

USGS Ecosystem Research for the Next Decade: Advancing Discovery and Application in Parks and Protected Areas through Collaboration

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Introduction

ECOSYSTEMS WITHIN PARKS AND PROTECTED AREAS IN THE UNITED STATES and throughout the world are being transformed at an unprecedented rate. Changes associated with natural hazards, invasive species, greenhouse gas emissions, and increasing demands for water, food, land, energy and mineral resources are placing urgency on sound decision-making that will help sustain our nation's economic and environmental well-being (Millennium Ecosystem Assessment 2005). In recognition of the importance of science in making these decisions, in 2007 the US Geological Survey (USGS) identified ecosystem science as one of six science directions included in a comprehensive decadal strategy (USGS 2007). The Ecosystems Mission Area was identified as essential for integrating activity within USGS and as a key to enhanced integration with other federal and private-sector research and resource management organizations (Myers et al. 2007).

This paper focuses on benefits to parks and protected areas from the USGS Ecosystems Mission Area, which expanded the scope of the original 2007 science strategy to identify the bureau's work in ecosystem science over the next decade (Williams et al. 2013). The plan describes a framework that encompasses both basic and applied science and allows USGS to continue to contribute meaningfully to conservation and management issues related to the nation's parks, protected areas, and ecological resources. This framework relies on maintaining long-standing, collaborative relationships with partners, both in conducting science and applying scientific results. Here we summarize the major components of the USGS Ecosystems Science Strategy, articulating the vision, goals, and strategic approaches, then outlining some of the proposed actions that will ultimately prove useful to those managing parks and

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protected areas. We end with a discussion on the future of ecosystem science for USGS and how it can be used to evaluate ecosystem change and the associated consequences to management of our nation's resources.

Vision for USGS ecosystem science

As a federal science agency, USGS is charged with providing scientific understanding to the Department of Interior (DOI) and the nation to help foster better informed decision-making about our natural resources. The ecosystem science envisioned by the strategy's framework encompasses studies of organisms and their environments across scales from genes to biomes, and over time periods from short term through the long view provided by the geologic past, and into projected futures. It requires studies across multiple spatial scales to better understand the interaction of local features of landscapes (such as water diversions) with global processes (such as climate oscillations). Exploration of human activity, such as park visitation and ecosystem services, as integral to ecosystem function is also an important component of the framework.

Discovery and application

To adequately address causes of ecosystem change and its consequences for parks and protected areas, over the coming decades science will be faced with integrating system responses to drivers of change including climate variability, landscape alterations, and effects of water and energy development. To help guide effective management of protected areas and to address problems that will increasingly affect humans, USGS will be required to integrate scientific discovery and application. The bureau's research will need to combine efforts to discover how ecosystems function, and apply these discoveries to better inform decisions faced by park and protected area managers.

Science enables the discovery of new knowledge that can be applied to problems of social importance (Stokes 1997). In this feedback system, applications of new knowledge by resource managers can lead to the identification of new science needs, and thus focus investigations that lead to the discovery of yet more new knowledge (Figure 1a). While this relationship between science and park management has been well established (Sellars 1997), as society moves into the 21st century an enhanced relationship between discovery and application is needed in which new knowledge originates from the application of existing knowledge, as well as from basic and applied research that is being conducted in parks and protected areas (Figure 1b). Thus, science does inform, but can in turn also be informed by, park resource management, with discovery and application overlapping rather than being mutually exclusive. The overlap of the two activities represents simultaneous application of knowledge and discovery of new knowledge, such as when science-based interventions are used to address park management goals as well as to obtain new knowledge (Martin et al. 2011; van Riper et al. 2013). This approach is efficient in focusing science on questions and key uncertainties of primary importance to management decisions, and will serve as a cornerstone for future USGS ecosystem science efforts.

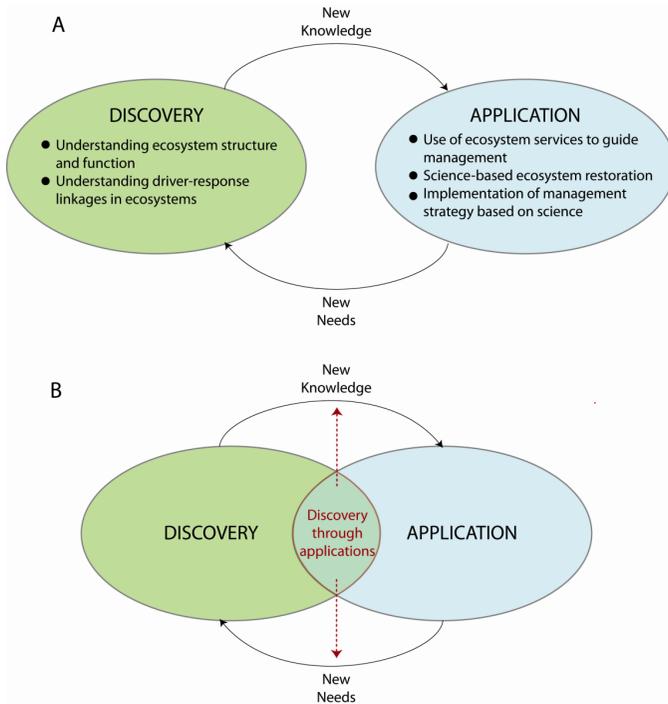


Figure 1. The relationship between discovery and application in ecosystem science. (A) Scientific discovery of new knowledge is applied to ecological problems while application in turn leads to focus on additional questions for discovery. (B) Application of new scientific knowledge by park and protected area managers can itself generate new knowledge.

Advancing science through collaboration

USGS is known for its multidisciplinary expertise and comprehensive, integrative research that is only further strengthened through collaborations and partnerships with the National Park Service (NPS) and other agencies. Strong collaborations enable science resources to be used efficiently and thus better support the information needs that protected area management agencies face. USGS has a highly distributed infrastructure with science centers and cooperative research units found in most every state; many are co-located with universities or within the facilities of other collaborators such as national parks. This geographic structure enhances the ability of USGS scientists to work with partners at all levels—local, territorial, state, tribal, federal, and non-governmental. Cooperative ventures that promote ecosystem-based management are expected to grow. Such ventures include the DOI Landscape Conservation Cooperatives, Cooperative Research Units, National Phenology Network, NPS inventory and monitoring programs, Cooperative Ecosystem Studies Units, National Ecological Observatory Network (NEON), Long Term Ecological Research programs, and

National Climate Science Centers. At a time of tightening budgets, it is critical for USGS to pursue research approaches that build on the strengths of complementary organizations.

Goals of USGS Ecosystems Science Strategy

The strategy is structured around five complementary and interconnected goals that reinforce a vision of science that addresses priority societal issues.

1. **Improve understanding of ecosystem structure, function, and processes.** This goal focuses on developing an understanding of how ecosystems work, including the dynamics of species, their populations, interactions, and genetics, and how they vary across spatial and temporal scales.
2. **Advance understanding of how drivers influence ecosystem change.** The challenges here are explaining the drivers of ecosystem change; their spatiotemporal patterns, uncertainties and interactions; and their influence on protected area ecosystem processes and dynamics.
3. **Improve understanding of the services that ecosystems provide to society.** Here the emphasis is on the measurement of environmental capital and ecosystem services in protected areas, and the identification of sources and patterns of their change in space and time.
4. **Develop tools, technologies, and capabilities to inform decision-making about ecosystems.** This includes developing new technologies and approaches for conducting applications-oriented ecosystem science that will benefit resource management. A principal challenge will be how to quantify uncertainty and incorporate it into decision analysis.
5. **Apply science to enhance strategies for management, conservation, and restoration of ecosystems.** This goal encourages an advisory role in which USGS ecosystem science is brought to bear directly on issues related to management and conservation of protected areas, with scientists working directly with park management to identify critical challenges, including development of novel approaches to monitoring, assessment, and restoration of ecosystems; new methods to address species of concern and communities at risk; and innovations in decision analysis and support to address imminent ecosystem changes and those already underway.

These goals collectively promote enhanced partnerships within and outside the USGS and emphasize the linkages between discovery and application (Figure 2).

Strategic approaches

Closely integrated with the five goals are four strategic approaches that provide a path forward for USGS ecosystem science. These approaches cut across all of the goals and are viewed as essential to the implementation of this strategy.

1. **Assess information needs for ecosystem science through enhanced partnerships.** Work with DOI and other agencies, practitioners, and institutions to identify, design, and implement priority decision-driven research.

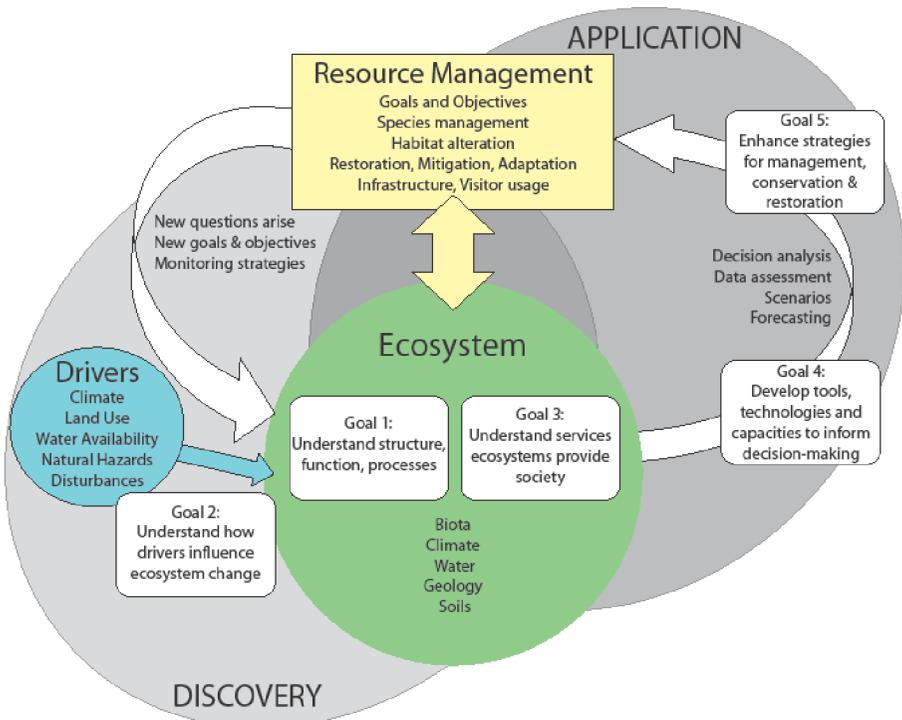


Figure 2. Integration of the USGS Ecosystem Science Strategy goals with scientific discovery and application. Strategic goals are shown along a continuum between discovery and application with links to other drivers. Disturbances include but are not limited to contaminants, fire, visitation, pollutants, pathogens, and resource utilization.

2. **Promote the use of interdisciplinary ecosystem science.** Design and conduct interdisciplinary process-oriented research in ecosystem science.
3. **Enhance modeling and forecasting.** Develop models to forecast ecosystem change, assess future management scenarios, and reduce uncertainties through an adaptive learning process.
4. **Support decision-making.** Use quantitative approaches to assess the vulnerabilities of ecosystems, habitats, and species, and evaluate strategies for adaptation, restoration, and sustainable management of protected areas.

These strategic approaches focus on the study of ecosystems and the drivers influencing their dynamics, while engaging protected area managers. Each approach can serve as a stand-alone program or as a scientific component of larger decision processes for conservation and management of our nation’s ecosystems into which parks and protected areas are embedded.

The strategic approaches also define institutional processes that will serve to continually test science directions and renew priorities as needed to maintain responsive and relevant sci-

ence that addresses protected area needs. Institutionalized collaboration within USGS and with external partners will assure applications of the latest techniques, information, assessments, maps, and decision-support tools that are needed to address ecosystem management issues that affect parks and protected areas. In addition, these strategic approaches provide flexibility in identifying both the systems to be studied and the scientific approaches to be used. Importantly, these approaches also are interconnected and can be effectively pursued simultaneously.

Proposed actions

Proposed actions put forward in the Ecosystems Science Strategy address some of the most pressing environmental information needs of parks and protected areas (Williams et al. 2013). These actions range from ongoing mission-critical to long-term strategic activities, and focus on interdisciplinary science. Through collaboration with partners and application to decision-making, these proposed efforts will provide scientific information that can be utilized to enhance management of parks and protected areas. The following list provides a small sample of what USGS scientists are presently undertaking, and illustrate the depth and breadth of USGS ecosystem science.

- Improving our understanding of the impacts of alternative energy development on ecosystems.
- Incorporating understanding of past patterns of environmental variability into forecasting future efforts of ecosystem restoration and management.
- Improving our ability to predict the occurrence and consequences of fire across protected area landscapes.
- Investigating the impacts of acidification on ecosystems.
- Working with resource managers to develop science-based restoration performance measures and targets.
- Implementing quick-response teams to investigate the scale and effects of environmental disasters.
- Developing integrated models for forecasting the consequences of climate change to parks and protected areas, within larger ecosystem contexts.
- Designing innovative approaches to study interactions between hydrology and ecology for establishment of hydrologic flow criteria aimed at ecosystem sustainability.
- Developing robust approaches to natural resource decision-making in the face of climate change.
- Developing the capacity of USGS scientists to become engaged in design and execution of adaptive management projects.

Future of USGS ecosystem science

The USGS Ecosystems Science Strategy is intended to guide the bureau over the next decade. Two aspects of the strategy are designed to ensure relevance as we move forward. First, it emphasizes integration of five goals, from discovery to application, that can be used

in real-time resource management and decision-making. This emphasis means that USGS ecosystems science will continue to be driven by the need to transform fundamental scientific understanding into relevant, actionable information, and to aid in the application of that information by protected area managers and practitioners into decision making. Second, the strategy will endure because of a commitment to communication and collaboration with other natural resource agencies and organizations. Through this commitment, USGS will continually evaluate and redefine ecosystem science directions to keep pace with information needs and emerging technologies, while seeking to maximize the value of collaborations. The strategy recognizes that USGS is one of many entities pursuing ecosystem science and that the greatest benefit to protected areas, society, and the nation will come from complementary applications of resources and talent.

Ecosystem science is interdisciplinary by nature and requires the incorporation of information technology and the biological, chemical, physical, and social sciences to address important and complex ecosystem issues. USGS includes scientists from many disciplines who can work together to better understand the components of and interactions within ecosystems. Thus, there already exists a strong framework for applying USGS interdisciplinary expertise to collaborative efforts with scientists from within and outside the bureau.

Similar to most strategic plans, the USGS Ecosystems Science Strategy contains goals, objectives and actions. Unlike many plans, however, it also contains a commitment to a new perspective on integrating discovery and application in ecosystem science, and a commitment to an ongoing process of communication and collaboration with outside organizations. These processes can serve to keep USGS ecosystem science current, flexible, and relevant to our nation's protected area needs.

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