of habitat patch size and arrangement on population viability.

NBS COORDINATION OF A NATIONAL DISTRIBUTED DATABASE

Most biodiversity data are produced locally and are dynamic. Therefore, the NBS should not attempt to develop a large, central

ized database facility to store and distribute biodiversity data. Instead, both the National Partnership and the NBS specifically should evolve a highly distributed network of databases connected through the Internet and by other appropriate means. Because most biodiversity data are maintained within states or by local jurisdictions and institutions, the NPBS will always be a highly decentralized, largely bottom-up effort. It is critical that this effort be well coordinated to minimize redundancy and to allow integration of data, but there will probably never be a single database of databases that will direct users to all relevant sources. The ERIN approach (as described in Chapter 2) was logical for Australia, where relatively few electronic databases existed earlier, but the United States already has a large number of such databases. Instead, data-sharing must be fostered through creative use of network tools. The NBS can contribute to this effort by taking the following steps:

Recommendation 3-11: The NPBS and the NBS should develop a highly distributed federation of databases, rather than a larger centralized database facility. To facilitate the sharing of data among the databases, the NBS should:

- **Establish a moderate-sized facility with personnel and computing capabilities for archiving and distributing regional and national NBS data sets and for meeting the proposed goals of a National Biological Status and Trends program.**
- **Use existing tools and develop new ones to help NPBS users locate data and information, both digital and nondigital. For example, the NBS should explore the establishment of region-specific and program-specific NBS database directories and a national directory of these directories that are accessible through powerful national information networks, such as Internet.**
- **Promote the adoption of data standards by NPBS partners by cooperating with existing efforts (e.g., ABC, 1993), by**

convening technical workshops and committees, and by providing leadership in developing and applying new standards for biological data.

INFORMATION DISSEMINATION

The National Partnership will supply data and information ranging from raw measurements to complex analysis and interpretation, and the results will be published in maps, graphical products, and reports. The Partnership (including the NBS) should use existing media and channels of information exchange whenever possible, including scientific journals, other publications, extension services (e.g., those of the U.S. Geological Survey and the U.S. Department of Agriculture), and information networks. Carefully reviewed technical reports containing original data or their interpretation should also be prepared as needed. Primary printed products must include map and graphical representations of spatial or time-series data for biogeographic areas, ecosystems, habitats, and species.

To ensure appropriate use, data must be subject to strong quality assurance and control. Published data sets should receive professional review before they are distributed. General guidelines for documentation and review of biological data are few, and development of such guidelines should be given high priority. For reasons of efficiency and utility, dissemination of NPBS information should be structured in the context of user interest in particular regions, habitats, or taxa. That means that users will have to define their queries precisely and consistently, including the level of detail and scale. In answering those queries, NPBS information should be presented to highlight what is and is not known by means of diverse, user-friendly formats that are readily accessible to users of varied background and expertise. That will help to ensure correct interpretation and appropriate use. For example, the implications of the reported presence or absence of a

given species depend greatly on the nature of the studies on which the report is based.

Software tools must be responsive to and readily accessible to all users, from both the public and the private sectors. Needs range from primary data to various kinds of derived products.

Recommendation 3-12: To facilitate use of the data that it generates, the National Partnership should develop software tools for data visualization and analysis, for data reformatting and conversion, for trend analysis of monitoring data, for spatial interpolation of sighting and collection data, and for GIS habitat modeling.

Assessments and Communication of Results to Decision-Makers

One of the challenges that the National Partnership must address is the effective communication of research results to resource managers, planners, and legislators. Much more is required than data summaries, technical reports, and professional articles. Those users have questions whose answers are not obvious in existing research products. Rather, policy and management actions often require reinterpretation of existing information. It is here that data and information are most vulnerable to inappropriate use and interpretation and that scientifically based assessments are extremely valuable. These assessments should be based on protocols developed to ensure that they clearly state, to the extent possible and in nontechnical language, such information as the current scientific understanding of the issues, the scientific uncertainties, the predicted consequences of possible actions, the uncertainties associated with those predictions, and what additional information is likely to reduce the uncertainties most rapidly. Deciding on what should be included in such assessments is not a trivial task, and it will take committees of scientists, natural

resource managers, and decision-makers to determine what information is possible and how such information should be presented.

Recommendation 3-13: The National Partnership should develop scientifically based protocols for the preparation of biological assessments for decision-makers.

Other possible mechanisms for providing such guidance include ensuring ready access to the scientists who produced the information, identifying other qualified scientists through directories of scientific expertise (using such institutions as State Heritage Programs and biological surveys), and forming standing scientific councils to support local and regional planning and decision-makers. In addition, clear standards for documenting biological datasets (metadata) should be implemented. Complete and accurate metadata are the only means of ensuring that researchers decades from now can use current data effectively.

Ensuring Scientific Quality

Information provided by the National Partnership must be of the highest scientific standards to provide the basis for objective and impartial management decisions and policy. The best ways to ensure such quality are to develop and implement standards as proposed in Recommendations 3-1, 3-3, and 3-11; and to use mechanisms to ensure the scientific review of information by appropriate professionals before it is disseminated to users. That will require a large increase in formal review by scientists both within the NBS and in the NPBS scientific community.

Recommendation 3-14: The NBS and other appropriate participants in the NPBS should adopt measures to ensure a uniformly high quality of information analyzed, interpreted,

or disseminated by them. Technical reports, articles submitted for publication in scientific journals, and similar products should be subject to peer review.

Achieving Widespread NPBS Product Communication

The National Partnership must be highly responsive to public and private-sector needs for primary data and derived products. Existing protocols for retrieving primary data can be cumbersome and slow. Where networks have been used to share data or products (e.g., the Gap Analysis Program and Breeding Bird Survey trend analyses), use of the information has increased substantially. Online data dictionaries must be adequate to guide appropriate use of the data. The NPBS should also maintain an online bibliography of its publications and project descriptions. Access should be facilitated by user-friendly interfaces with intelligent search and browse capabilities.

The U.S. Global Change Research Program has considered these and many other issues related to data management and exchange and has drafted a set of policy statements (Committee on Earth Sciences, 1992). These policies articulate a commitment to establishing and maintaining long-term data sets, full and open sharing of the full suite of global data, data archiving, data standards, data access and affordability, and clear definition of the duration of the period in which scientists retain exclusive use of original data. These policies extend beyond primary data to include enhanced data products that are especially useful to users outside the scientific research community. The Global Change Research Program data-management policies are consistent with those adopted by the Data and Information System for the International Geosphere-Biosphere Programme (IGBP) and could serve as the core of an NPBS data and information policy.

The NPBS should develop a plan for publication of selected,

peer-reviewed, regional and national primary biological data sets in CD-ROM form or in other digital media. The Partnership should also expand electronic publication of data summaries in a form that supports management applications. Selected regional and national databases and data summaries should be published in digital formats.

Many users of biological data do not have network access or adequate hardware and software. Even those who do often require information in other forms. The NPBS must continue to make print products available. The most important of those are peer-reviewed scientific articles and reports. Examples of end products in printed or electronic format that are of fundamental practical value to those who manage, use, or study biological resources include taxonomic monographs and revisions; regional floras; faunas; field guides and manuals; detailed range and habitat maps; atlases of the distribution and trends in regional biodiversity, ecological communities, and ecological systems; and scientific studies that interpret existing biological diversity in light of evolutionary history.

Recommendation 3-15: To meet the growing needs of all sectors of society for biodiversity data and information, the National Partnership should increase its capability for publication and product communication substantially. That should include increased online access to data, reports, and bibliographies; publication of selected data sets in CD-ROM format and in other media; and expanded publication of synthetic documents, such as atlases and summaries of surveys and trends.

4

COORDINATION OF THE NATIONAL PARTNERSHIP FOR BIOLOGICAL SURVEY

The National Partnership for Biological Survey will provide, for the first time, an organized framework for collaboration among government and nongovernment organizations at the national, regional, state, and local levels. Much of the information on biological resources resides at the state and local levels, and many decisions about biological resources are made there. Many government and nongovernment organizations in the United States are active in the field of biological survey, and all need to participate in a truly comprehensive national effort.

Because of the broad array of organizations involved in the Partnership, successful implementation of the concept will require that a complex set of institutional relationships be managed effectively. The National Biological Survey being established within the Department of the Interior has a broad range of responsibilities, but it cannot by itself come close to meeting the full range of needs and objectives in scientific research, inventory, and information management described in the preceding chapters. The committee has concluded that the management of the National

Partnership will require flexible and creative approaches to organizational structure and coordination. The establishment of the NBS provides the catalyst for establishing a broad new national framework for providing the information needed to manage our nation's biological resources, with DOI playing a lead role in establishing the new relationships.

This chapter identifies needs for coordination and collaboration and recommends ways to meet those needs. The mechanisms discussed are intended to allow the National Partnership to adapt to changing circumstances and priorities and to encourage full collaboration among all interested parties. The unprecedented requirements for coordination among the various entities that collect, curate, analyze, evaluate, or use data that describe functioning ecosystems and their components preclude a top-down pyramid of responsibility. Instead, all the participants in the NPBS should be viewed as active collaborators. The coordination mechanisms that we discuss are intended to foster an open collaborative process. The complexity and need for flexibility and collaboration are illustrated by such examples as Partners In Flight, the Neotropical Migratory Bird Conservation Initiative (see Box 4.1). The organization of Partners in Flight is an example of the kind of networking that will be needed to achieve the goals of the National Partnership. In fact, Partners In Flight is only one of many existing national collaborative efforts that will participate in the NPBS.

The increasing interest in regional management systems—which take into account not only the requirements for survival of individual endangered species, but also the future of the ecosystems that sustain them and many others and add that amenity to human lives—will require increasingly complex cooperative arrangements. It is a complex problem to balance development—which at its worst might amount to the one-time conversion of potentially renewable natural resources and at its best might rest on the sustainable use of those resources—with the preservation of natural and seminatural areas that include values of other kinds, as we have seen, for example, in recent years in connec

tion with the ancient forests of the Pacific Northwest. Considerations of this sort often also involve international relationships; for example, the work being carried out by the provincial government of British Columbia, jointly in part with the government of Montana, includes important innovations in dealing with ecosystems at a regional level. Similar considerations apply in California, where a promising coordinated regional strategy involves the cooperation of the pertinent state and federal agencies, as well as private conservation groups (see Box 3.2). However, achieving an integrated regional strategy will be complicated by the dispersion of management authority for different kinds of organisms, habitats, and water resources over federal, state, and county agencies (see Box 2.3 for an example).

ROLE AND FUNCTIONS OF NBS

The National Biological Survey should assist in enabling DOI to meet the diverse mandates of its bureaus, including setting priorities for acquisition of lands. To accomplish that, the NBS should seek internally to integrate and standardize inventory, monitoring, and research efforts of the various DOI land-management agencies. That would cover the almost 300 million acres of DOI-managed lands and the species that come under DOI management authority. The NBS should also facilitate access to data necessary to enable state and local managers to make better informed resource decisions.

In addition, the NBS should be able to identify organisms and communities at greatest risk and determine their management needs before having to resort to enforcement of the Endangered Species Act or imposition of stringent regulatory controls under other authorities. That should be done through research (whether carried out by the NBS or other agencies), inventory, monitoring, and communication of the resulting information to policy-makers and land managers.

The NBS should encourage and facilitate the development of

BOX 4.1: NEOTROPICAL MIGRATORY BIRD CONSERVATION—PARTNERS IN FLIGHT

Declines in neotropical migratory-bird populations have focused attention on the need for conservation of these species and the lack of firm data on the status of many. The Partners in Flight program, catalyzed by the National Fish and Wildlife Foundation, brought federal, state, and private partners together with a common goal to protect species of neotropical migratory birds and conserve their habitats, including North American breeding grounds, Latin American wintering grounds, and the migration routes that connect them. An active partnership including all 50 state fish and wildlife agencies, 14 federal agencies, and 38 private conservation organizations and corporations are working together under signed agreements toward this goal.

With over 350 species breeding in, migrating through, or wintering in more than a dozen countries from Canada to Latin America, needs were too big for one organization or country to handle alone. The Fish and Wildlife Service (FWS) and the state wildlife agencies are leading in expanding monitoring and population assessment efforts, and the U.S. Forest Service is aiding in those efforts by conducting research and formulating active land-management plans. The Bureau of Land Management is conducting research in management on riparian systems that are vital for breeding, migration, and wintering habitats in the western half of the United States. The Department of Defense, the National Park Service, various U.S. Department of Agriculture agencies, and a vast array of nongovernment organizations are collaborating with two basic thrusts in mind. The first is to develop and implement adequate monitoring, analytical, and research programs to assess the needs of birds and their habitats; and the second is to implement active land management first on federal lands and then through partnerships with private landowners that control even larger areas of the continent. International programs are aided through direct involvement by Canadian agencies and entities and through the Western Hemisphere program of FWS working with Latin American countries.

Nine working groups—covering monitoring, research, information and education, legislative issues, and five regions (including international)—are focusing on local needs and priorities. Meetings, workshops, and symposia have advanced a habitat-based initiative focusing on a specific list of neotropical migrants with priorities for work.

Working groups include open membership, and meetings are attended by representatives of federal and state agencies, national and local nongovernment organizations, universities, and the forest-products industry. Participants meet as peers to design effective, scientifically credible conservation plans and have produced a priority list of species, lists of research priorities on a regional basis, and a needs assessment for monitoring with protocols for standardized procedures for expanding scope and coverage. Programs eventually will address land management by various agencies to benefit neotropical birds. Attention to land-management agencies with vast holdings of rangelands, parks, refuges, and national forests is a logical start toward ecosystem-scale management.

The NBS logically would help orient and support this program to achieve the scale of work necessary for effective conservation of this large and diverse group of migratory birds.

NPBS research to meet the needs of the nation for biological resources and sustainable ecosystems. The effort will encourage other agencies and groups to see themselves in the context of the larger enterprise. Much necessary monitoring and much of the essential research will be done by agencies and entities other than the NBS. In addition, the NBS should establish institutional points of contact to facilitate communication among the various elements of the National Partnership.

Recommendation 4-1: The NBS should have a dual mission: to meet the scientific research and information needs of DOI for management of the lands within its jurisdiction and species for which it has responsibility (and geographic areas that affect either of the above) and to provide national leadership and vision for the NPBS.

Although the NBS will be a scientific organization, it must have strong and reciprocal relationships with management experts in

DOI bureaus, so that their mandates can be met through accurate and timely scientific information. Meeting these demands for knowledge to support the management functions of DOI will create a tension with the goal of serving as the core agency for the National Partnership. There will be some creative tension between the desire to pursue new scientific inquiries about biological resources and the need to conduct studies that are focused specifically on current management needs. The early history of the U.S. Geological Survey (USGS) in DOI clearly illustrates those tensions (see Box 4.2) Mechanisms should be identified to ensure that the NBS can meet each of these equally important parts of its dual mission in the long term.

One of the reasons cited by the Secretary of the Interior for the establishment of the NBS was the need to ensure objective, high-quality science that will be responsive to user needs. Several groups have raised a concern that an independent NBS will be less responsive to the user needs of the land-management agencies in DOI than the present organizational arrangement, where research expertise is contained within each of the relevant agencies.

The NBS must have the expertise necessary to design and conduct research, interpret results and share them with decision-makers in other bureaus, and coordinate the nation's broader efforts in the National Partnership—including identifying gaps in expertise and research and seeking to fill them either through the NBS or through the resources and mandates of other agencies and organizations. In this view, the NBS has a responsibility to take the broadest possible perspective and to help the country to recognize its deficiencies in knowledge and expertise. No government agency today has such a mandate, and many kinds of research are not done. Many scientists believe that organismal biology has declined, in part for this reason.

DOI does not and cannot possess all the scientific skills or personnel to carry out the functions of the NPBS by itself. In a sense, DOI should operate its NBS as a "national trust" designed to ensure the success of the National Partnership for Biological Survey. Its dual mission requires balancing specific needs for

DOI programs with the broader needs of the country. The hands-on scientific work of the NBS should be lean and focused. In other words, in-house research, monitoring, analysis, and application to problems of ecosystem management should be directed primarily at DOI management and mission needs, and many of these needs should be met through contracts and grants so as to maintain a national network of capabilities. A cadre of experienced scientists should work with other participants in the National Partnership to identify information needs and stimulate programs that will satisfy those needs and provide leadership.

The fundamental purpose of the NBS is to provide a rational and objective scientific basis for meaningful stewardship of the nation's biological resources. Its scientific credibility and reputation are therefore of utmost importance, and they must be protected and reflected in a comprehensive and rational leadership plan.

The conduct of scientific investigations at the NBS should be as free as possible from political influences that could adversely affect the scientific credibility of the new agency or prevent it from performing research that, although it could lead to politically unpopular results, is scientifically necessary. A well-managed and effective program of external review of the NBS programs will be essential, and peer review of all programs in the NBS is highly recommended. The director of the NBS must be an acknowledged and respected professional leader in the biological-science community and should be selected in a way that helps to ensure the scientific independence of the agency, as has long been the case in the selection of the director of USGS. The director of the NBS could be appointed for a 6-year, once-renewable term of office and selected from a list of candidates suggested to the Secretary of the Interior by appropriate representatives of the scientific community. A chief scientist should be similarly appointed, and the term of office could be staggered with that of the director for purposes of continuity. The chief scientist should be free of management responsibilities other than for the development of scientific programs.

BOX 4.2: BALANCING USER NEEDS WITH THE ADVANCEMENT OF SCIENCE: THE EARLY EXPERIENCE OF THE U.S. GEOLOGICAL SURVEY

The U.S. Geological Survey, created on March 3, 1879, was charged with the following combination of responsibilities: "classification of the public lands and examination of geological structure, mineral resources, and products of the national domain." The legislation stemmed from a report of the National Academy of Sciences, which in June 1878 had been asked by Congress to provide a plan for surveying the territories of the United States.

For the survey's initial program of work, the first director, Clarence King, chose to emphasize mining geology, to devote but a small effort to general geology, and to confine paleontology and topographic mapping to what was necessary to support the geologic studies. In doing so, King emphasized practical studies at the expense of basic ones. He nonetheless expected that the facts gathered in the mining geology studies would lead to advances in basic science.

A mining geology program began in 1879 with comprehensive studies of the geology and technology of three great mining districts—Leadville in Colorado and Comstock and Eureka in Nevada—and the collection of mineral statistics in the western states. In addition, through a cooperative arrangement with the Tenth Census, mineral statistics were collected in the eastern states, iron resources in all parts of the country were systematically studied in the field and in the laboratory by a variety of techniques, and an effort was made to trace the continuation of the copper-bearing rocks of Michigan and Wisconsin through northeast Minnesota to the Canada boundary. There investigations in general geology included the unfinished studies of the earlier surveys in the Colorado Plateau region, on the Quaternary history of valleys in Utah, and on the geology of the Rocky Mountain region north of New Mexico and west of the 94th meridian.

King resigned as director in March 1881. Despite his short tenure, he had such a profound influence on the survey's organization and mode of operation that his imprint was clearly evident decades later and still can be recognized. King's choice to succeed him was John Wesley Powell, almost King's antithesis in background, education, and experience. Both had wide-ranging scientific interests, but King's centered on mathematics and geophysics, and Powell's tended toward natural history and anthropology. In geology, which Powell considered part of geography, he was primarily concerned with land forms and land use.

King and Powell also differed greatly in their philosophies of administration, which King apparently did not realize when he resigned. King had given the work of the geological survey a mission orientation, planned the goals, and selected the staff, but given them freedom to choose their methods of work in order to achieve the goals. Powell allowed the staff to choose not only their methods of work but the subjects they would investigate as well. That alone meant an immediate change in the geological survey's program. In addition, because Powell looked on geology and topography as independent but closely related parts of the greater field of geography, he made the topographic work of the geological survey independent of geologic studies as soon as he became director.

During Powell's first 3 years as director, the survey prospered, and its appropriations grew steadily, amounting to $386,000 for the fiscal year beginning July 1, 1884. By that time, King's simple organization of the survey into mining geology and general geology had been transformed. General geology, initially described by Powell as structural geology and paleontology, became five divisions of geology and five of paleontology. The chemical laboratory, mining statistics, preparation of illustrations, and the library were "accessory" divisions. Without benefit of formal organization, the geological survey was also investigating the irrigation of arid lands, the relief from floods that would be afforded the lower valley of the Mississippi by using waters from the Rocky Mountains for irrigation, and the geographic distribution of the great forest areas.

In a mood for economy, Congress in 1892 slashed appropriations for scientific agencies, especially those items which seemed to have little immediate practical purpose. The Geological Survey's appropriations for geological surveys, paleontology, and chemistry and physics were drastically reduced, and several statutory positions were eliminated. Only the appropriation for the report on mineral resources went unscathed, although the appropriation for topographic surveys was cut only a little. The Senate then appointed a Select Committee to "investigate the operations of the United States Geological Survey, the efficiency and utility of such a survey, together with the progress made and economy observed in this work."

The congressional action was clearly aimed at Powell and his administration of the Geological Survey. The principal reason was that Survey science was not serving the great economic interests of the country although the all-encompassing nature of the Survey work or resentment of Powell's ideas of land reform and the closing of the public domain during the Irrigation Survey, to which some historians have attributed the action, may have played a part. In particular, Senators from the mining states in the West, which were also states in the arid regions, wanted economic geology restored to the preeminent position it had had under King, and members of Congress in the South and East wanted economic geology investigation in their regions. A few powerful Senators in fact wanted to force Powell's resignation and to restore King to the directorship.

Powell submitted his resignation in May 1894. The Secretary of the Interior promptly recommended to President Cleveland the appointment of Charles D. Walcott as the third director.

Basic science was an integral part of the Geologic Branch under Walcott. Fundamental studies were made in the genesis of ore deposits, in paleontology and stratigraphy, in glacial geology, and in petrography. The geologic time scale was revised, new definitions for rock classes were developed, and the first geologic map folios were published.

COORDINATING THE NATIONAL PARTNERSHIP

In its deliberations about coordination and management of the NPBS, the committee reached the following conclusions:

1. Coordination among federal agencies, with state and local agencies, and with such entities as museums and universities is a key to the success of the NPBS. These participants perform different activities that are essential for the generation of useful information, and the needs identified in Chapters 1 and 2 cut across the geographic foci of the activities and jurisdictions of these organizations. Effective coordination mechanisms will

facilitate the ability of the Partnership to perform work that crosses political and jurisdictional boundaries.

2. The most important long-term consideration for local, state, and federal management and regulatory agencies and many private-sector users will be the use of NPBS-generated, scientifically based information by decision-making bodies and policy-setters. The information will directly enhance land-and water-use practices for the preservation and management of biological resources.
3. An important guiding concept is to work through state organizations for local application of NPBS data. Whereas ecosystems and biota are not constrained by state boundaries, the current structures of most DOI agencies and many other federal agencies recognize state boundaries. For example the Bureau of Land Management (BLM) is organized on the basis of state offices, and BLM districts lie primarily within state boundaries. National Wildlife Refuges and National Marine Sanctuaries are encompassed primarily within state boundaries, as are national parks, Indian reservations, and many reclamation projects. Most national forests lie within state boundaries, as do most military reservations. The USGS Water Resource Division has state offices. Other federal agencies such as the Environmental Protection Agency (EPA) and the U.S. Department of Agriculture (USDA) also recognize state boundaries. There are strong reasons to have a focus on states within a broader organizational framework—it gets things done on the ground. State agencies that are critical to the success of the NBS include wildlife agencies, parks, forestry and land agencies, environmental regulatory agencies, museums, universities, and biological (natural history) surveys. Much wider recognition must be accorded the broad authority of county governments over land-use planning on both public and private lands. Once federal regulatory decisions or court actions are complete, implementation of programs is often at the county level by entities that traditionally have not had ready access to, or skills to interpret, biological data.
4. Both NPBS and NBS activities might develop a scientific

focus on regions larger than the states, but the regions should be determined by problem-specific needs and situations. Because a state organizational structure for the NBS is recommended, it is unlikely that either the National Partnership or the NBS needs alternative geographical bases. Nonetheless, collection, analysis, and dissemination of data may, for some purposes, be categorized by ecological criteria that do not necessarily correspond with any political boundaries, such as watersheds, vegetation zones, or wildlife migration routes.

The above conclusions, along with findings described in earlier chapters, have led the committee to believe that an effective coordination mechanism is required. Because the scope of the activities of the National Partnership are quite broad, and because of the extensive amount of intergovernmental and nongovernmental coordination, the committee believes that no existing model for national and federal coordination is readily adaptable to the National Partnership for Biological Survey. A unique and innovative process for coordination will probably need to be developed. The committee did not attempt to prescribe a detailed coordination mechanism. Instead, the committee concluded that a formal mechanism should be established and that it should embody the specific characteristics described below.

Mechanism for National Coordination

Recommendation 4-2: Formal mechanisms should be established for coordination among the entities with responsibilities for the National Partnership for Biological Survey. The mechanisms should collectively exhibit the five characteristics described below.

The coordination mechanisms should

- *Provide for high-level, balanced input from diverse partici#*

pants and users into the development and implementation of the Partnership. Because the NPBS will be a national program that cuts across political, jurisdictional, and geographic boundaries and involving both governmental and nongovernmental entities, it needs a mechanism through which all sectors involved can advocate, justify, and discuss proposed programs and activities that will affect them and, to the degree possible, reach consensus on a balanced and effective agenda. Bottom-up input, although important, is not sufficient to ensure that participants and users will communicate sufficiently with each other, that the federal participants in the Partnership will obtain sufficient and balanced input from nonfederal participants, or that nonfederal participants will have sufficient authority within the program to ensure their involvement.

- *Take full advantage of the federated structure of American government, in particular the states.* The key role of states in the management of the nation's biological resources, in the structure of Congress, and in other aspects of government makes them natural foci for Partnership programs and activities.
- *Have a clear lead organization with primary responsibility and authority for fostering coordination.* Only a federal government entity has the breadth of charge, access to resources, and sufficiently broad mission responsibility to play this role. Within the constellation of federal agencies, and for reasons described in Chapter 1, the committee believes that the lead agency should be DOI. The most logical alternative focus, the Executive Office of the President (EOP), was rejected by the committee for four reasons: First, the committee believes that an agency with mission responsibility related to the nation's biological resources would be able to focus more effectively on the needs of the Partnership than can the EOP with its myriad responsibilities and need to respond to shifting issues. Second, the lead agency can take direct action in response to input from participants and users, whereas the EOP must work through mission agencies. Third, although the EOP has a number of policy-coordination responsi

bilities, it is not itself operational and cannot act on the kinds of day-to-day issues that the Partnership will involve. Fourth, the EOP does not have the kinds of mechanisms for direct involvement with the states that are critical to a program like the Partnership with its substantial nonfederal participation.

- *Provide for continuity of involvement by participants and users.* As discussed in previous chapters, an effective Partnership will require long-term, continuous commitment from those involved. Temporary advisory bodies can play important roles, but they are not an adequate substitute for a permanent mechanism of coordination that will play a key role in such tasks as the developing and implementing standards for data acquisition and information management, making sure that what is learned from Partnership activities shapes future programs and priorities appropriately, and ensuring that participants and users have timely, up-to-date information on the status of and trends of changes in the nation's biological resources.
- *Be designed to encourage active, voluntary participation.* Because of the diverse character of the Partnership, much of the involvement in it will need to be voluntary, especially for nonfederal participants. If the program is to be successful, ways must be found for all key stakeholders to "buy in" to the process and support it over time. A top-down, centralized approach is unlikely to engender the full and enthusiastic cooperation of all critical participants. Coordination will best be achieved through leadership, consensus-building, and positive incentives, such as funding for interagency collaborative activities, state programs, and extramural research, provision for personnel exchange, the development of a strong sense of shared mission, and unequivocal support from key leaders throughout the participating community.

In addition to the Partners In Flight program, the committee reviewed a number of possible models for national and federal coordination, including the National Commission on AIDS, the Federal Drug Policy Office, the Federal Coordinating Council on Science, Engineering, and Technology, the Arctic Research

Commission and the Interagency Arctic Research and Policy Committee. The committee believes that none can serve as an exact model for the coordination mechanisms needed for the Partnership, but the committee was able to draw concepts from each to create several possible approaches, which are discussed below.

Coordination among nonfederal participants might be accomplished via a standing body comprised of appropriate representatives of those involved in the Partnership, such as state agencies, national scientific institutions, major scientific disciplines, nongovernment natural-resource organizations, museums, and private-sector organizations involved in the development and management of biological resources. The link to federal programs could be provided through the Secretary of the Interior. Such a group could identify and recommend national (not solely federal) policies and priorities for biological-resource assessment (not management decisions) and make recommendations for all segments of the Partnership, both federal and nonfederal. It could also review NPBS programs for their appropriateness to policies and priorities and recommend appropriate changes.

In the committee's view, what is needed is a high-level forum for the discussion, development, and implementation of policies and priorities for all nonfederal stakeholders in the National Partnership, not merely an advisory body. Recommendations for programs would be passed to the appropriate entity for action and feedback. Each representative would work directly within the sector of the community (e.g., museums, etc.) that he or she represents to implement policies and priorities.

An effective mechanism for federal coordination might be an interdepartmental committee on biological survey. Such a committee could be chaired by the Secretary of the Interior and include the heads of key federal departments and agencies involved in the Partnership, especially the Departments of Agriculture, Commerce, Defense, and Transportation, EPA, and the National Science Foundation. The mechanism should provide

cross-agency coordination of federal policies and participation in the Partnership and it should identify federal-agency priorities for the conduct of biological research and resource assessments.

The interagency committee would be both a forum for high-level policy discussion and coordination and a framework for increased day-to-day interaction at the working level. Issues related to the implementation of the National Partnership by the federal government could be effectively coordinated by this committee, which would function as a peer agency, without the need for extensive involvement by the Executive Office of the President. However, the President could increase incentives for coordination through the budget process —for example, higher budgetary priority could be given to collaborative work such as the regional projects described in Chapter 2 (Recommendation 2-13), than for noncollaborative work in a given region. Any major interagency policy disputes that could not be settled by the federal coordinating mechanism likely would need to be handled through established policy-coordination procedures in the White House. A means for regular feedback between the federal and nonfederal coordinating mechanisms should also be established.

Appropriate mechanisms also need to be established to obtain scientific advice for the Partnership and to ensure proper data management. These mechanisms would identify priorities for research and protocols for surveys and inventories; establish procedures for quality assurance in research and data management, including the development of database standards; plan the development of the NPBS data network; and develop recommendations for ensuring access to data by public and private users. One way to obtain the necessary advice and guidance would be to establish committees in science and data management.

Coordination within the Department of the Interior

Much of the work of the NBS will be directed toward providing

high-quality scientific information to improve decision-making by the land-management agencies within DOI. The department has proposed the establishment of a policy board consisting of senior representatives of all DOI bureaus, whose function would be to "offer guidance to identify priorities for NBS so that it can produce data useful for resource managers." Establishment of such a board by secretarial order would underscore its importance. It should be chaired by the director of the NBS. In addition, a secretarial order could establish a process and criteria for identifying and setting priorities for research needs within the department. The process should provide for field managers to identify research needs and local and regional priorities, which would be reviewed and consolidated into the NBS research program. It should permit open discussion of priorities within the department, in the recognition that funding limitations probably will not permit all research needs to be met.

Field and State Coordination

Recommendation 4-3: The Secretary of the Interior should establish, through either existing or new DOI or other appropriate facilities, an office in each state to facilitate joint NBS and broader Partnership activities and to provide a communication channel among state agencies, private and individual participants, and federal agencies.

This might be the most important consideration for ensuring that the NBS achieves liaison with all possible contributors. DOI (through BLM, National Park Service [NPS], the Minerals Management Service, USGS, and The Fish and Wildlife Service [FWS]) has a working relationship for land management with state and county governments and has regulatory relationships for trust species through the Endangered Species Act, the Migratory Bird Treaty Act, Great Lakes Fishery Councils, various fisheries legislation, and other laws. Therefore, this relationship can

logically be a starting point for coordination at the state level. The proposed offices should provide for coordination among USDA, EPA, DOI, the Department of Defense (DOD), the National Oceanic and Atmospheric Administration (NOAA), the U.S. Forest Service, and any other federal agency charged with working within a state, as well as with relevant state and private agencies, such as museums, universities, and conservation organizations.

An appropriate mechanism for coordination at the state level would be planning or steering committees that would coordinate biological research and inventory activities within each state. Such committees would consist of representatives of state and federal agencies and other cooperating parties.

The precise composition and size of the committees would need to be appropriate for the needs of their particular states. The committees would provide for data management and accessibility to user groups within their states. The state committees would maintain liaison and information transfer with the coordinating bodies.

BUDGETARY CONSIDERATIONS

The formal establishment, organization, management, and coordination of the National Partnership for Biological Survey will greatly improve the effectiveness of federal expenditures on biological science relevant to natural-resource management. An informal inventory of federal spending on research in environmental biology identified annual total federal spending of almost $1 billion, excluding inventory and data-management activities. The coordination mechanisms recommended in this chapter will greatly improve the efficiency and expenditure of federal funding, including evaluation and prioritization of current spending on programs relevant to the goals of the Partnership. Nonetheless, there likely will be a need for increased federal investments. In view of the

purpose and objectives of the National Partnership, there appear to be a number of important gaps in current federal and national programs. Bridging those gaps will require both new and expanded federal programs.

Department of Interior

On the basis of the material submitted to the committee by DOI, it appears that all the existing biological research activities and expertise in the land-management bureaus have been identified for possible transfer to the NBS. We believe that such a sharp distinction of responsibility will not adequately meet the needs of the land-management bureaus. For example, in many instances a land manager might require on-site scientific expertise to address an immediate and narrow issue. Under the department's proposal, such requirements would have to be met by the NBS. We believe that this arrangement would not be most responsive to the land manager's needs and would unduly burden the NBS with tasks that would not contribute to the nation's understanding of its biological resources. We recommend that the land-management bureaus retain sufficient scientific expertise to accomplish three separate functions: to address unique site-specific biological-resource issues at individual land-management units, to address specific short-term issues, and to facilitate interaction between the land-management bureaus and the NBS to ensure that the NBS is responsive to the needs of the other bureaus. Such retention would require a careful examination of the activities and expertise currently proposed for transfer to the NBS—an examination that could be conducted if the proposed personnel transfers are implemented in phases, as recommended in Chapter 5. It would also require addition of resources to the NBS to enable it to meet its mission. The issue of how best to balance the scientific research needs specific to individual bureaus with larger, cross-bureau and national needs is important and

should probably be addressed in a study by an independent group of experts.

The NBS needs to develop a core staff capability in an appropriate range of the biological and information sciences. It will need to augment its initial staff capability with new staff in key scientific disciplines. The staff proposed to be transferred initially to the NBS were employed for other reasons, already have a full range of responsibilities, and might not be appropriate for transfer to the NBS. The NBS will need additional scientific staff in such areas as botany, taxonomy and systematics, population biology, invertebrate zoology, ecology, social sciences, statistical design and analysis, and information sciences.

Recommendation 4-4: The NBS should perform a systematic assessment of needs based on existing staff capabilities and program requirements and develop and implement a plan to hire needed experts. This should be the highest priority in the application of additional budget and staffing resources. In addition, the NBS should have the core staff capability necessary to support the coordination mechanisms of the National Partnership.

It is equally important that the internal staff capability within the NBS be held to a minimum. The NBS should not attempt to "do it all" with in-house staff. Rather, it should seek to use other federal resources and to rely increasingly on externally funded research to meet its mission requirements. Those points are discussed in more detail below.

Many of the scientific disciplines and the expertise needed by the NBS are currently in other federal programs. DOI therefore has arranged for the temporary detail of a number of key people from other agencies to DOI to assist in the formation of the NBS and recommends that this practice be extended and expanded. Temporary personnel exchanges between the NBS, other federal agencies, and other participants in the NPBS can be an effective way to augment NBS scientific expertise and core capabilities.

Such exchanges also can provide an opportunity for NBS personnel to learn more about other federal agencies' programs and thus promote increased coordination and enhance opportunities to develop cooperative activities. Interagency personnel exchanges can be an effective mechanism to leverage existing federal personnel resources, minimize duplication among the agencies, and provide a rapid infusion of additional skills to the NBS.

Recommendation 4-5: DOI and the NBS should establish a continuing program of personnel exchanges among the federal agencies and other participants in the NPBS. Such exchanges will help to provide needed expertise to the NBS, minimize duplication of effort, and promote improved coordination among federal programs.

Biological research covers a broad spectrum from fundamental research to focused and locally applicable research. A robust national program of biological research must encompass the entire spectrum. Increased federal investments in basic research in support of NPBS needs should be assigned to NSF, which has management expertise and experience in supporting basic scientific research. The increased funding should be focused on increasing the amount of research on biological issues that directly assist NPBS needs. Increased federal research investments in the NBS initially should be focused on augmenting research programs that are directed toward DOI's mission requirements. Many of these programs focus on ecosystem biology and management. It will be appropriate to consider adding funding in the future to enhance NBS programs in conducting extramural research. Peer review of all these components is essential to their continued success.

Recommendation 4-6: The NBS should rely strongly on extramural research to meet its mission requirements.

To meet the needs of the land-management agencies in DOI, the NBS will need to perform much short-term research. It

should seek to rely heavily on extramural research, much of which can be implemented through the Cooperative Research Units (CRUs) to be transferred to the NBS from FWS and NPS. New funding would be needed to staff existing CRUs fully and to build the broader programs needed for the NBS to be successful. Increased reliance on extramural research programs at the CRUs can also strengthen training programs for future biological scientists. Staffing needs for CRUs should clearly be an important focus of the recommended needs assessment for NBS.

DOI should expand the scope of CRUs to include agreements with the nation's universities, museums, and other appropriate parties to operate or support programs or laboratories focused on specific groups of organisms and studies of ecosystems. The taxonomic units would train specialists, conduct surveys, complete taxonomic research, develop research and reference collections, and maintain taxon-specific databases. The CRU model has served wildlife and fisheries management needs well, and it could meet critical needs for research on taxa of concern to DOI missions.

Recommendation 4-7: The NBS should develop mechanisms to use research and inventory programs in other federal agencies.

There are extensive biological research and inventory programs in NOAA, USDA, EPA, the Smithsonian Institution, and DOD. Each of those agency programs would make substantial contributions to the NPBS. Their coordination and integration could be accomplished through the proposed coordination mechanisms. However, because the other federal programs are governed by their missions and legislative authorities, they might not be fully responsive to the broader purpose and objectives of the NPBS in the absence of additional incentives. The NBS might have to enter into specific cooperative agreements with the other agencies and provide cofunding for specific programs. Effective use of the

other federal programs will necessitate some funding increases for NBS to support new interagency collaborative research activities. However, the increased investments by the NBS would be cost-effective, in that they would avoid the need for the NBS to undertake large new programs of its own.

Recommendation 4-8: The Secretary of the Interior should support expanding the scope of financial assistance for state programs to make the states full participants in the National Partnership.

The states receive funding for activities under the Pittman-Robertson, Wallop-Breaux, and Endangered Species Acts that covers research surveys and inventories and management actions focused on sport fish, game animals, and endangered species, respectively. The states have undertaken a much broader range of programs, including Heritage Data Centers, that focus on a broad range of biological resources and will have a critical role in the evolving NPBS. DOI should work with the states to expand the scope of financial support for state programs as important components of the NPBS.

Budget Prioritization

In terms of the NBS, the recommendations listed in this section on budgetary considerations should have high priority for any federal budget increases; additions to the NBS core staff should have the highest priority. The budget increases for the priority areas discussed in this chapter could be offset to some extent through a careful review and restructuring of the programs transferred to the NBS from other bureaus. The committee recognizes that many worthy programs need to compete for federal and nonfederal funds. To the greatest extent possible, additional funding for the National Partnership should be made available

from savings that result from the increased efficiency that will come from more effective coordination and from programs that are judged to have lower priority. Specific recommendations for reprogramming are beyond the purview of this committee. However, it should be noted that new investments made in the work of the Partnership are very likely to result in net long-term budgetary savings by helping to anticipate and avoid costly environmental conflicts and repair efforts.

DOI, through the NBS, should immediately begin to exercise the leadership and coordination responsibilities recommended by this committee to leverage other federal biological research spending more effectively. Initial high-priority subjects for increased leveraging and coordination of federal biological research spending would include those mentioned in Chapter 2. Effective leveraging of other federal programs might necessitate small increases in NBS budgets for interagency collaborative research activities.

Non-DOI Federal Agencies

Recommendation 4-9: Agencies whose participation is essential to the success of the National Partnership, especially NSF, should receive increased funding for the study of U.S. biodiversity so that the NPBS can take full advantage of the nation's taxonomic and ecological expertise.

Such support should represent a long-term commitment to the goals of the NPBS. We believe that the recommendations adopted by the National Science Board (1989) for biodiversity research should be implemented as soon as possible to enhance the national and global contribution of U.S. science in this field. These were not specifically focused on biodiversity within the United States, but added emphasis on the national territory would greatly enhance the objectives of the Partnership and is compatible with the

aims of the National Science Board report. NSF's program of extramural funding reaches all segments of the academic community. We therefore concluded that increasing funding levels for the appropriate programs would be an effective way of improving the scientific knowledge appropriate for dealing with biodiversity in the U.S.

To examine the actual and potential role of NSF in supporting the study of U.S. biodiversity, it is pertinent first to review current funding levels, using FY 1992 as a baseline. For community ecology, ecosystem research, and long-term ecological research, more than 80% of all new awards, amounting to about $19 million in FY 1992, were made for research conducted in the United States. Similarly, about 80% of new awards in population biology, amounting to about $4.5 million, were made for studies in the United States. For systematics research relevant to the NPBS, however, the total allocation for new awards in FY 1992 was only $0.8 million (about one-third of the total awarded—for nine grants), and for taxonomic monographs and revisions, only $0.4 million (for three grants of the seven awarded); $6 million was awarded for the support of all systematics collections. Given that hundreds of individual scientists, working individually and cooperatively, are able to contribute substantially to our knowledge of U.S. biota if adequately funded, those figures were obviously much too low to serve the national interest well. New funds should be sought to support biotic surveys, inventories, and monographs directed at priority groups recognized by the NPBS. These funds should include publication and dissemination costs, which are an important part of the NPBS effort (see Chapter 3). Similar programs, using systems of peer review like those used successfully by NSF, should be implemented to the greatest extent possible by the other agencies engaged in the National Partnership.

Funding will also need to be made available for other agencies whose participation is essential to the success of the Partnership. Units whose activities are already integral parts of the national

effort in biological survey—such as the National Marine Fisheries Service, the National Ocean Service, and the Forest Service—will need additional resources if they are to play the roles for which they are well suited in the overall effort. The parts of DOD oriented to biological survey will likewise need additional resources to become full partners in the NPBS, and these resources must be sought in future budget cycles. The roles of the above agencies with respect to the National Partnership should be clearly established as an official part of their missions. For such organizations as the U.S. Army Corps of Engineers, however, which have extensive land-management and permitting responsibilities and large cadres of biologists, appropriate steps should be taken to allow them to address directly the needs of the NPBS in the future; the national welfare clearly makes such a mandate highly desirable. Future funding needs for the other agencies should be carefully assessed within the framework of the NPBS. There also should be opportunities to use existing resources more efficiently and effectively through better integration and coordination.

RELATIONSHIP TO RECOMMENDATIONS OF OTHER REPORTS

Since December 1992, a number of reports on subjects relevant to this committee's work have emerged. Specifically, reports have been released by the National Research Council's Committee on Environmental Research (NRC), the Carnegie Commission on Science and Technology (Carnegie), and the National Commission on the Environment (NCE); and the Committee on the National Institute for the Environment (CNIE) has continued to evolve its ideas. The proposals from those groups bear on the recommendations in this report. In addition, the new national administration and Congress have been active in proposing or implementing changes. Those activities are reviewed briefly to place our report in context.

There is a strong concordance among the reports of NRC, Carnegie, NCE, and CNIE in analyzing the problems that face environmental research. All recognize the need for leadership at the highest levels of government, the need for a national strategy, and the need for coordination of efforts among the many agencies performing environmental research. All emphasize the need for a status and trends program and for improvements in information-gathering and handling in government. All those are also key recommendations of the present committee.

The reports differ, however, in the means that they propose for organizing the effort to solve the problems. CNIE proposes the formation of a National Institute for the Environment. Carnegie and NCE vest the Office of Environmental Quality and EPA with substantial responsibilities. NRC emphasizes the importance of cultural changes, such as a focus on long-term studies and creation of a National Environmental Council, that would be implemented whether departments were left as is or a suggested Department of the Environment were established. The implementation of any of the broad-scale recommendations in the other reports could affect the utility of some of the specific recommendations in this one. However, this committee believes that the broad needs, functional requirements, and recommendations made here would not be affected. A strong National Partnership, with a key central role for the National Biological Survey, will remain essential for understanding the current state of the nation's biological resources, how that state is changing, and the causes of those changes.

5

IMPLEMENTATION

The purpose and objectives of the National Biological Survey and the National Partnership for Biological Survey are broad and ambitious. They will not be reached quickly or easily. The Department of the Interior already has acknowledged that the internal reorganization leading to the establishment of the NBS on October 1, 1993, is only the first step toward a fully functional NBS.

The committee strongly believes that specific implementation steps for both the NBS and the National Partnership should be phased in over a multiyear period according to a well-planned strategy. Otherwise, it is likely that too many tasks will be initiated at once with insufficient personnel and budgetary resources, that programs will be started before clear goals have been established, and that the results will therefore fall short of the high expectations for providing the effective and credible scientific information needed by decision-makers. A set of clear priorities for implementation should be established that emphasize prudent and tested actions and provide some early results. That

course of action will help both the NBS and the NPBS to produce quickly the kinds of results that are essential if they are to show their value to the nation. Most of the recommendations in this chapter apply specifically to the NBS. However, other members of the Partnership will need to be strongly involved in various aspects of the fulfillment of the research and information needs described in previous chapters, including many of those for which specific recommendations are made here for the NBS.

STRATEGIC IMPLEMENTATION PLAN

Recommendation 5-1: Development of the National Partnership and National Biological Survey should be guided by a single Strategic Implementation Plan developed under the leadership of the Department of the Interior with the full participation of NPBS partners.

The plan should provide for a phased approach, including specific milestones and priorities for implementation, in recognition that the effort will be subject to both budget and personnel constraints. It should identify specific near-term (immediately to within one year), intermediate (within 3 years), and longer-term (within 5 years) priorities regarding personnel and administrative management, research, inventory, and data management.

DOI should take the lead in development of the implementation plan, because many of the steps will focus on the NBS. The plan should encompass the entire scope of the Partnership and should be developed in conjunction with other participants, through the proposed coordination mechanisms. The process for development and coordination of the implementation plan should be used as an opportunity to build a consensus among all the participants in the NPBS and to establish priorities.

The plan should identify specific near-term actions that will provide early results. It should also include mechanisms to ensure accountability among the many participants in the Partnership.

Finally, it should incorporate a process for continuing assessment of the work of the NPBS. The proposed coordination mechanisms should be used to ensure accountability and assess the progress of implementation of the Partnership.

The initial draft of the implementation plan should be developed and released quickly for public comment, at least in outline form, if possible within 90 days after the establishment of a coordination mechanism. The plan should be updated annually for at least the next 2 years.

IMPLEMENTATION PRIORITIES IN PERSONNEL AND ADMINISTRATIVE MANAGEMENT

Near-Term Priorities

Recommendation 5-2: The following issues should be addressed as rapidly as possible so that the NBS can begin substantive work in the last quarter of calendar 1993: appointment of key leaders, establishment of coordination mechanisms, phased personnel transfers, and development of an FY 1995 budget initiative for DOI, the National Science Foundation (NSF), and other agencies involved in the Partnership.

Provided below are more details related to this recommendation:

- *Personnel appointments.* The Secretary of the Interior should appoint three key leaders for the NBS: the director, the chief scientist, and an assistant director for data management. Until they are in place, effective direction and planning of the NBS cannot begin.
- *Coordination mechanisms.* Appropriate steps should be taken to implement mechanisms for coordination within the National Partnership, described in Chapter 4.
- *Phased personnel transfers.* The proposed transfers of peo

ple to NBS programs from the existing bureaus of DOI should be phased in over time and not implemented all at once as DOI currently plans. The committee is concerned that the transfers might leave the other bureaus, such as the Fish and Wildlife Service and the National Park Service, without adequate scientific capabilities for them to carry out their management responsibilities. Phased transfers would result in a more orderly process and would provide a better opportunity to assess their impacts on the management agencies.

It appears likely that Congress will appropriate funding to the NBS for full transfers of personnel effective at the start of FY 1994. However, the committee believes that the phased transfer process referred to above can be implemented consistently with such an appropriation. The bulk of the transfers would take place immediately. The cost of personnel not transferred to the NBS in the initial phase could be reimbursed through the NBS appropriations. Alternatively, revisions to the current plans for personnel transfer could be incorporated into a budget reprogramming.

- *FY 1995 budget request.* DOI, NSF, and other appropriate agencies should develop initiatives for their FY 1995 budgets to obtain additional funding needed to carry out recommendations in this report. The committee recommends that the NBS FY 1995 budget be increased by about the same percentage as in the DOI budget request for FY 1994. We further recommend that NSF research programs related to the work of the National Partnership, as described in Chapter 4, be assigned a high priority for a budget increase, and that relevant programs in the National Oceanic and Atmospheric Administration, the Forest Service, the Smithsonian Institution, and the Environmental Protection Agency also receive funding increases. The committee also recommends funding of the Fish and Wildlife Conservation Act to provide increased resources for state wildlife programs concerned with native wildlife that are not consumptively used (i.e., nongame programs). As discussed in Chapter 4, the committee believes that these near-term budget increases are necessary if the National Partnership is to be launched successfully.

Intermediate-Term Priorities

Recommendation 5-3: During the first 3 years, broadening the mix of scientific disciplines in the NBS and developing a multiyear authorization should have high priority.

- *Broadening the mix of scientific disciplines in the NBS.* In view of the broad scientific needs of the NBS, the expertise of DOI scientists that are expected to make up the initial staff is inadequate. All possible sources of scientific expertise available in institutions, organizations, and government agencies should be drawn to provide information. At the same time, every effort should be made to enhance the capabilities of the NBS by increasing the numbers and proportions of scientists with expertise pertinent to the overall objectives of the NBS, rather than merely attempting to build expertise by reassigning personnel. Key subjects of expertise include taxonomy and systematics, ecology, botany, population biology, invertebrate zoology, social sciences, statistical design and analysis, and information sciences. In addition, it is vital that each survey research unit have full capability in geographical information system (GIS) technology. Such competence is not available throughout the proposed network of NBS facilities.
- *Multiyear authorization:* The federal agencies involved in the National Partnership should develop a multiyear strategy and budget for federal NPBS programs as a means to ensure their effective coordination. In addition to the National Biological Survey, other involved agencies should seek multiyear legislative authorizations for their NPBS programs beginning in FY 1996. A multiyear authorization would be an important expression of legislative and executive support for the National Partnership and could help to provide a measure of funding stability and program continuity, although the programs would still be subject to the standard appropriations process.

Long-Term Priorities

Recommendation 5-4: Within 5 years, the NBS should develop a strong capability in ecological analysis.

Over the longer term, the NBS should continue to add scientists who are able to fill major gaps in biological knowledge, who have skills in the analysis of ecological systems at all levels, and who are familiar with the geographic locations in greatest need of evaluation vis-a-vis degree of conflict with human activities. Evaluating existing and probable future human activities—whether metropolitan growth, sustainable land use, or nonrenewable extraction—is crucial to making a determination as to the potential ecological impact of such activities.

IMPLEMENTATION PRIORITIES IN RESEARCH AND INVENTORY PROGRAMS

The broad scope of the National Partnership requires an unprecedented research and inventory effort to understand the nation's biological resources. The overall objectives of NPBS systematic and ecological research and inventory programs are to create a strong information base about the nation's biological resources and to analyze the status and trends of those resources. To achieve these objectives, major short-term program-planning decisions regarding research and inventory activities must be made.

Near-Term Priorities

Recommendation 5-5: During its first year, the NBS should give high priority to assessing existing national biological

databases and identifying priorities for additional information, assessing collections, establishing a register of taxonomic specialists and identifying gaps, developing a national research plan, and initiating regional collaborative pilot projects.

These research priorities are described further below:

- *Assessment of the existing national biological databases and identification of priorities for additional information.* Initiation of a major effort to assess the whereabouts, availability, and quality of existing data and expertise and development of a plan to fill key gaps.
- *Assessment of collections*. Initiation of a national assessment to identify collection-holding institutions and the extent of their coverage. On the basis of the assessment, a national strategy should be developed for new survey and inventory work to fill gaps and for curation and maintenance of the collections and their associated data.
- *Register of taxonomic specialists*. Establishment of a national register of taxonomic specialists, identification of which high-priority groups lack specialists, and institution of training or retraining programs to fill the gaps in expertise.
- *Research plan.* Convening workshops of specialists to determine which taxonomic groups and ecosystems meet criteria for intermediate-term, near-term, or long-term attention; establishment of a national plan for corresponding research; and evaluation of taxonomic groups, communities, and ecosystems according to criteria recommended in Chapter 2 with establishment of priorities and identification of responsible parties. Research plans will be needed by both the NBS (for DOI's needs) and the NPBS (for overall national needs).
- *Regional collaborative pilot projects.* Planning and initiation of pilot projects (Recommendation 2-13) to study species biology, community processes, and ecological interactions to determine which taxa, ecosystems, and geographical areas warrant highest

priority and use of the results to design larger-scale and long-term studies. As with the research plans, these actions need to be taken by both the NPS and other NPBS participants.

Intermediate-Term Priorities

Recommendation 5-6: By its third year, the NBS should establish or expand its research programs in environmental indicators and inventories of areas rich in biological diversity, of unique ecosystems, and of potential candidate areas for restoration, and it should develop a series of manuals, monographs, and atlases and a system of ecological classifications based on attributes.

- *Environmental indicators.* Expansion and intensification of research to identify the most useful indicators of environmental trends.
- *Inventories of areas rich in biodiversity.* Initiation of activities for a substantial number of biogeographic areas or habitats that have high species richness or assemblages of unique species. Such areas might include California, Hawaii, and Florida. These inventories would provide resource managers and policy-makers a much better base of information to guide future decisions on multiple-use management.
- *Inventories of unique ecosystems.* Thorough inventory of a small number of communities and ecosystems that are unusually threatened so that conservation plans can be developed before the situation is critical.
- *Inventories to guide restoration.* Inventory of a subset of the nation's ecosystems (e.g., rivers) for the purpose of identifying ecosystems where restoration efforts are likely to provide the greatest benefit for a moderate cost.

- *Information services.* Preparation of a series of manuals, monographs, atlases, and field guides for the taxa and ecological units studied in both print and electronic format.
- *Ecosystem classifications.* Definition of core ecosystem attributes and development of functional ecosystem classification schemes.

Long-Term Priorities

Recommendation 5-7: By its fifth year, the NBS should broaden its scientific priorities to include research efforts in restoration biology and expanded inventories, should develop models to predict the status and trends of ecological systems, and should work to fill remaining gaps.

- *Restoration biology.* An expanded program of research in restoration biology.
- *Expanded inventories.* Gradual expansion of the inventory of the nation's biodiversity to less well-known groups.
- *Development of predictive models.* Broadening programs to ascertain the power of data to predict the status and trends of ecosystems and species so as to anticipate species declines and community perturbations resulting from human activities. In addition, modeling efforts should seek to develop methods for applying the knowledge gained from model systems to a broad range of habitats. The completion of DOI's terrestrial Gap Analysis Program and the initiation of aquatic gap analysis are important steps in the development of such models.
- *Filling gaps.* Broadening of research programs to initiate research on neglected species, populations, communities, and ecosystems that are judged to be of special importance for scientific, economic, recreational, or cultural reasons.

IMPLEMENTATION PRIORITIES IN DATA MANAGEMENT

At a 1985 symposium on the need for a national biological survey (Kim and Knutson, 1986), those in attendance agreed that massive computerized data collection was essential. Computerized databases on the nation's ecosystems and biota are vital components of the NPBS. A program that did not involve an extensive, easy-to-use, computerized data network would be unable to accomplish its goals.

Near-Term Priorities

Recommendation 5-8: During its first year, the National Partnership, under the lead of the NBS, should develop a strategic plan for information management, and the NBS should establish a data-management office headed by a senior official.

- *Plan for information management.* Development of a strategic plan for information management should be developed as part of the overall NPBS implementation plan. The plan should identify the user groups to be served, the functions to be provided, and the kinds of products needed to meet user needs. The plan should also document and evaluate relevant activities and information resources that are pertinent to the NPBS. DOI should take the lead in this effort, with the initial focus of information management being within the NBS. However, the plan should encompass all data-management activities of the Partnership, and all its participants should be involved. Oversight and assessment of the implementation of the strategic plan should be performed through the proposed coordination mechanisms.
- *Data-management organization.* Establishment of a separate data-management office at the NBS headed by a senior-level official (assistant director or higher). The office should be

provided with personnel and equipment dedicated to distributing regional and national NBS data sets and supporting NBS activities.

Intermediate-Term Priorities

Recommendation 5-9: By its third year, the National Partnership, under the leadership of NBS, should establish the foundations of a networked, distributed, National Biotic Resource Information System.

Because the essential data on biological resources are maintained in a variety of private, local, state, and federal sources, the development of a national network of distributed databases is a critical objective. The NBS should take the lead in developing a national data network by

- Establishing a moderate-sized data management facility, the primary mission of which is to manage NBST data, but which will also include a directory service to help NPBS users locate and/or access information available through the national network.
- Identification of appropriate linkages with other database sources.
- Coordination of a series of workshops involving potential contributors and cooperators in the network to coordinate and standardize collection and management of data.
- Major expansion of online access to biological-resource data and expediting of creative use of Internet, user interfaces, and graphical communication.
- Support of existing private, local, and state efforts to develop regional and statewide databases.
- Detailed study of several model systems as pilot projects to evaluate approaches to data collection, interpretation, and application.
- Active cooperation with federal interagency initiatives to coordinate and manage data on biological resources.

- Moderate expansion of the database facility and staffing to handle the increased activities.
- Substantial increase in the NBS capabilities for publication and electronic communication.

The data management facility should focus on archiving and distributing data sets and meeting the goals of DOI's proposed National Biological Status and Trends program.

Long-Term Priorities

Recommendation 5-10: By its fifth year, NPBS should develop programs to deploy new information technology, expand its publication capabilities, and evaluate its data-management programs.

- *Deployment of new information technology.* Implementation of a continuing program to use newly discovered and enhanced information technologies in data collection, management, and dissemination.
- *Expansion of publication capability.* Increased online access to information and publication of related data sets, atlases, and summaries.
- *Program evaluation.* NBS leadership in developing the capability to evaluate the success of completed and continuing studies and to design new ones. Overall evaluation and assessment of data-management activities should be accomplished through the proposed mechanisms for coordination.

SUMMARY

This chapter has discussed the steps needed to implement the actions in this report. The first key step is the development of a single strategic implementation plan that would guide the develop

ment of the National Partnership for Biological Survey and National Biological Survey. This plan should be developed under the leadership of DOI and with the full participation of NPBS partners.

As part of this plan, priorities need to be set. The following list summarizes all the near-term, intermediate-term, and long-term priorities noted in this chapter.

Near-Term Priorities (Immediately to within 1 Year)

NBS

- Appoint key leaders
- Phase in personnel transfers
- Assess existing national biological databases
- Identify priorities for additional information
- Assess collections
- Establish register of taxonomic specialist
- Develop national research plan
- Initiate regional collaborative pilot projects
- Establish data-management office headed by senior official

NPBS

- Establish national coordination mechanisms
- Develop FY 1995 budget initiative for DOI, NSF, and other agencies involved
- Develop strategic plan for information management
- Develop national research plan
- Initiate regional collaborative pilot projects

Intermediate-Term Priorities (within 3 Years)

NBS

- Broaden mix of scientific disciplines
- Establish or expand research programs in environmental indicators
- Establish or expand research programs in inventories of areas rich in biological diversity, unique ecosystems, and potential candidate areas for restoration
- Develop series of manuals, monographs and atlases and system of ecological classifications based on attributes
- Establish moderate-size data-management facility

NPBS

- Develop multiyear authorization
- Establish national data network

Long-Term Priorities (within 5 Years)

NBS

- Develop strong capability in ecological analysis
- Broaden scientific priorities to include research efforts in restoration biology
- Expand inventories
- Develop predictive models
- Fill information gaps

NPBS

- Develop programs to deploy new information technology
- Evaluate data-management programs.

Although priorities might change over time, the committee believes that phasing the steps outlined above according to a well-planned strategy will lead to a successful NBS and National Partnership. If a clear strategy is not developed, it is likely that the results will fall short of providing the effective and credible scientific information needed by decision-makers. Establishing the priorities outlined here will help both the NBS and the NPBS to provide quickly the kinds of results that are essential if they are to show their value to the nation.

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APPENDIX A:

BIOGRAPHICAL INFORMATION ON COMMITTEE MEMBERS AND PROFESSIONAL STAFF

COMMITTEE MEMBERS

Peter H. Raven ***(Chair)*** is director of the Missouri Botanical Garden and Engelmann Professor of Botany of Washington University. He received his Ph.D. from the University of California, Los Angeles in 1960. He is home secretary of the National Academy of Sciences and member of the National Science Board. He holds honorary degrees from several universities, is a member of several foreign academies of sciences, and has received numerous international honors and awards, including the International Prize for Biology from the government of Japan, the Prize for Environment of the Institute de la Vie in Paris, and the Volvo Environment Prize.

Michael J. Bean is chair of the Environmental Defense Fund's Wildlife Program where since 1977 he has been a principal strategist in legislative efforts to strengthen protection for en

dangered species, other wildlife, and wildlife habitats. He serves on the boards of the Environmental Law Institute and the Xerxes Society and is the recipient of numerous awards, including the Society for Conservation Biology's Distinguished Achievement Award. His publications range from *The Evolution of National Wildlife Law*, which is generally regarded as the leading reference on wildlife conservation law, to articles for scientific, popular, and legal periodicals. He is a 1973 graduate of Yale Law School.

Frank W. Davis is an associate professor of geography at the University of California, Santa Barbara. He received his Ph.D. from The Johns Hopkins University Department of Geography and Environmental Engineering in 1983. Currently, he is principal investigator of the California Gap Analysis project, a participant in IBM's Environmental Research Program, and a member of the editorial board of *Conservation Biology* .

Gordon P. Easton is director of the Lamont-Doherty Earth Observatory of Columbia University. Previously, he was president of Iowa State University for four and one-half years. Dr. Eaton received his Ph.D. at the California Institute of Technology. In 1963, he joined the U.S. Geological Survey and he became the associate chief geologist in 1978. His honors include the U.S. Government Senior Executive Performance Award.

Sharon G. Haines is manager, natural resources, International Paper. She received her Ph.D. in forestry and soil science from North Carolina State University in 1977. She is the Chair of the Forest Science and Technology Board of the Society of American Foresters and a former associate editor of *Soil Science Society of America Journal* and *Southern Journal of Applied Forestry*.

Joseph Hezir is executive vice president of the EOP Foundation, Inc. He also is the managing partner of the EOP Group, Inc., a consulting firm that specializes in regulatory-strategy development and problem-solving. Mr. Hezir served for 18 years in the White House Office of Management and Budget (OMB).

From 1986 to 1992, he served as the OMB deputy associate director for energy and science, with oversight responsibility for the budgetary, regulatory, legislative, and policy-development activities of a number of federal agencies.

Jeremy B.C. Jackson is a senior scientist at the Smithsonian Tropical Research Institute (STRI) in the Republic of Panama, where he is director of the Center for Tropical Paleoecology and Archaeology. He received his Ph.D. from Yale University in 1971, and was professor of ecology at The Johns Hopkins University before moving to STRI in 1984. His current research includes historical patterns of diversity and extinction in tropical America in relation to the formation of the Isthmus of Panama and the ecology and conservation of tropical coastal communities.

Christopher B. Leinberger is managing director of Robert Charles Lesser & Co., the largest independent real-estate advisory firm in North America. He specializes in metropolitan development trends and strategic planning for cities and real-estate companies. He is a graduate of Swarthmore College in urban sociology and Harvard Business School in strategic planning. He also attended the University of Michigan's Survey Research Center and the Martin Luther King School of Social Change and was a Coro fellow in Los Angeles.

Judith L. Meyer is professor of ecology at the University of Georgia, Athens. She received her Ph.D. in ecology and evolutionary biology from Cornell University in 1978. Her research interests are in the field of aquatic ecology with a focus on stream ecosystems, microbial food webs, and land-water interactions. She is president-elect of the Ecological Society of America.

William Molini is director of the Nevada Department of Wildlife, having been appointed in 1982. He received his education from Utah State University in wildlife management. He served as president of the International Association of Fish and Wildlife Agencies in 1989-1990 and of the Western Association of Fish and Wildlife Agencies in 1982. Among his awards are the

Conservation/Service Citation from the National Wildlife Federation and the President's Public Service Award from The Nature Conservancy.

Nancy R. Morin is assistant director of the Missouri Botanical Garden and convening editor for Flora of North America. She received her Ph.D. from the University of California, Berkeley in 1980. She is an adjunct professor of botany at Washington University and the University of Missouri St. Louis. She serves on the editorial committee for the Flora of China and on the council of the International Organization for Plant Information.

Lorin I. Nevling, Jr. is chief of the Illinois Natural History Survey in the Illinois Department of Energy and Natural Resources and Affiliate of the Department of Plant Biology, University of Illinois at Champaign-Urbana. He received his Ph.D. from Washington University in 1959. He has served at the Arnold Arboretum, Gray Herbarium, Farlow Herbarium, and Library of Cryptogamic Botany, all of Harvard University, and at the Field Museum of Natural History.

Gordon H. Orians is professor of zoology and environmental studies at the University of Washington, Seattle and formerly directed the Institute for Environmental Studies there. He is an ecologist and environmental scientist who conducts research on the evolution of vertebrate social systems, the structure of ecological communities, plant-herbivore interactions, the ecology of rare species, and environmental aesthetics. He is a member of the National Academy of Sciences.

Paul G. Risser is president of Miami University in Oxford, Ohio, where he also holds the rank of professor of botany. He received his Ph.D. from the University of Wisconsin-Madison in 1967. He chairs the Board On Environmental Studies and Toxicology of the National Research Council. He is past president of the American Institute of Biological Sciences and the Ecological Society of America.

Robert J. Robbins is associate professor of medical infor

mation and director of the Applied Research Laboratory at the William H. Welch Medical Library of The Johns Hopkins University and director of the Informatics Core of the Genome Data Base. He received his Ph.D. from Michigan State University in 1977. Before going to Johns Hopkins in 1991, he served as program director for database activities in the biological, behavioral, and social sciences at the National Science Foundation. He serves on the advisory boards of several biological databases and on the Human Genome Coordinating Committee for the Department of Energy.

Jay M. Savage is professor of biology at the University of Miami in Coral Gables. He received his Ph.D. from Stanford University in 1955. His research has concentrated on the evolutionary and historical determinants of the distribution of vertebrates, their ecologic role in tropical forests and biogeographic theory. In 1963 he was instrumental in founding the Organization for Tropical Studies (OTS) which is now a consortium of 55 U.S. and Latin American institutions devoted to graduate education, research and conservation in the tropics, and has a central office and field stations in Costa Rica; he served as its president in 1974-1980.

Rollin D. Sparrowe received a Ph.D. in wildlife ecology from Michigan State University in 1969. He is Vice-president of the Wildlife Management Institute, in Washington, D.C. Previously, he served with the U.S. Fish and Wildlife Service as chief of the Division of Cooperative Research Units, chief of the Division of Wildlife Research, chief of the Office of Migratory Bird Management, and deputy assistant director for refuges and wildlife. Dr. Sparrowe is president-elect of The Wildlife Society, a member of the Society for Conservation Biology, and a professional member of the Boone and Crockett Club. He has received a number of awards for outstanding service, including the U.S. Department of the Interior's Superior Service Award and the Meritorious Service Award.

Victoria J. Tschinkel is a senior consultant for environmen

tal issues with the law firm of Landers and Parsons in Tallahassee, Florida. She was secretary of the Florida Department of Environmental Regulation in 1981-1987 and was involved in the development of major environmental legislation. She is a member of the boards of directors of numerous private and public organizations, including Resources for the Future, the Environmental and Energy Study Institute, the National Commission on the Environment, the German Marshall Fund of the United States, and Phillips Petroleum Company. She also chairs the advisory council of the Gas Research Institute.

Quentin D. Wheeler is chair and associate professor of insect taxonomy of the Department of Entomology, Cornell University. He received his Ph.D. from the Ohio State University in 1980. He is a research associate of the American Museum of Natural History, New York City. He is vice president of the Association of Systematics Collections, vice president of the International Willi Hennig Society, and past president of the Coleopterists Society.

PROFESSIONAL STAFF

Eric A. Fischer is project director of the Committee on the Formation of the National Biological Survey and director of the Board on Biology and the Institute of Laboratory Animal Resources of the National Research Council. He received his Ph.D. from the University of California at Berkeley in 1979. As an American Association for the Advancement of Science Congressional Science Fellow, he worked on federal science policy and science education for the U.S. Senate Budget Committee. He became deputy director of the Smithsonian Tropical Research Institute in Panama, and then senior vice president for science and sanctuaries at the National Audubon Society, before coming to the Research Council.

Deborah D. Stine is a senior program officer for the Committee on the Formation of a National Biological Survey, project director for a National Academy of Engineering workshop on corporate environmental responsibility, and study director of the Committee on Risk Assessment of Hazardous Air Pollutants. At the National Research Council since 1989, Dr. Stine previously served as staff officer of the Committee on Science, Engineering, and Public Policy's Panel on Policy Implications of Greenhouse Warming, focusing on the mitigation of greenhouse-gas emissions. Her specialties are environmental engineering, policy analysis, and decision-making.

APPENDIX B:

NATIONAL BIOLOGICAL SURVEY FISCAL YEAR 1994 BUDGET JUSTIFICATION

The task of this committee is not to undertake an evaluation of the details of the Department of the Interior's proposal for the National Biological Survey. Nonetheless, the reader may find it useful to see key parts of this proposal. Thus, this appendix contains excerpts of the DOI's FY 1994 budget justification to Congress that describes the mission and organization that DOI has proposed for the National Biological Survey.

GENERAL STATEMENT

Overview

"The National Biological Survey will produce the map we need to avoid the economic and environmental 'train wrecks' we see scattered across the country. NBS will

provide the scientific knowledge America needs to balance the compatible goals of ecosystem protection and economic progress. Just as the U.S. Geological Survey gave us an understanding of America's geography in 1879, the National Biological Survey will unlock information about how we protect ecosystems and plan for the future."

Bruce Babbitt
Secretary of the Interior

Perhaps no other function at the Department of the Interior is as critical to natural resource decision-making as is science. In a world marked by growing demands for natural resources and increasing complexity and competition, it is imperative that sound and comprehensive science provide the basis for informed and timely answers. This is particularly true in the area of biological science where our awareness of man's impact upon the diversity and interdependence of life grows daily.

In recent years, the need for broader and more timely biological information has been readily apparent in the numerous controversies and potential economic dislocations surrounding endangered species decisions. Unfortunately, the scientific information being provided often appears only after the crisis has emerged, not before, when there is still time to act effectively.

The creation of the National Biological Survey (NBS) as a freestanding bureau within the Department of the Interior is aimed at filling the vacuum that currently exists for broad scale biological information and assessments of the Nation's natural resources. Science, in the context of the NBS, includes traditional research (including that carried out in cooperation with state agencies and universities) as well as inventorying and monitoring to identify status and trends, and information transfer.

The Department proposes to establish the NBS by combining substantial portions of the biological research and survey activities of three Departmental bureaus — the U. S. Fish and Wildlife

Service (FWS), the National Park Service (NPS), the Bureau of Land Management (BLM)-and smaller research activities from five other Departmental bureaus-the Minerals Management Service (MMS), the Office of Surface Mining Reclamation and Enforcement (OSM), the Bureau of Reclamation (BOR), the U.S. Geological Survey (USGS), and the Bureau of Mines (BOM). Organizationally, the NBS will report to the Assistant Secretary for Fish and Wildlife and Parks.

The NBS will 1) perform research in support of biological resource management; 2) inventory, monitor, and report on the status and trends in the Nation's biotic resources, and 3) develop the ability and resources to transfer the information gained in research and monitoring to resource managers and to others concerned with the care, use, and conservation of the Nation's natural resources.

The Department is proposing to establish a new bureau to:

- Develop an anticipatory, proactive biological science program that will enable land and resource managers at federal, state, and local levels to develop comprehensive ecosystem management strategies and respond to resource issues in a timely and efficient manner. This will maximize opportunities for constructive cooperation between economic development and resource conservation interests, thus reducing costs and avoiding unnecessary conflicts.
- Enable Departmental managers to target resources so as to respond to the most critical national biological resource concerns while ensuring that local concerns are also addressed.
- Establish national leadership and focus for the Department's biological science program, enhancing its credibility and providing a greater incentive for natural resource managers and others to rely upon scientifically generated data and conclusions.
- Reduce overlap and duplication among the biological research, inventory and monitoring, and information transfer efforts

of the bureaus within the Department, and improve the quality and productivity of the Department's overall biological science efforts.

- Give land and resource managers within the Department more timely, objective scientific information essential for decision-making and for structuring more effective partnerships with federal, state and local entities.

Mission and Activities

The mission of the NBS will be to gather, analyze and disseminate the information necessary for the wise stewardship of our Nation's natural resources, and to foster an understanding of our biological systems and the benefits they provide to society. The NBS will act as an independent science bureau, without advocating positions on resource management issues and without regulatory or land and water development authorities.

The NBS will support the appropriate management of land and living resources by, 1) providing information on the abundance, distribution and health of biological resources, through a coordinated, inventory and monitoring program for plants, animals and ecosystems, that will produce a biennial report on status and trends in the Nation's biological resources; 2) furthering the understanding of the functioning of biological systems, their relationships with other resources and their responses to human and environmental stress, through a research program organized around species, population and ecosystem research; and 3) communicating the results of both inventory, research, and technology and methods development, through a state-of-the-art technology development and information transfer element. The NBS will build on existing capabilities within the Department, and will augment them with special emphasis on improved, statistically significant, comprehensive status and trends, and expanded effort on ecosystem and landscape levels of research.

NBS's activities will be fully responsive to the management and

information needs of Interior bureaus, and will be closely coordinated with other federal agencies, state and local governments, the private sector, and nongovernmental organizations. Several means will be used to ensure that NBS will meet the needs of Departmental and other research users. It will hold meetings of resource managers, research customers, and research managers in each ecoregion at least annually, to help identify resource trends and research needs and priorities; it will also use a policy board and a science council, to include representatives of Departmental resource management bureaus and external science interests (state, federal, and academic), respectively, to advise on national trends and needs. The NBS will formalize the needs and services to be provided through Memoranda of Understanding negotiated with each bureau. Finally, NBS will maintain the presence of its scientists in resource managers' facilities, to emphasize through physical proximity the objective of continuing a close working relationship with the customer. The goal is to make the change in organization a transparent one, with no obstacles to meeting resource managers' needs while improving the level and quality of support.

NBS will serve the land and resource managers' and policymakers' needs for information on the structure, functioning and responses of biological resources and systems under the management of the Department's bureaus, to enable them to better fulfill their missions. Building on the existing network of relationships, NBS will focus on a broad array of biological information and research needs, from the national and regional levels, through ecosystem and landscape levels, to local and site-specific needs. The research will be both basic as well as problem and issue oriented. NBS will provide the best available, timely information necessary for Department bureaus to make policy and natural resource management decisions at the local level. NBS will also serve, on a reimbursable basis, the needs of other federal and state agencies, local governments, and other entities.

NBS will expand existing inventory activities to produce a coordinated inventory and monitoring program yielding statistical

ly significant results on the status and trends in abundance, health and distribution of plants, animals, and ecosystems. This will include efforts to identify declines in, or degradation of, ecosystems and their component species and populations prior to the time they are reduced to critical levels demanding severe protection. The inventory program will be conducted in concert with other federal agencies, state agencies, State Heritage Programs, nongovernmental organizations, and academia.

A program for technical development and information and technology transfer will provide managers with tools and information to help interpret and apply biological information in order to better manage natural resources. It will involve: (1) development, modification and adaptation of emerging technologies, (2) development of predictive models based on the research data, for use by managers, (3) development and improvement of techniques, methods and protocols for gathering, synthesizing, analyzing and storing data, and (4) a program to transfer and encourage the effective use of information and technologies by bureau policymakers and natural resource managers.

Cooperative research units remain an important element of NBS's approach. These units will provide scientists and education to help meet local, site-specific, and specialized research needs of the Department, other federal and state agencies. Through existing units, state natural resource agencies already have an established, effective partnership with the federal research capability of the Department. Cooperative research efforts have provided professional graduate education, technical assistance, and resource management information for state and federal resource management agencies at significantly lower costs than each could have provided for themselves.

NBS Headquarters and Field Organization

The programs and functions of the NBS will be carried out through the following major organizational components:

Headquarters Office

Consists of the Director, Deputy Director, Assistant Directors, and the staff offices and divisions reporting to them (see organizational chart) and provides national policy formulation and program direction for each of the programs implemented under the NBS research, inventory, and information transfer. The Headquarters office directly supervises research and inventory activities that are national in scope. The Headquarters office receives guidance from a Policy Board which consists of Interior bureau representatives, and a Science Council which is made up of representatives from the federal, state, nongovernmental, and academic biological science community. The Science Council assists in improving coordination with entities outside of the Department of the Interior and ensuring that NBS's agenda fully reflects national concerns. The Headquarters office maintains contacts with Departmental and bureau offices, the Office of Management and Budget, the Office of Personnel Management, Congress, other federal and state agencies, national organizations, the media and members of the public; and provides central administrative direction and procedures for NBS activities.

Ecoregional Centers

Each Center is headed by an Assistant Director, and has overall responsibility for providing line management, procedural and operational guidance for all NBS activities-except national programs-within the region under its jurisdiction. Centers also have responsibility for national program policy development and support for delegated program areas under their jurisdiction, for coordination and communication with local managers and other research customers within their jurisdictions, for providing delegated technical and administrative support functions within their jurisdictions, and for supervising the activities conducted by Research Centers, Cooperative Research Units, and other Region

al research scientists. There are 4 Ecoregional Centers, located in Leetown, WV; Lafayette, LA; Ft. Collins, CO; and Seattle, WA. (See map, page 6, for regions and associated centers.)

Research Centers

Each headed by a Center Director, have responsibility for directing and conducting large scale regional research, monitoring, and information transfer activities within their specialty areas of jurisdiction; for coordination with and support to resource managers and other research customers; for providing administrative support as delegated; and for supervising Field Stations for whom they have jurisdiction. There are a total of 12 Research Centers and 40 Field Stations.

Cooperative Units

Each headed by a Unit Leader, have responsibility for conducting research, graduate-level education, and technical assistance activities in support of Interior bureaus, other federal and state agencies, and universities. Their activities are most often local, regional, or statewide in nature, but they may address larger scale issues as special expertise is needed. Acting in concert, they can also provide a nationwide network of research stations. There are a total of 72 Cooperative Units.

Inventory and Monitoring Activities

The Assistant Director for Inventory and Monitoring will direct national efforts for the status and trends, and establish policy, standards, and protocols for a coordinated inventory and monitoring program at the local and regional level. Activities will include efforts to inventory the abundance, distribution, and health

of indicator plants, animals, and ecosystems. Standardized protocols will be established in cooperation with other agencies to enhance comparability of methods. It will include existing inventory programs, including the National Wetlands Inventory, Gap Analysis Program, Biomonitoring of Environmental Status and Trends, and other new components.

Information Transfer

The Assistant Director for Information Transfer will direct activities related to management and storage of data within the NBS as well as the transfer of scientific information to research customers. These activities include the development of scientific publications, databases, and syntheses of information generated by research and inventory and monitoring programs.

Bureauwide Support Offices

The Geographic Information System Technical Center, located at Denver, Colorado, and headed by the Technical Center Director, provides bureauwide technical, scientific, data management and administrative services. It will maintain field stations for local and regional support in Onalaska, Wisconsin, and other locations in the future.

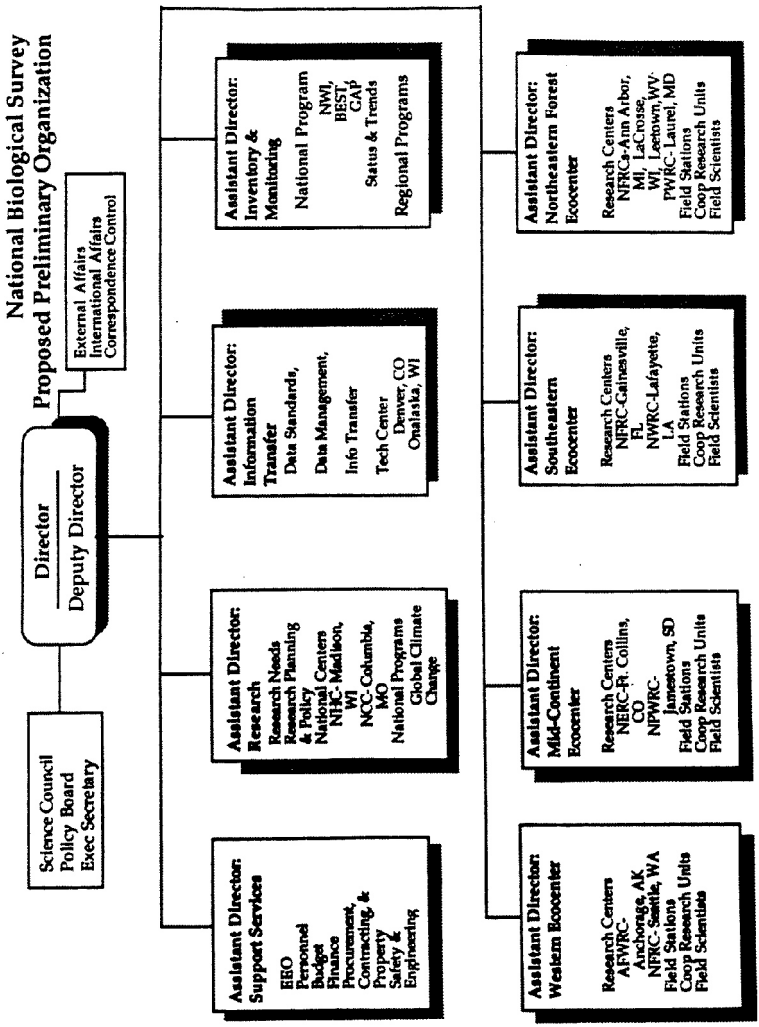
Only those resources necessary to accomplish the basic mission of NBS will be transferred to NBS. Researchers and support staff will move to NBS if they are involved in formation and testing of hypotheses, whether laboratory or field-based; basic or applied and mission oriented, research on subjects such as systematics, population dynamics, physiology, behavior, ecology, habitats, biodiversity, and ecosystem processes and functions; and national inventories or those of national significance. Staff involved in applying biological information to management decisions will not

be transferred. For example, the Department's existing organizations will continue to decide whether 1) to list a species under the Endangered Species Act, 2) determine appropriate grazing levels on a specific land parcel, and 3) evaluate alternative road alignments. Most biologists in the Department will not be transferred to NBS. The majority of the Department's biologists are involved in the application of biological information to decisions, rather than in research and major inventory efforts, and will remain in the resource management bureaus.

Inventory and monitoring activities to be transferred to NBS will include those national and regional level efforts that are necessary for, and can contribute to, a comprehensive national picture of the abundance, distribution, and health of biological resources. Purely local efforts will not be transferred but, rather, will be supported by the technology development and standardization efforts of NBS.

The NBS will provide a variety of benefits. It will:

- Provide a national focus and leadership for quality inventory and monitoring, biological research, technology development and transfer, and cooperative biological research.
- Ensure that science remains independent from management's application of science. This separation of functions will enhance the integrity and objectivity of scientific results.
- Consolidate many separate, overlapping functions into one organization, enhancing overall productivity and capability, avoiding duplication, and taking advantage of economies of scale.
- Expand the research information and technical support available to all clients.
- Provide a clear statement about the importance of quality, professional science.
- Provide the opportunity for proactive, anticipatory research that will help avoid future "train wrecks".



NATIONAL BIOLOGICAL SURVEY
Ecocenters

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