

BUILDING A SCIENTIFIC
BASIS FOR ENSURING THE
VITALITY AND
PRODUCTIVITY OF
U.S. ECOSYSTEMS

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Introduction

Federally supported research plays an essential role in meeting the challenges of ensuring that the vitality, diversity, and productivity of ecological systems can support current and future societal needs. The National Science and Technology Council (NSTC) was established by the President in November 1993 to coordinate research and development activities across all federal agencies. Its Committee on Environment and Natural Resources (CENR) has reviewed overall federal environmental R and D priorities and identified an integrated subset of priorities for better understanding and predicting how our ecological systems respond to changing environmental conditions. The priorities include improving our ability to document change in ecological systems, to understand ecological processes and interactions with human activities, to predict consequences of change, and to increase the range of potential solutions. The CENR suggests that federal agencies begin implementing these priorities by: (1) developing an integrated network of ecological research and observation sites to improve the efficiency and comparative analysis of federal efforts; and (2) conducting national and regional integrated assessments that document the health of our environmental systems and provide this information to decision-makers.

A national goal for ecosystem science

Ecosystem science can be defined as the scientific study of the processes influencing the distribution and abundance of organisms, the interactions among organisms, and interactions between organisms and the transformation and flux of energy and matter (Likens 1992). This definition

implies that ecological systems are open in that they exist as a continuum through space and time through the exchange of water, energy, and materials. As a consequence, an ecosystem approach to research, assessment, and management of natural systems and their resources is needed to ensure adequate consideration of all important ecosystem components, processes, and interactions and the cumulative effects of present and future environmental change. A national goal for the study of ecological systems that emerged from a review by the National Science and Technology Council's Committee on Environment and Natural Resources (CENR) recognizes the need to understand the interdependent relationship between human and natural systems at many spatial and temporal scales. The goal is to adequately understand the role of ecological systems in establishing and influencing local to global environments to ensure their sustained productivity, vitality, diversity, and societal value.

Underlying this need is the recognition that the pursuit of an improved quality of life has often produced unintended threats to the vitality, diversity, and productivity of ecological systems. Continued decreases in the resilience of ecological systems indicate that their capacities to sustain life are being reduced, but exactly how and why these systems are changing is incompletely understood. What is indisputable, though, is that the basis for economic and human development has been the availability and health of the natural resources supported by these ecological systems, and to support further human development, we must sustain its ecological base. An essential ingredient for meeting this challenge is acquiring appropriate scientific information on the current condition of our ecological systems; the value of these systems in ecological, social, and economic terms; and forecasts of future conditions when various new technologies, management approaches, and protection and conservation policies are applied.

Recognizing the essential role that

Federally supported research plays in meeting these challenges, the CENR conducted a review of environmental research and development priorities across the Federal government and developed an integrated set of priorities for improving both the understanding of and the scientific basis for management of ecological systems.

The results of this review are providing a framework for developing a systems approach to monitoring, research, and assessment of ecosystems by: (1) building upon and synthesizing existing resource assessments, (2) improving the capabilities to conduct assessments through focused research and monitoring designed to broaden our understanding and baseline information on ecological and social systems, and (3) addressing critical knowledge gaps for improving the productivity and utility of ecological systems.

Priorities for federal action

The CENR review identified two priorities as essential for reaching these goals. The first priority is to support research, using an ecosystem approach, designed to improve the scientific basis for assessing the vulnerability of natural systems to multiple natural and human-induced stresses and to understand the role of ecological systems in regulating environmental changes. The second is to use the results of this research to develop periodic national and regional assessments that integrate ecosystem-level information on the extent, status, and trends of multiple resources and their environment and an evaluation of ecological responses to the multiple factors influencing them.

Research

Long-term, high-quality monitoring, research, and modeling efforts are essential for improving the understanding and scientific basis for natural resource, ecosystem, and environmental decision-making. Most ongoing efforts are needed for understanding the processes by which individual organisms and their environment interact or to support specific agency mission needs related to land and re-

source management. However, additional focus is needed to understand the more complex ecological consequences of environmental change. This new focus is needed to develop a better understanding of how natural and managed ecological systems function and how they respond to multiple human and natural drivers of change, ultimately increasing our ability to ensure their productivity and vitality.

Four categories of research emerged from the review as being most needed. They are:

1) Improve methods for documenting change: Efforts are needed to develop and standardize ecosystem monitoring protocols; to coordinate, analyze, and synthesize existing data; and to develop remote sensing and other new tools to better identify the status, trends, and vulnerabilities of ecological systems and their drivers of change.

2) Improve the understanding of natural processes and their interactions with human activities: Efforts should focus on developing key indicators of ecosystem condition, on conducting ecosystem-scale studies capable of linking natural and socioeconomic systems, and on characterizing the impacts of multiple stresses on water resources, ecosystem processes (e.g., production, decomposition), ecological dynamics (e.g., species interactions), and social and economic processes (e.g., valuation of ecosystem goods and services) that influence and are influenced by resource sustainability.

3) Increase our capacity to predict the consequences of change: More focus is needed on developing simulation and prediction models that forecast ecosystem impacts of multiple drivers and quantifying the uncertainty associated with our ability to predict functions, responses, and consequences of different management and policy options.

4) Increase the range of potential solutions: There is a need to improve partnerships and communications among scientists, managers, policy-makers, and other stakeholders, to develop cost-effective restoration and

mitigation options, to develop cost-benefit and environmental valuation techniques, and to identify realistic measures that ensure the productivity and vitality of our social and ecological systems.

Implementing these research priorities will take a diverse set of approaches and participation of all parts of the research establishment. Both organized and curiosity-driven investigations, initiated and implemented from perspectives that cut across a broad spectrum of disciplines and ecological system types, are needed. The CENR review indicated a specific need for identifying and supporting a set of sites that can provide "benchmarks" for comparison, integration, and synthesis—a national network of ecological research and observation sites. While these sites are not the only locations appropriate for ecological systems research, the identification and development of such a network would be an essential step for reducing inefficiencies, enhancing comparative analysis, and combining standardized monitoring efforts with appropriate intensive research.

Synthesis

While monitoring, research, and model development focused in the above priority areas will increase our predictive understanding of ecological and social systems and their interactions, it is equally important to focus on ways to transfer this knowledge and capability to decision makers. The CENR review recommended periodic and interactive synthesis and assessment as an effective means to bridge this gap between scientific discovery and decision making. Agencies conduct assessments of resources (e.g., fisheries, forests), habitat characterizations (e.g., water quality, soil type), and specific issues (e.g., climate change, acid rain) at a variety of scales to meet specific missions and mandates. What is needed, however, are efforts to synthesize this information to increase our understanding of the significance of interactions among resources, their linkages to variations in the natural and human

environment, and their responses to the multiple factors driving change. While there are some efforts directed at this level of integrated synthesis, significant gaps remain at the regional and national levels. At a minimum, these synthetic or integrated assessments should identify ecological trends, relate these trends to their causes and consequences, and predict future scenarios under different management and policy options. More specifically, these assessments should:

- Document coincident status and trends of multiple resources and related environmental, demographic, and socioeconomic conditions within ecologically defined regions;
- Relate these status and trend assessments to their human and natural causes and consequences, predict future trajectories and rates of change, and quantify the uncertainty associated with those forecasts, and identify the data, information, and research needed to improve predictions and reduce uncertainties in the future; and
- Evaluate the natural and socioeconomic implications of science-based technological, management, and policy options.

While these assessments are clearly policy relevant, their development must maintain scientific neutrality. The first two components should be performed by scientists from within and outside government, must withstand the scrutiny of peer review, and be designed to support the third component, which must involve all relevant stakeholders from both the science and management communities.

Designing and conducting integrated environmental assessments at national and regional scales is a difficult task. The CENR review recommends that an effort begin immediately to design and complete the first major synthesis within the next 2 years. This effort should involve stakeholders in the design and review of the synthesis, be designed to jumpstart an interactive and iterative process, and serve as the starting point for improving our ability to integrate environmental information, measure

the status of the environment, and provide policy-relevant information that is responsive to changing conditions.

Conclusions

The strategy and recommendations of the CENR require not only that the various Federal agencies coordinate their activities, but that the management and science functions within and among agencies better coordinate their efforts. A likely future without significant budget increases will require a clear focusing of federal research priorities to produce results that are relevant to policy, management, and societal needs. This ecological research, monitoring, and assessment review is an example of how the CENR is helping to identify avenues through which Federal agencies can focus and improve their coordination of environmental research, the involvement of non-Federal stakeholders, and the effectiveness of this research. This review suggests

that the crosscutting research priorities of documenting change, understanding natural processes and human interactions, predicting consequences, and providing solutions, focused through a coordinated national ecological research and observation network, will provide the scientific foundation needed for organized tracking and assessment of the nation's natural resources and for gaining a comprehensive picture of the vitality and productivity of our ecological systems.

The authors acknowledge the outstanding work by the members of the CENR Ecosystem Working Group. The full report (of the same title) upon which this paper is based can be obtained from the senior author. As a result of the recommendations of this report, the Environmental Monitoring Team was formed by CENR to prepare a National Framework for Environmental Monitoring and Research. A report on the framework will be available this year.

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