

Integrating Adaptive Management and Ecosystem Services Concepts To Improve Natural Resource Management:

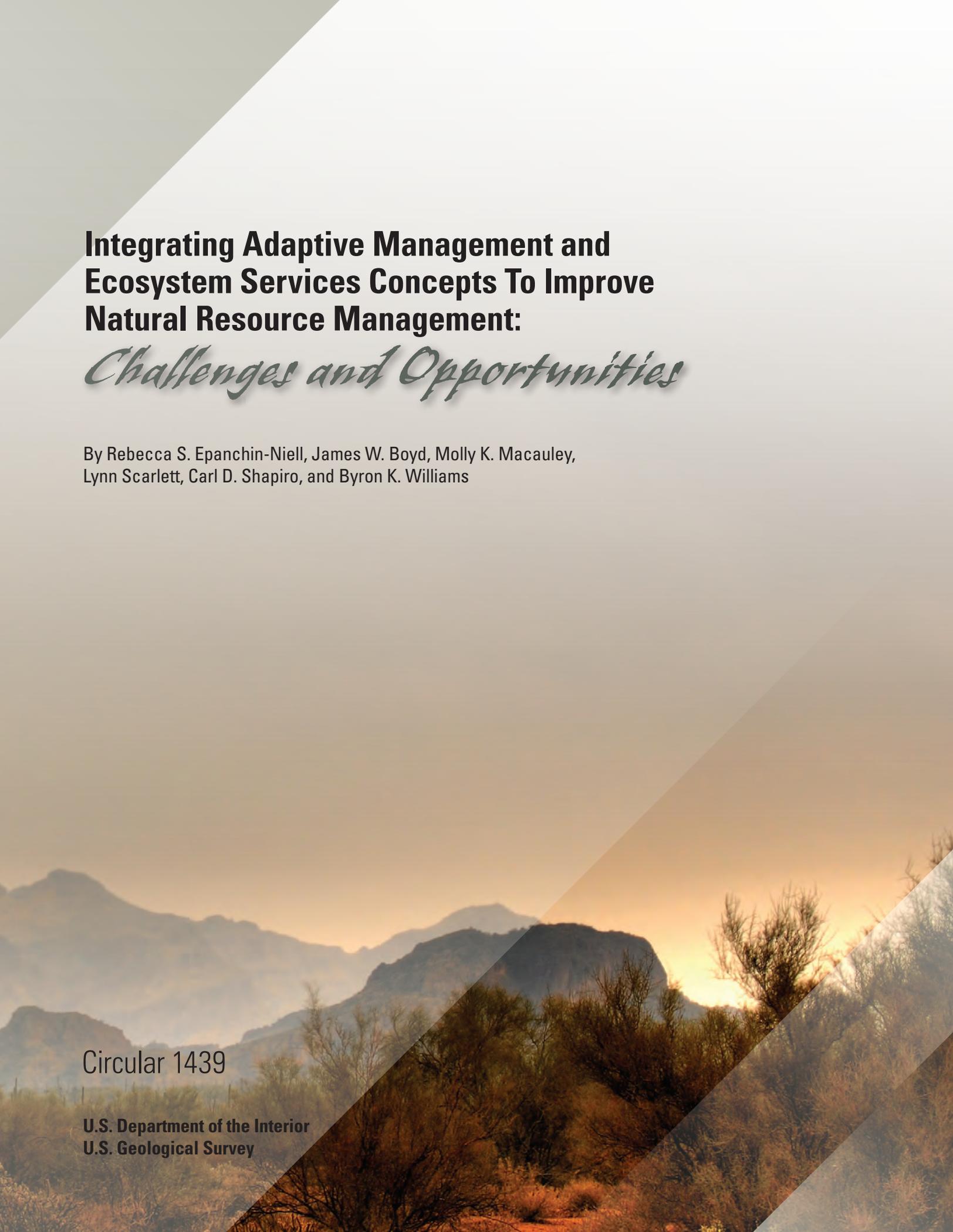
Challenges and Opportunities



Circular 1439

U.S. Department of the Interior
U.S. Geological Survey





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By Rebecca S. Epanchin-Niell, James W. Boyd, Molly K. Macauley,
Lynn Scarlett, Carl D. Shapiro, and Byron K. Williams

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**U.S. Department of the Interior
U.S. Geological Survey**

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U.S. Geological Survey, Reston, Virginia: 2018

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Suggested citation:

Epanchin-Niell, R.S., Boyd, J.W., Macauley, M.K., Scarlett, Lynn, Shapiro, C.D., and Williams, B.K., 2018, Integrating adaptive management and ecosystem services concepts to improve natural resource management—Challenges and opportunities: U.S. Geological Survey Circular 1439, 62 p., <https://doi.org/10.3133/cir1439>.

Library of Congress Cataloging-in-Publication Data

Names: Epanchin-Niell, Rebecca S., 1975- author. | Geological Survey (U.S.), issuing body.

Title: Integrating adaptive management and ecosystem services concepts to improve natural resource management : challenges and opportunities / by Rebecca S. Epanchin-Niell [and five others].

Other titles: U.S. Geological Survey circular ; 1439. 1067-084X

Description: Reston, Virginia : U.S. Geological Survey, 2018. | Series:

Circular, ISSN 1067-084X ; 1439 | Includes bibliographical references.

Identifiers: LCCN 2018012009 | ISBN 9781411342217 | ISBN 1411342216

Subjects: LCSH: Ecosystem services. | Adaptive natural resource management.

Classification: LCC QH541.15.E267 E73 2018 | DDC 333.72--dc23 | SUDOC I 19.4/2:1439

LC record available at <https://lcn.loc.gov/2018012009>

ISSN 1067-084X (print)
ISSN 2330-5703 (online)
ISBN 978-1-4113-4221-7

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Abbreviations

BLM	Bureau of Land Management
BMP	best management practice
EIS	environmental impact statement
MCDA	multicriteria decision analysis
NAWMP	North American Waterfowl Management Plan
NEPA	National Environmental Policy Act
NGO	nongovernmental organization
PEIS	programmatic environmental impact statement
RFF	Resources for the Future
RMP	resource management plan
USGS	U.S. Geological Survey

Acknowledgments

The work described in this circular is the result of collaboration between the U.S. Geological Survey and Resources for the Future conducted through Cooperative Agreement no. G11AC20548. More information on Resources for the Future can be found at rff.org.

The authors are very grateful for the time, thought, and resources that workshop participants, presenters, and facilitators contributed to make this effort and report possible. We thank Dale Humburg of Ducks Unlimited, Leonard Shabman of Resources for the Future, and Jim Nichols, Dianna Hogan, and Michael Runge, all of the U.S. Geological Survey, for their thoughtful comments on this report. The authors also greatly appreciate the expertise, hard work, and high-quality effort provided in producing this document. We thank Jonas Casey-Williams for his thorough and timely edits, which greatly improved the document's readability. Carol Quesenberry is thanked for her production and layout efforts, which resulted in a beautiful and easy-to-read publication. The authors also appreciate the efforts of Shonté Jenkins, who represented the authors throughout production and facilitated a smooth process and a high-quality and timely final product. The authors wish to express a special appreciation of our dear friend, colleague, and coauthor, Molly Macauley—a bold and creative thinker, full of curiosity, dynamism, and kindness. We are grateful for the insights and wisdom that Molly shared with us and with the world over the years, and for her compassion, encouragement, and mentorship. We miss Molly deeply.



Integrating Adaptive Management and Ecosystem Services Concepts To Improve Natural Resource Management: *Challenges and Opportunities*

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Executive Summary

Overview

Natural resource managers must make decisions that affect broad-scale ecosystem processes involving large spatial areas, complex biophysical interactions, numerous competing stakeholder interests, and highly uncertain outcomes. Natural and social science information and analyses are widely recognized as important for informing effective management. Chief among the systematic approaches for improving the integration of science into natural resource management are two emergent science concepts, adaptive management and ecosystem services. Adaptive management (also referred to as “adaptive decision making”) is a deliberate process of learning by doing that focuses on reducing uncertainties about management outcomes and system responses to improve management over time. Ecosystem services is a conceptual framework that refers to the attributes and outputs of ecosystems (and their components and functions) that have value for humans.

This report explores how ecosystem services can be moved from concept into practice through connection to a decision framework—adaptive management—that accounts for inherent uncertainties. Simultaneously, the report examines the value of incorporating ecosystem services framing and concepts into adaptive management efforts.

Adaptive management and ecosystem services analyses have not typically been used jointly in decision making. However, as frameworks, they have a natural—but to date underexplored—affinity. Both are policy and decision oriented in that they attempt to represent the consequences of resource management choices on outcomes of interest to stakeholders. Both adaptive management and ecosystem services analysis take an empirical approach to the analysis of ecological systems. This systems orientation is a byproduct of the fact that natural resource actions affect ecosystems—and corresponding societal outcomes—often across large geographic scales. Moreover, because both frameworks focus on resource systems, both must confront the analytical challenges of systems modeling—in terms of complexity, dynamics, and uncertainty.

Given this affinity, the integration of ecosystem services analysis and adaptive management poses few conceptual hurdles. In this report, we synthesize discussions from two workshops that considered ways in which adaptive management approaches and ecosystem service concepts may be complementary, such that integrating them into a common framework may lead to improved natural resource management outcomes. Although the literature on adaptive management and ecosystem services is vast and growing, the report focuses specifically on the integration of these two concepts rather than aiming to provide new definitions or an indepth review or primer of the concepts individually.

Key issues considered include the bidirectional links between adaptive decision making and ecosystem services, as well as the potential benefits and inevitable challenges arising in the development and use of an integrated framework. Specifically, the workshops addressed the following questions:

- How can application of ecosystem service analysis within an adaptive decision process improve the outcomes of management and advance understanding of ecosystem service identification, production, and valuation?
- How can these concepts be integrated in concept and practice?
- What are the constraints and challenges to integrating adaptive management and ecosystem services?
- And, should the integration of these concepts be moved forward to wider application—and if so, how?

Anticipated Benefits of Integration

There is substantial uncertainty about the biophysical and societal consequences of people intervening in natural systems. Adaptive management provides a disciplined, quantitative approach to understanding systems and resolving decision-relevant uncertainties to improve system management. The concept of ecosystem services facilitates the definition and measurement of ecology-related societal outcomes. Integration thus provides an opportunity to adaptively manage not just natural resource conditions but also societal outcomes tied to resource conditions. Furthermore, adaptive management can help refine, over time, the set of ecosystem service outcomes considered as most important to communities and natural resource beneficiaries.

A key feature of all management and policy decisions that affect natural resources is that they also affect the provisioning of ecosystem services. Thus, failure to explicitly consider the effects of management or policy decisions on a system's suite of relevant ecosystem services can lead to unintended consequences, collateral damage, and missed opportunities, and these ramifications highlight the importance of expanding potentially narrow management objectives to consider the range of ecosystem services that may be affected. An ecosystem services lens also can broaden the focus of management to include consideration of how ecosystem components come together in processes and comprise systems and to link those processes to the socioeconomic dimensions of resource management and implications for communities.

The production and valuation of ecosystem services are evolving areas of knowledge, and ecosystem service analysis adds complexity and new dimensions of uncertainty to previous resource models. Given that adaptive management is a response to uncertainty and seeks to improve management outcomes in the face of uncertainty, applying adaptive management approaches when managing ecosystem services is likely to enhance resource outcomes by reducing uncertainties that hinder effective management, including uncertainties about the effects of management on the production and valuation of ecosystem services. In addition, social and technical learning can help to refine the set of services to be considered.

Integration of an ecosystem service lens within an adaptive management framework also may facilitate stakeholder engagement by providing metrics that are meaningful to people, ensure that diverse values are represented, communicate management objectives more effectively, reframe a problem in a way that invites new management options that lessen conflict, facilitate weighing of tradeoffs by clearly articulating values and objectives, and promote transparency and enhance defensibility of decisions.

Adaptive Management-Ecosystem Services Integration

A conceptual integration of ecosystem services and adaptive management links all elements of adaptive management with the identification, production, and valuation of ecosystem services. Integration of ecosystem services into adaptive management immediately reflects an expansion of the resource management objectives and thus has implications for all parts of the adaptive process, including which stakeholders are at the table, what is monitored, the models that are used, and ultimately the management actions that are selected.

Ecosystem services are already explicitly managed in a variety of contexts, and implementing such management adaptively, with monitoring, learning, and updating, may lead to better outcomes than a static management strategy based only on current knowledge. Learning can reduce uncertainty in the biophysical and social production processes and hence in the consequences of possible management actions. Adaptive management also can help identify the relevant ecosystem services and policy interventions, through stakeholder engagement and iterative and adaptive learning about the social and biophysical system.

The report describes four case studies that help to highlight and explore the challenges and benefits of implementing an integrated adaptive management-ecosystem services approach. Although none of the case studies provide a complete example for replication elsewhere, they nonetheless provide insights about each component of an integrated adaptive management-ecosystem services application, as described in the report.

Challenges to Implementation

While the linkage of ecosystem services and adaptive management frameworks seems to be a natural fit that could improve management outcomes, the integration faces institutional, cultural, and technical challenges confronting the approaches independently, as well as challenges specific to integration. Integration may make management too costly and complicated in some cases, and both approaches require substantial human capacity and upfront resources. In addition, institutional or policy constraints can limit management and experimentation. While practical guidance for implementing adaptive management is increasingly available, the availability of such guidance for ecosystem services remains limited, which further challenges the integration.

Future Directions and Needs

Although serious challenges are faced by both independent and integrative application of adaptive management and ecosystem services concepts, integration has the potential to substantially improve outcomes. Applications that explicitly integrate these two decision concepts may make the processes easier because the approaches, taken alone, frequently leave out key components of the decision context.

Progress in uniting these approaches will require that the joint framework that links the two concepts be as sleek and simple as possible, without losing account of socioecological processes and uncertainties. We also need better understanding of the management contexts for which the benefits of integration are most likely to outweigh the capacity, time, and resource costs. Applying an integrated adaptive management-ecosystem services approach places a premium on being able to explain its importance simply and on the approach making management easier or providing substantial net benefits.

Examples are needed of where adaptive management-ecosystem services integration has been implemented effectively and can be replicated elsewhere. The development of new applications likely will depend on decision makers being convinced that the integration will solve a real problem that they are facing. Such development could arise through integration of ecosystem services analysis into an adaptive management effort that is just entering its deliberative phase or that is in the process of reevaluating objectives or framing. Alternatively, adaptive management could be brought to a context where ecosystem services already are being managed for explicitly but where management is hindered by uncertainty.

Adaptive management and ecosystem services are evolving areas of knowledge and application. This, in itself, makes their integration challenging. Development of accepted practical guidance for applying an ecosystem services approach is likely to provide an important foundation for integrating ecosystem services evaluation into an adaptive management framework. Furthermore, greater interaction among expertise, methods, models, and data would be a benefit to both communities of practice.

Furthering this integrative approach depends on continued interaction and collaboration between researchers and practitioners. Application of the approach is needed to further develop conceptual understanding, and we hope that the conceptual framework explored in this report will help to move the integration forward in practice and research. The feedback between concept and application is integral to the development of a usable framework and for enhancing adoption of this approach.



A conceptual integration of ecosystem services and adaptive management links all elements of adaptive management with the identification, production, and valuation of ecosystem services.

◆ *The two frameworks are complementary. Greater interaction among expertise, methods, models, and data will benefit both communities of practice.*



Introduction

This report is the product of a partnership between the U.S. Geological Survey (USGS) Science and Decisions Center and Resources for the Future. The partnership is focused on better understanding the benefits and challenges of integrating adaptive management and ecosystem services to improve natural resource management.

Although the literature on adaptive management and ecosystem services is vast and growing, this report is not intended to be an indepth review or primer on these concepts or to provide new definitions or insights regarding these concepts individually. Rather, this report synthesizes the results of two workshops that focused on the concepts' integration and aims to accurately reflect the workshop discussions and the insights derived from them.

As frameworks, ecosystem services analysis and adaptive management have a natural—but to date underexplored—affinity. Both are policy and decision oriented in that they are attempts to represent the consequences of protection, restoration, and resource management actions on outcomes of interest to communities, households, regulators, or businesses. Although adaptive management traditionally focuses less on societal outcomes than does ecosystem services analysis, its focus on management-relevant outcomes is of inherent societal relevance.

Both frameworks take an empirical approach to the analysis of ecological systems. This systems orientation is a byproduct of the fact that natural resource actions affect ecosystems—and corresponding societal outcomes—across large landscape and watershed scales. Moreover, because both frameworks focus on resource systems, both must confront the analytical challenges of systems modeling—in terms of complexity, dynamics, and uncertainty.

Given this affinity, the integration of ecosystem services analysis and adaptive management poses few conceptual hurdles. In fact, the two frameworks are complementary. Greater interaction among expertise, methods, models, and data will benefit both communities of practice.

Motivation and Objectives

Natural resource managers make decisions involving ecosystem processes, large spatial areas, complex biophysical interactions, numerous competing stakeholder interests, and highly uncertain outcomes. Adaptive management (also referred to as “adaptive decision making”) and ecosystem services analysis are two emergent science concepts that can help identify and guide successful resource management strategies. Adaptive management is a deliberate process of learning by doing that focuses on reducing uncertainties about management outcomes and system responses to improve management over time. Ecosystem services is a conceptual framework and set of methods designed to evaluate how changes in ecosystems and natural resources affect economic and societal well-being.

From its outset, adaptive management was developed on a foundation of decision analysis and structured decision making (Gregory and others, 2012). In fact, the term itself describes a particular kind of structured decision making that accounts for uncertainty as well as efforts to reduce uncertainty that can lead to improved management outcomes (Holling, 1978; Walters, 1986; Williams and others, 2009; Williams and Brown, 2014). On the other hand, the concept of ecosystem services was developed, at least initially, around the recognized need and importance of accounting for nature’s value in human activities (Millennium Ecosystem Assessment, 2005). To date, much of the work on ecosystem services has focused on describing ecosystem services and ascribing value to them.

In this report, we synthesize discussions from two workshops that explored the conjecture that the concepts and practices of ecosystem services and adaptive management are complementary and that their integration can lead to improved natural resource management outcomes. This document reports on the workshops’ initial efforts to explore such an integration. Key issues considered include the bidirectional links between adaptive decision making and ecosystem services, along with the potential benefits and inevitable challenges arising in the development and use of an integrated framework. Specifically, the workshops addressed the following questions:

- How can application of ecosystem service analysis within an adaptive decision-making process improve the outcomes of management and advance understanding of ecosystem service identification, production, and valuation?
- What does this integration look like conceptually and in practice?
- What are the constraints and challenges to this integration?
- Should, and if so, how might the integration of these concepts be moved forward to wider application?

Approach

To explore potential benefits and challenges of integrating ecosystem services and adaptive management approaches for managing natural resources, we convened experts for two multiday workshops (see appendix 1 for a list of participants). The first workshop, held in June 2012, brought together thought and policy leaders on adaptive management and ecosystems services from Federal agencies, nongovernmental organizations (NGOs), academia, and nonprofits. The workshop focused on conceptual development of an integrated framework, with particular focus on the likely benefits and challenges anticipated on the basis of participants’ knowledge. The second workshop, held in April 2013, brought together experts and practitioners to focus on four case studies, in three natural resource management contexts, in which ecosystem services concepts are integrated within an adaptive decision process to varying extents. The management contexts included evaluation of best management practices for development in Clarksburg, Maryland; Bureau of Land Management (BLM) resource planning across scales; and adaptive waterfowl management. The goal of the second workshop was to synthesize understanding gained from the case study examples to develop a foundational framework for integrating ecosystem services and adaptive decision making and to explore the benefits and practical challenges of this integration. This report represents a synthesis of discussions from the two workshops, as well as the authors’ analysis and conclusions.



Background

Adaptive Management

Adaptive management is a learning-based approach to resource management and involves the use of management itself to learn about a resource system and the consequences of management interventions (box 1). From an operational point of view, adaptive management simply means the iterative application of learning by doing and adjusting management on the basis of what's learned. Management interventions are treated as "experiments," in which learning contributes to management by providing information on which to base management decisions, and management reinforces learning by implementing actions that are useful in investigating the resource system. The sequential application of these activities leads to improved understanding of resource behaviors and responses and to improved resource management based on that understanding.

◆ *The primary goal of adaptive management is to manage the system well, and learning is the means to that outcome.*

Learning can take several forms, including scientific learning about the natural system and social learning focused on the values provided by the system and the governance structure for decision making. However, the primary goal of adaptive management is to manage the system well, and learning is the means to that outcome. Likewise, the goal of adaptive management is not to eliminate system uncertainty but to reduce uncertainties to allow for better management choices. Indeed, adaptive management is only warranted if reducing uncertainty is likely to lead to changes in management that could substantially improve outcomes (that is, if there is a high value of the information that may be learned).

Ecosystem Services

"Ecosystem goods and services" refers to ecological features, qualities, and processes (associated with, for example, wetlands, sea marshes, rivers, forests, and grasslands) and their contributions to individual, business, and community well-being (box 2). These goods and services include harvested resources for consumption, water purification, coastal storm and surge protection, recreation, mitigation of air pollution, soil protection, aesthetic values, existence values, and so forth. Many ecosystem services are not obvious and are difficult to measure, in part because they generally are not traded in markets and have characteristics of public goods. Because ecosystem services are difficult to observe and value, their value often is unaccounted for in policy and management decisions. For this reason, quantifying ecosystem service values (monetary or otherwise) can lead to improved natural resource decision making. For example, ecosystem service values can be used to help evaluate the benefits of alternative management actions, to serve as inputs into cost-benefit analyses, or to design payment schemes that incentivize provisioning of ecosystem services by land managers. Ecosystem services analysis also can illuminate and resolve natural resource-related conflicts and tradeoffs.

Ecosystem service analysis requires an identification of key ecosystem services for a particular resource system and decision context, an understanding of how these services are produced by the resource system, and an accounting of the relative values of the services as guides to decision making. Identification, production, and valuation of ecosystem services are critical components in a goal-directed, experience-based framework for resource management, and all these components would benefit from further investigation and development.



Box 1: Adaptive Management

Adaptive management has been used in resource management since at least the 1950s. It was given formal expression by Holling (1978), Walters (1986), and Lee (1993), and the current literature is extensive. Various aspects of adaptive management are emphasized in the existing literature, including variation in the details of the decision-making and learning processes. Nonetheless, the crux of this approach is using the process of management to learn about the system being managed, and then using what is learned to adjust and improve management over time. While recognizing the variation in how adaptive management frameworks have been articulated in practice and in the literature, this report uses as a starting point the description detailed by the U.S. Department of the Interior in its technical and applications guides (Williams and others, 2009; Williams and Brown, 2012).

Adaptive management is an iterative process of decision making, implementation, monitoring, and learning that is incorporated into future decision making. It generally follows a two-phase process. The deliberative phase establishes a management framework that includes stakeholder engagement, identification of management objectives and action alternatives, and development of predictive models about the system and monitoring protocols for evaluating the effects of management actions. The second phase is an iterative phase that begins the sequence of feedback between learning and management actions (fig. 1). This technical learning phase often is referred to as “single-loop learning” (Pahl-Wostl, 2009). With some frequency, the process then needs to break out of the iterative technical learning phase to revisit the deliberative phase to adjust objectives, alternatives, and monitoring. This institutional learning about the framing of a management problem has been variously referred to as “evolutionary problem solving” (Shabman, 2005) and “double-loop learning” (Pahl-Wostl, 2009), and we use the latter term in this report.

Adaptive management approaches may be classified as active or passive, depending on the degree to which, when selecting management choices, the approach considers the benefits of what may be learned. Active adaptive management explicitly considers the value of reducing uncertainty when selecting management choices and often involves controlled experimentation. In contrast, passive adaptive management typically selects management choices on the basis of the best available information but nonetheless updates system understanding over time to improve subsequent management choices.

In either case, adaptive management is only appropriate if it can improve managers' abilities to achieve objectives. Thus there must be a means for updating decisions in response to what is learned, ways to reduce uncertainty through monitoring, and real value from reducing uncertainty by potentially altering the desired choice of management. "Value of information" is a measure of the degree to which objectives could be better met if uncertainties were reduced, and the "value of information" from adaptive management should be greater than its costs in order for adaptive management to be warranted.

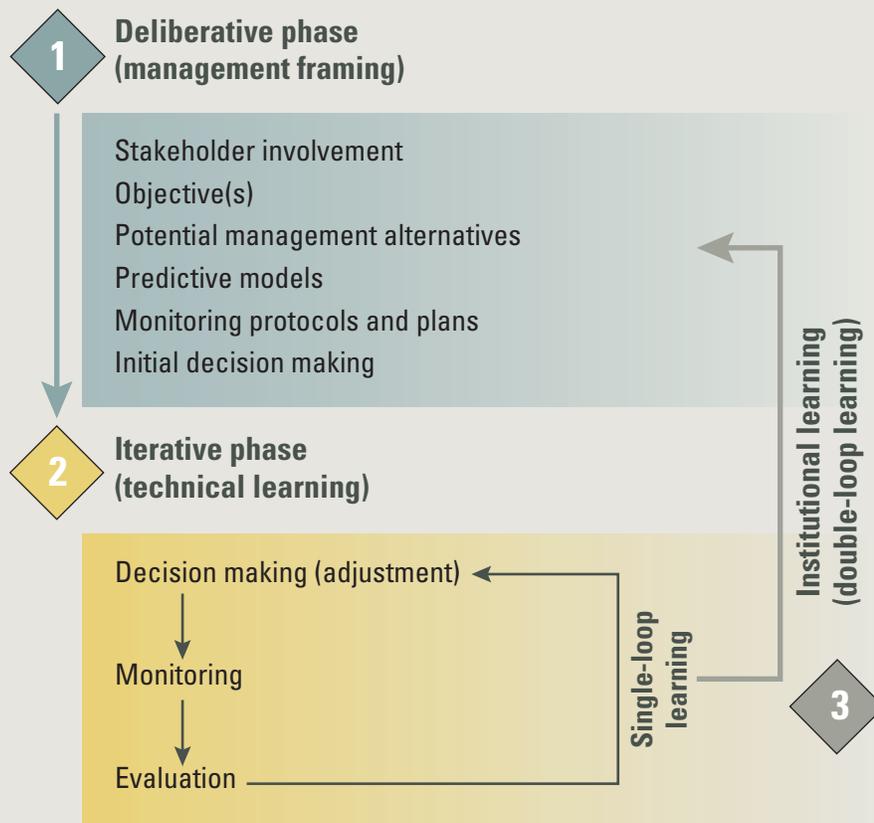


Figure 1. Elements of adaptive management (modified from Williams and others, 2009).

2

Box 2: Ecosystem Services

The concept of ecosystem services initially grew from a desire to show that ecosystems have value and should be protected (Millennium Ecosystem Assessment, 2005). Indeed, the growth in attention given to ecosystem services analysis comes from a desire on the part of resource managers to provide an appreciation of management's role in improving ecological, societal, and economic outcomes. However, ecosystem service characterization also is critical for assessing tradeoffs and informing decision making. Because ecosystem service analysis links ecological understanding with socioeconomic outcomes, it can help inform processes such as the following (Scarlett and Boyd, 2015):

- Natural resource planning and priority setting, including environmental impact assessment under the National Environmental Policy Act evaluations and land use planning by communities, governments, and conservancies
- Regulatory mitigation and compensation requirements associated with wetland loss, conservation banks, Federal Energy Regulatory Commission mitigation measures, and natural resource damage assessment
- Conservation grant and loan programs, including farm bill land conservation payments and the disbursement of Safe Drinking Water Act (42 U.S.C. §300f) and Clean Water Act (33 U.S.C. §1251 et seq.) Revolving Loan funds

As with adaptive management, the literature on ecosystem services is growing and varies in its characterization of ecosystem values. Some conceptual frameworks are useful for communicating the types of services provided by ecosystems (for example, provisioning, regulating, and cultural services, as described in the Millennium Ecosystem Assessment). Some frameworks are more amenable than others to the measurement or quantification of ecosystem service values, which can facilitate decision making for ecosystem management. Here we describe a framework that facilitates valuation by framing ecosystem service production analogously to conventional economic production theory (Boyd and Krupnick, 2009; Boyd and Brookshire, 2011).

An ecological production framework for ecosystem goods and services consists of four linked components (Boyd and Krupnick, 2009; Boyd and Brookshire, 2011) (fig. 2):

- 1. Actions or interventions** are policy or management changes (for example, land cover conversion, restoration, protection, or resource management) that affect natural resources and trigger biophysical changes in the ecosystem.
- 2. Biophysical or ecological production functions** are relationships that link management actions to changes in socially meaningful biophysical outcomes (Daily and Matson, 2008).
- 3. Ecological endpoints** are measurable biophysical outcomes that have direct relevance to human welfare (for example, species abundance, water quality, storm surge protection). These endpoints are the bridge between the biophysical system and economic assessment because they are the aspect of the system that holds specific value.
- 4. Economic production functions** are the processes or relationships that describe how inputs (for example, biophysical and other inputs) combine to produce human well-being.

Figure 2 highlights how a policy change or management action can induce a change in human welfare based on changes in the underlying biophysical system (Boyd and Brookshire, 2011). A policy intervention that causes land cover change can lead to changes in two different ecological endpoints (that is, species abundance and surface-water flow): the land cover change affects surface-water flow and species habitat directly, and the habitat change affects species abundance. This framework identifies the key features of the biophysical system, including the set of ecological endpoints that represents the values produced by the system, that must be understood to assess changes in value of ecosystem services.

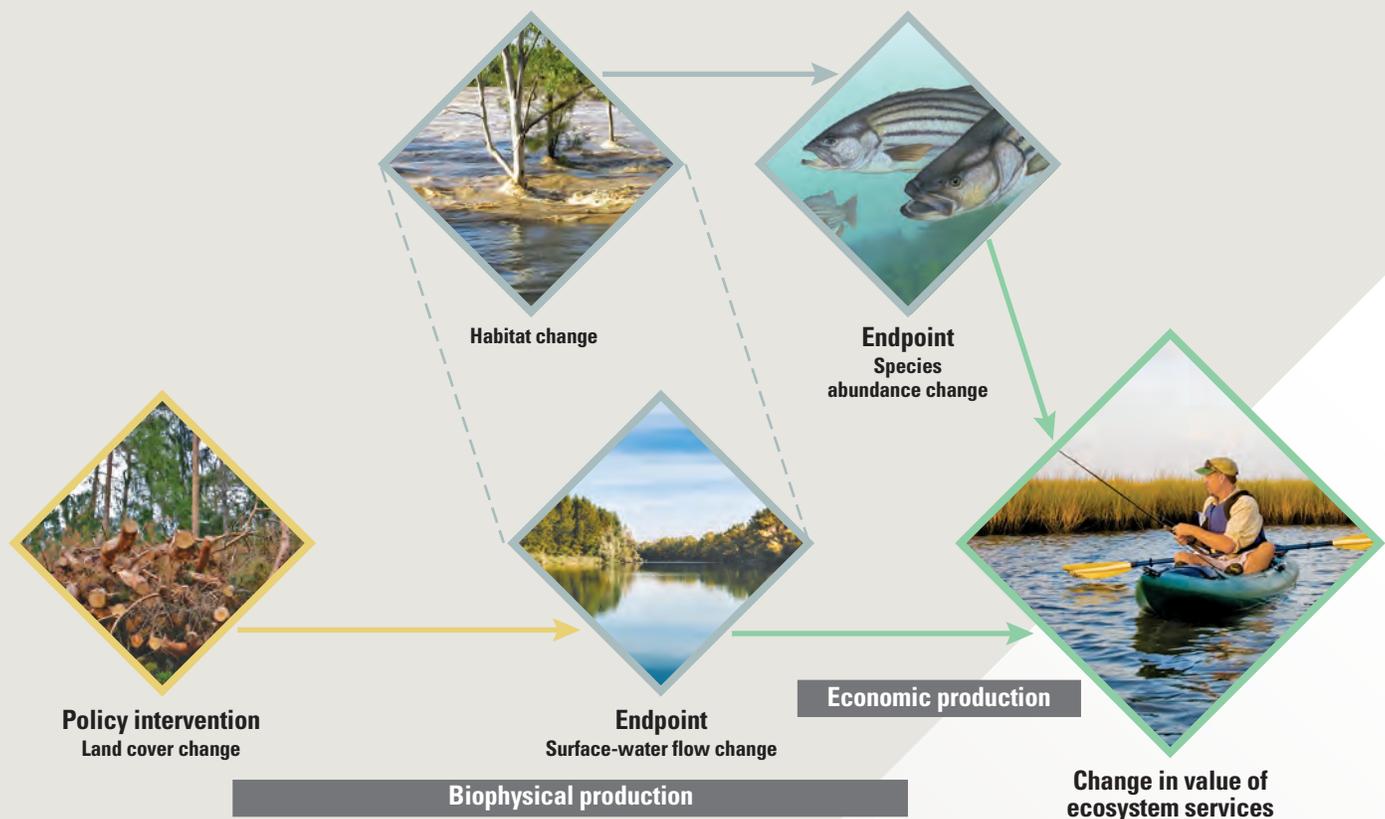


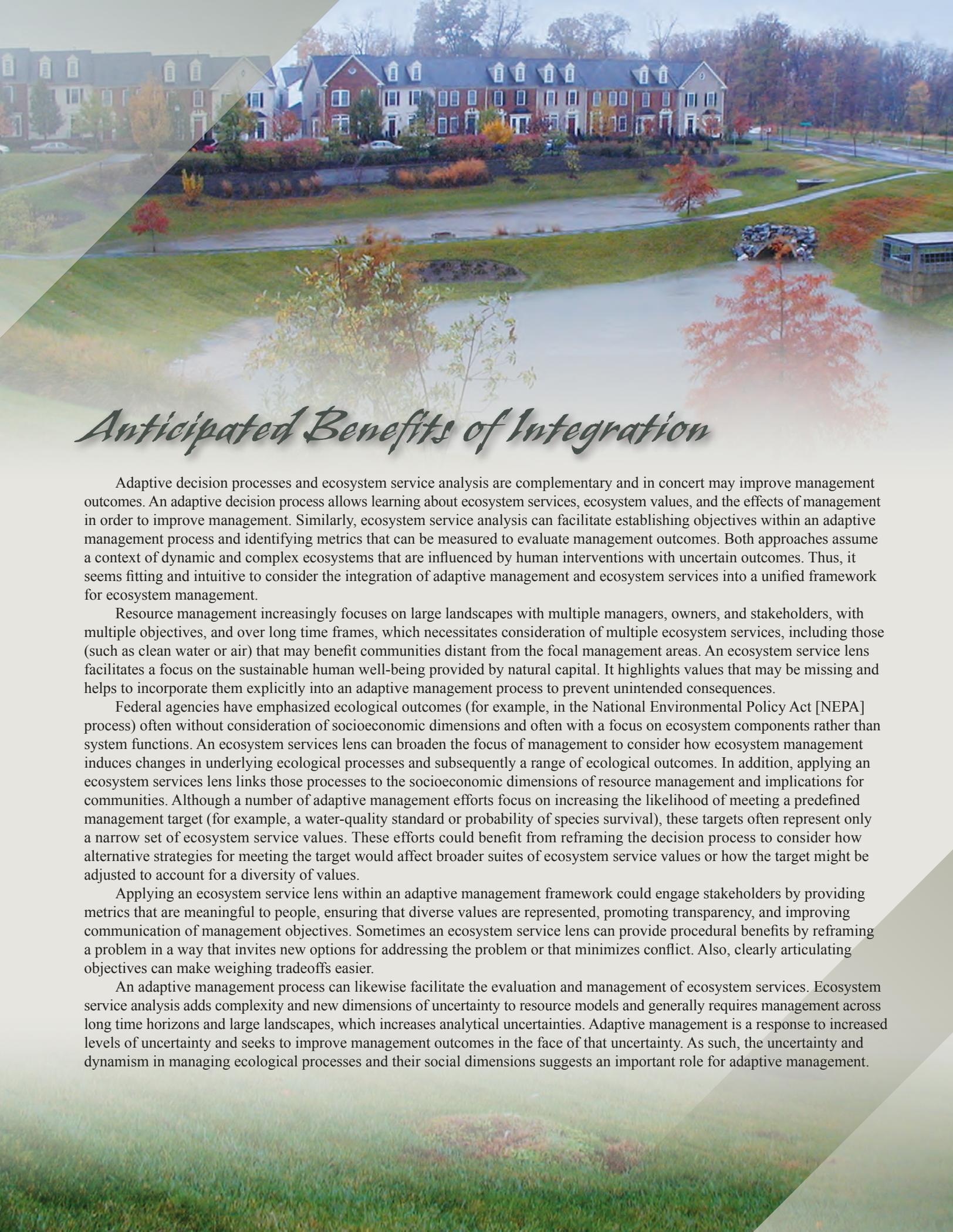
Figure 2. A conceptual example of biophysical and economic production of ecosystem service values (modified from Boyd and Brookshire, 2011).

The biophysical endpoints (for example, species abundance change) combine with other inputs to produce benefits to human well-being that can be assessed using monetary or nonmonetary valuation approaches. For example, in valuing open space for recreation, not only does the quality and quantity of open space matter, but so do its scarcity, the availability of substitute open spaces, and its accessibility. Some basic rules of thumb suggest that, all else being equal,

- the scarcer an ecological feature, the greater its value;
- the scarcer the substitute for an ecological feature, the greater its value (substitutes are goods or services that at least partly satisfy similar wants or needs);
- the more abundant the complements to an ecological feature, the greater its value (complements are goods that go together or enhance each other);
- the larger the population benefiting from an ecological feature, the greater its value (usually); and
- the larger the economic value protected or enhanced by the feature, the greater its value (usually) (Boyd and Brookshire, 2011).

Economic valuation approaches to assigning monetary values to ecosystems services include revealed preference (for example, hedonic analysis, travel costs models), stated preference (for example, contingent valuation analysis), and benefit transfer analyses. These approaches are rapidly developing, increasingly applied, and critical for providing direct input into cost-benefit analyses or for efficiently pricing ecosystem service payment mechanisms. However, monetary valuations are costly and require specific economic capacity, thus limiting their widespread application.

Ecosystem benefit indicators are a nonmonetary approach for describing changes in welfare that result from ecosystem changes. Ecosystem benefit indicators are “quantitative, countable features of the physical and social landscape that depict the ways in which ecological endpoint changes produce changes in human welfare” (Boyd and Brookshire, 2011). They help describe the biophysical and other inputs that affect the value of ecosystem services, including the scale of demand for a given biophysical endpoint and the distribution of those endpoints relative to populations that may value them. In addition, ecosystem benefit indicators can describe other economically relevant factors, such as the scarcity of the biophysical endpoint and the availability of substitutes or complements. This approach can provide quantitative descriptions that are useful in ranking the benefits of alternative management options.



Anticipated Benefits of Integration

Adaptive decision processes and ecosystem service analysis are complementary and in concert may improve management outcomes. An adaptive decision process allows learning about ecosystem services, ecosystem values, and the effects of management in order to improve management. Similarly, ecosystem service analysis can facilitate establishing objectives within an adaptive management process and identifying metrics that can be measured to evaluate management outcomes. Both approaches assume a context of dynamic and complex ecosystems that are influenced by human interventions with uncertain outcomes. Thus, it seems fitting and intuitive to consider the integration of adaptive management and ecosystem services into a unified framework for ecosystem management.

Resource management increasingly focuses on large landscapes with multiple managers, owners, and stakeholders, with multiple objectives, and over long time frames, which necessitates consideration of multiple ecosystem services, including those (such as clean water or air) that may benefit communities distant from the focal management areas. An ecosystem service lens facilitates a focus on the sustainable human well-being provided by natural capital. It highlights values that may be missing and helps to incorporate them explicitly into an adaptive management process to prevent unintended consequences.

Federal agencies have emphasized ecological outcomes (for example, in the National Environmental Policy Act [NEPA] process) often without consideration of socioeconomic dimensions and often with a focus on ecosystem components rather than system functions. An ecosystem services lens can broaden the focus of management to consider how ecosystem management induces changes in underlying ecological processes and subsequently a range of ecological outcomes. In addition, applying an ecosystem services lens links those processes to the socioeconomic dimensions of resource management and implications for communities. Although a number of adaptive management efforts focus on increasing the likelihood of meeting a predefined management target (for example, a water-quality standard or probability of species survival), these targets often represent only a narrow set of ecosystem service values. These efforts could benefit from reframing the decision process to consider how alternative strategies for meeting the target would affect broader suites of ecosystem service values or how the target might be adjusted to account for a diversity of values.

Applying an ecosystem service lens within an adaptive management framework could engage stakeholders by providing metrics that are meaningful to people, ensuring that diverse values are represented, promoting transparency, and improving communication of management objectives. Sometimes an ecosystem service lens can provide procedural benefits by reframing a problem in a way that invites new options for addressing the problem or that minimizes conflict. Also, clearly articulating objectives can make weighing tradeoffs easier.

An adaptive management process can likewise facilitate the evaluation and management of ecosystem services. Ecosystem service analysis adds complexity and new dimensions of uncertainty to resource models and generally requires management across long time horizons and large landscapes, which increases analytical uncertainties. Adaptive management is a response to increased levels of uncertainty and seeks to improve management outcomes in the face of that uncertainty. As such, the uncertainty and dynamism in managing ecological processes and their social dimensions suggests an important role for adaptive management.

The process of stakeholder engagement in adaptive management can help to identify the range of ecosystem services at play and those most valuable to communities and other stakeholders. Double-loop learning within adaptive management can help refine this set of relevant ecosystem services over time. Understanding of the biophysical production and the valuation of ecosystem services may be improved through the processes of technical learning and updating management. Because uncertainties surrounding the production and valuation of ecosystem services are sometimes large, adaptive management can ultimately improve the outcomes of managing for ecosystem service values.

◆ *The uncertainty and dynamism in managing ecological processes and their social dimensions suggests an important role for adaptive management. The process of stakeholder engagement in adaptive management can help to identify the range of ecosystem services at play and those most valuable to communities and other stakeholders.*

When considering implementation of adaptive management or application of an ecosystem service lens on public lands or by Federal agencies in the United States, the National Environmental Policy Act (NEPA) is a key policy affecting the process. Managers may be concerned that uncertainties associated with ecosystem services analysis could hinder implementation because of the substantial documentation required to describe the uncertainties under NEPA. Similarly, some managers have expressed that adaptive management may be difficult to implement within the NEPA process because it requires clearly identifying the thresholds that will trigger a management change and the subsequent management actions. However, building adaptive management into the NEPA process up front can enable management to be updated in response to learning without requiring new NEPA documents. Also, application of an adaptive management framework may facilitate ecosystem service implementation by acknowledging the uncertainties and developing a plan to effectively manage ecosystem services in the presence of uncertainties. This may reduce the burdens of documentation while also improving outcomes. Adaptive management can also lead to more defensible and transparent decisions, which may reduce the likelihood of costly litigation or extended conflict.

Although in some cases transparency can be seen as inviting litigation, in litigious environments transparent explanation of how decisions were made is critical. One could ideally show that, conditional on the objectives that were identified and science available, the best decision was made. Clear articulation and transparency can help a process withstand litigation, and an approach that employs adaptive management and applies an ecosystem service lens can facilitate this transparency.

In many contexts of natural resource management, progress can be hindered by seemingly irresolvable conflict, as tradeoffs generally must be made when managing for multiple objectives. An adaptive management process facilitates decision making in these contexts. For example, incorporating multiple hypotheses about system processes into an adaptive management process can help demonstrate respect for alternative views and understanding while also facilitating systematic learning. It also may be possible to implement and compare multiple strategies in a way that helps to prevent confrontation and encourage cooperation during the learning process.

Similarly, in cases of conflicting values, producing an inventory of ecosystem services can facilitate progress by providing a means for channeling tensions to allow engagement by conflicted groups that need to work together. An example where this might be applicable is in defining protected areas for biodiversity, such as locally managed marine areas in the Pacific Northwest, where the location of the protected areas has been defined but the definition of “protected” remains elusive. Articulation of ecosystem services associated with protection options may make salient variables that are already the subject of conflict and thereby bring them into a negotiating context where they can be traded off against other variables.



3

Box 3: Complementarity of Ecosystem Services and Adaptive Management

Adaptive management and ecosystem services analysis can contribute to the planning and management of dynamic landscapes with the potential for improved management through improved understanding. In addition, there are clear synergies between these frameworks. A key feature of all management and policy decisions that affect natural resources is that they also affect the provisioning of ecosystem services. Thus, failure to explicitly consider the effects of management or policy decisions on a system's suite of relevant ecosystem services can lead to unintended consequences, collateral damage, and missed opportunities, and these ramifications highlight the importance of expanding potentially narrow management objectives to consider the range of ecosystem services that may be affected. The production and valuation of ecosystem services are evolving areas of knowledge, and ecosystem service analysis adds complexity and new dimensions of uncertainty to previous resource models. Given that adaptive management is a response to uncertainty and seeks to improve management outcomes in the face of that uncertainty, applying an adaptive decision process to managing ecosystem services is likely to enhance management outcomes.



A desert landscape featuring numerous saguaro cacti in the foreground and middle ground. In the background, there are rugged mountains under a sky with a warm, golden glow, suggesting a sunset or sunrise. The overall scene is a typical Southwestern desert environment.

Relevant Contexts for Application of an Integrated Approach

The relevance of adaptive management, ecosystem services, or their integration can be considered in numerous decision contexts. Importantly, adaptive management is relevant only in contexts where reducing uncertainty can provide real gains in terms of improved management outcomes (that is, contexts where information has a high value). Such contexts require that management can be updated and that reductions in uncertainty could alter management performance. For ecosystem service analysis to be applicable, management must have the potential to alter ecosystem outcomes and the values they provide to stakeholders.

For example, within the context of broad policy decisions that translate into law, broadening the focal value set by applying an ecosystem services lens may be relevant; however, adaptive management is unlikely to be applicable unless there would be opportunity to revisit and update the policy decision. In the context of development of regulatory or statutory structure, depending on the statutory context and the specificity of the regulatory goal, applying an ecosystem services lens again may be relevant to help incorporate a wider value set and prevent unintended consequences. Adaptive management, in turn, may be relevant for contexts that involve repeated regulatory decisions or periodic regulations, but it is less relevant for static regulatory contexts. In the context of resource management planning, which can unfold at many scales, applying an ecosystem services lens to more explicitly consider multiple values is relevant so that management options can address those values more explicitly. In addition, because of the uncertainty in systems management, adaptive management may be particularly relevant if there are opportunities for management to be updated over time in response to learning in ways that would improve management, or if learning can be applied to subsequent decisions.

Policy and management implementation can unfold through centralized or decentralized means. For example, public land managers can make specific decisions and implement them directly with little uncertainty about what specific actions will be taken after their decisions. In contrast, policies that indirectly affect private managers' decisions, such as through incentives or markets, induce decentralized, uncertain management actions. In this context, adaptive management may be as useful for improving understanding of the human system and behavioral responses as for reducing uncertainties in the ecological system and associated values. Coordinated management efforts represent mixtures of centralized and decentralized management, and these efforts are relevant governance structures for adaptive management and ecosystem services implementation.

In any context that may be relevant for adaptive management or applying an ecosystem services lens, one needs to decide whether adding the additional complexity is worthwhile. The consideration of ecosystem services may depend on to what extent the range of objectives can be expanded to consider a broader set of goals. Also, although implicitly managing for ecosystem services may work in some cases, in cases in which the production of multiple services is not aligned, explicit consideration may be critical. Adaptive management is most useful where there is system uncertainty (for example, uncertainty or disagreement about underlying system dynamics or the expected effects of management) and where management actions are taken through time such that they can be influenced by learning. In situations where management is too rigid to respond to learning or where learning is unlikely to influence management choices, adaptive management provides little benefit.

Adaptive management may be as useful for improving understanding of the human system and behavioral responses as for reducing uncertainties in the ecological system and associated values.

The following provides some guidance for balancing the potential benefits and costs attendant to the use of an ecosystem services approach alone, an adaptive management approach alone, or an integrated framework that includes both:

- If decision making is recurrent in the face of substantive uncertainty that hinders management, but decision making legally guided by only one or a few ecologically based objectives, adaptive management might prove useful without explicitly considering ecosystem services.
- If ecosystem management involves decision making at a single point in time with only limited uncertainty or uncertainty that does not hinder management choices, but a large number of ecosystem services need to be accounted for in the decision-making process, an ecosystem services framework might usefully be applied without considering adaptive management.
- If decisions are recurrent, uncertainty is substantial, the value of information is high, and it is important to account for a wide range of ecosystem services in decision making, an integrated framework that includes both adaptive management and ecosystem services may be appropriate.

That said, an integrated frame of reference that includes both adaptive management and ecosystem services can usefully serve as an aid in determining which context is likely to be the most appropriate in a particular instance.





Conceptual Framework for Integration

A conceptual integration of ecosystem services and adaptive management links all elements of adaptive management with the identification, production, and valuation of ecosystem services (fig. 3). While integration of ecosystem services into adaptive management may immediately reflect an expansion of the resource management objectives, it has implications for all parts of the adaptive process, including which stakeholders are at the table, what is monitored, the models that are used, and ultimately the management actions that are selected. An ecosystem services lens can help identify whether adaptive management is looking at the most relevant possible actions with respect to policy and decision making. It also can help identify what outcome measures are societally relevant to facilitate social interpretation and aid social scientists and decision makers. For example, applying an ecosystem services lens may suggest measuring a different set of outcomes or translating outcomes into endpoints that are socially meaningful, such as translating a measure of land cover change into species abundance change.

Ecosystem services can be integrated into adaptive management to different degrees. For example, an ecosystem service lens could simply be applied to identify and measure ecological endpoints that have social meaning. Alternatively, an expansive vision could entail treating human well-being as the outcome that is adaptively managed. A middle ground might entail adding social measures to the biophysical outcomes that are being measured (for example, we gained 100 acres of wetlands and improved groundwater quality for 75 households).

The form and process of ecosystem service and adaptive management integration may vary across policy contexts. For example, an ecosystem services approach could facilitate specification of an objective function in situations where systems management already is employed (for example, within national forests). In this case, integration simply provides a method for evaluating outcomes. In more narrow decision contexts, such as implementation of adaptive species recovery under the Endangered Species Act (Public Law 93–205), integration can seek to account for effects of management on ecosystem service values while making primary decisions for the well-being of the species. In this way, ecosystem services can broaden the objectives while managing in the presence of a constraint (for example, maintaining a minimum level of species abundance).

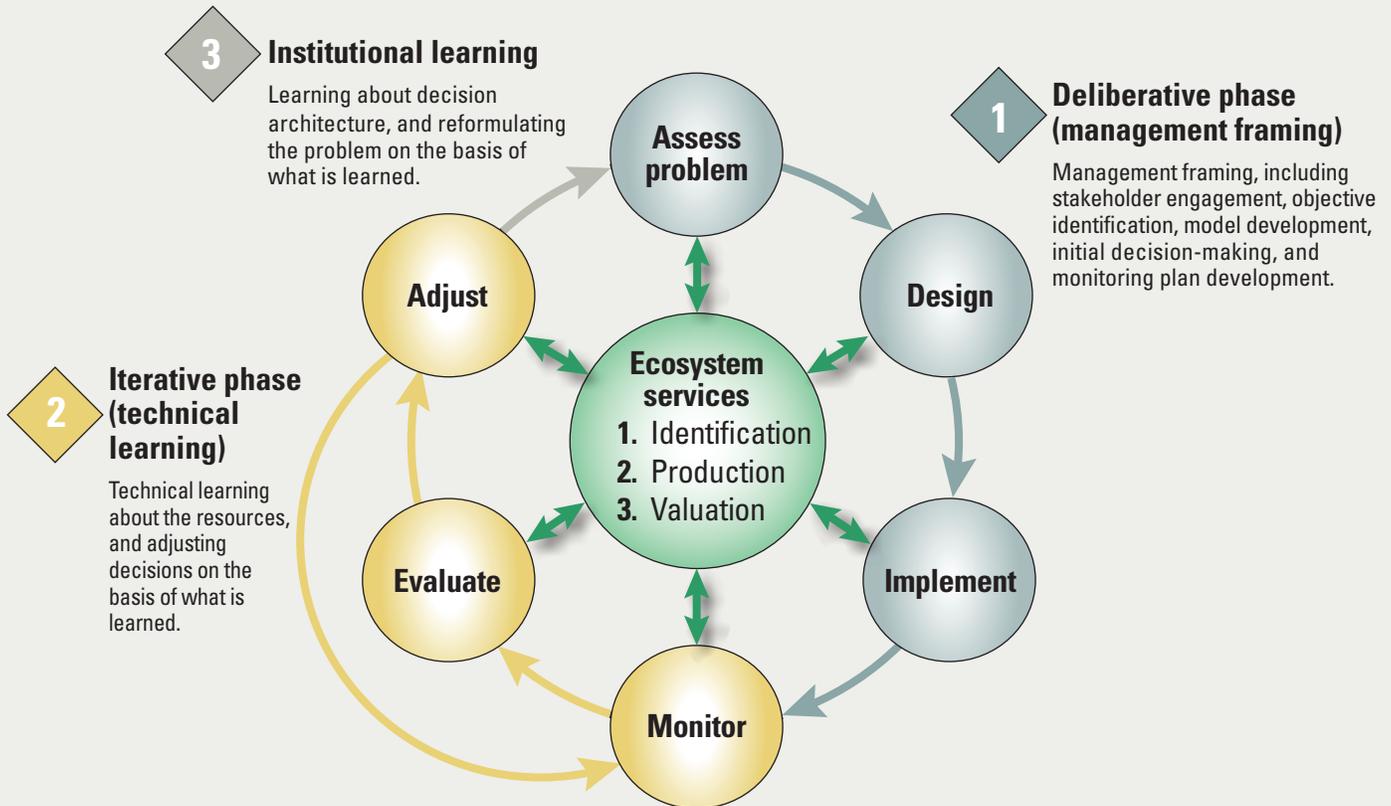


Figure 3. Conceptual framework for integration of ecosystems services and adaptive management. Each component of adaptive management (the outer ring of actions) feeds into understanding the identification, production, and valuation of ecosystem services (inner circle) to improve management outcomes. Simultaneously, consideration of ecosystem services affects each element of the adaptive management decision process. See boxes 1 and 2 for descriptions of adaptive management and ecosystem service approaches, respectively.

Although ecosystem services exist whether or not they are considered in management decisions, they are the explicit focus of management in a variety of contexts, including some market-based programs for ecosystem service provision, various regulatory contexts (for example, compliance under Section 404 of the Clean Water Act, through creation of mitigation banks), and managing for human welfare within a region (for example, management in the San Pedro watershed). In these cases, implementing programs adaptively, with monitoring, learning, and updating, may lead to better outcomes than designing a static management or payment strategy based on current knowledge. Adaptive management can facilitate identification of the relevant ecosystem services, the associated ecological endpoints that people care about, and the relevant policy interventions. Furthermore, adaptive management can employ monitoring and learning to reduce the uncertainty in the biophysical and social production processes to improve management (fig. 4).

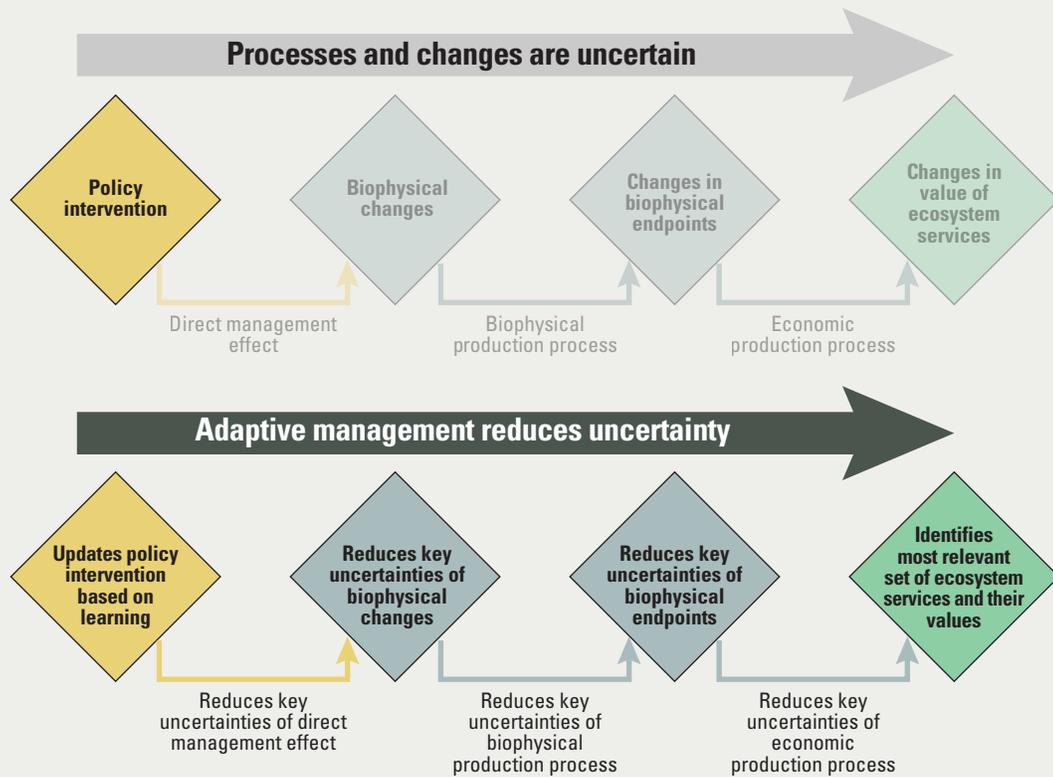


Figure 4. A conceptual diagram of how adaptive management can improve resource management by reducing key uncertainties in the production of ecosystem service values. **Top:** Each of the underlying ecosystem service production processes (arrows) and biophysical and social changes (blue and green diamonds) are uncertain. **Bottom:** Adaptive management can facilitate effective management of ecosystem services by enabling updating of management (yellow diamond) as targeted learning reduces the key uncertainties that limit effective management, which may include uncertainties about underlying social and biophysical processes as well as the state of the system. Adaptive management also can help identify the set of ecosystem services values (green diamond) and policy options (yellow diamond) that are most relevant.



Four Example Case Studies: An Empirical Evaluation

During the second workshop, we examined three natural resource management contexts in which, to varying extents, ecosystem services concepts have been integrated into adaptive decision processes. The set of case studies, which span geographic and temporal scales, regions, and management contexts, includes

1 Evaluation of best management practices for suburban development in Clarksburg, Md.;

2 BLM resource planning across scales with a focus on solar development;

and adaptive waterfowl management in North America, including

3 Adaptive harvest management, and

4 The North American Waterfowl Management Plan.

We describe these cases studies next, with particular focus on the key components of an integrated ecosystem services-adaptive management approach and lessons learned. The following descriptions represent the “state of the world” as of April 2013 when the workshop was held, as well as the discussions about the examples.

1

Case 1: Evaluation of Best Management Practices for Suburban Development in Clarksburg, Maryland

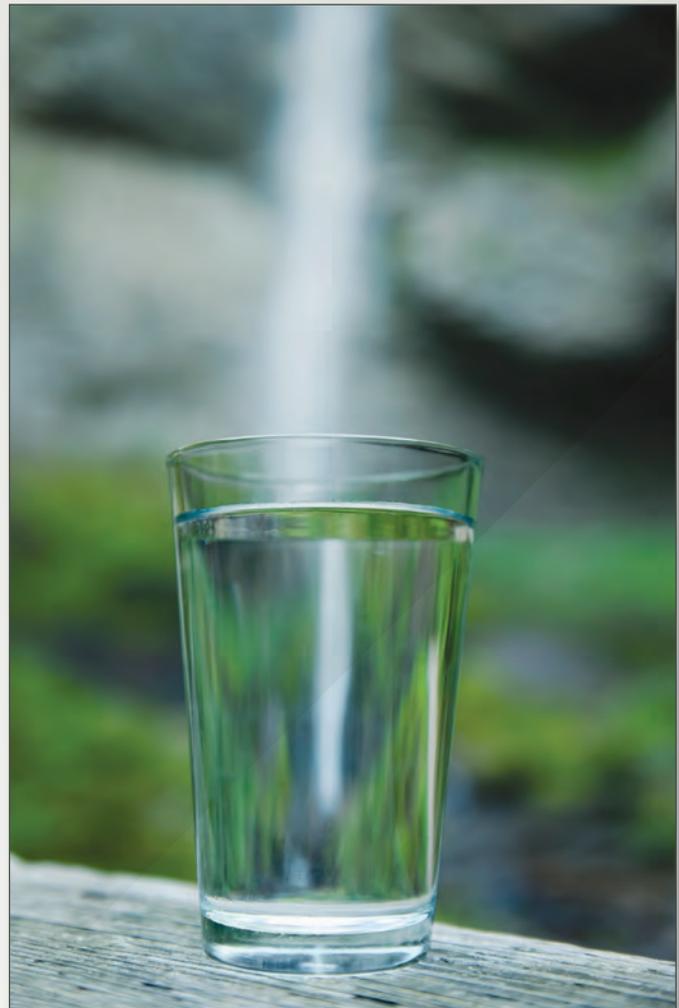
Clarksburg, Md., is at the outer, northwestern fringes of the Washington, D.C., metropolitan area and is under intense development pressure. The region has high-quality streams whose quality and preservation would be threatened by urbanization in the absence of special water-quality protection measures and appropriate land use controls (Montgomery County Code, Section 19–61[h]). In recognition of at-risk water resources, the 1994 Clarksburg Master Plan established a long-range vision that staged development of different sections of the Clarksburg area over time to allow for learning about the effectiveness of water-quality protection measures and land use controls with the goal of protecting area water resources during and after development.

Special water-quality protection measures (termed “best management practices” or BMPs) are used to mitigate development effects on stream water services (including quality, quantity, timing, availability, and flood control) and physical and chemical habitat services. However, considerable uncertainty exists about the ability of BMPs (sometimes termed “green infrastructure”) to maintain service provisioning during and after development. The adaptive management approach enabled by the staged development allows for monitoring and assessment of the effectiveness of the BMPs. This learning is being used to inform continued development of the region and support a limited amendment to the 1994 Clarksburg Master Plan, with current focus on development being considered in the Tenmile Creek watershed.

The adaptive management approach is being implemented by Montgomery County. The primary decision makers are the Montgomery County Planning Board, whose decisions strive to incorporate stakeholder feedback. The stakeholders primarily are the county residents. However, the community is growing, its values are changing over time, and the development decisions will affect the composition of future stakeholders and the value sets at stake.

Stakeholder feedback to the planning board has largely been intermediated by county planners who have organized meetings and workshops with the community to solicit community input on the importance of different goals, particularly goals focused on outcomes related to community building, transportation, environment, and the economy. Stakeholders also can leave comments on the county’s website. Although most comments on the website have been against development, alternative views have been voiced during the stakeholder meetings.

The Montgomery County Council, which has final decision power, has the goal of achieving community building goals while protecting the Tenmile Creek watershed. This broad goal is specified by the 1994 Clarksburg Master Plan, but determining what constitutes “protection” of the watershed is at the discretion of the council, and how tradeoffs should be weighed has not been fully articulated. The primary concerns factoring into the council’s objective appear to be water-quality impacts, housing availability, and job availability.



When describing the environmental concerns from development to the planning board, the county planners initially referred to the affected ecosystem services as “environmental impacts.” They described impacts affecting carbon sequestration, return of water to the air by evapotranspiration, release of oxygen to the air, stream and upland habitats, terrestrial and aquatic plant and animal communities, natural soil structure and biology, infiltration of rainwater, surface-water and groundwater flows, moderation of air and water temperature, minimal pollution inputs, and water-quality treatment. This initial list of impacts did not come from stakeholders.

Lists of values and their importance to stakeholders have since been developed. Water quality, amenity values, and recreation are probably the ecosystem services most at stake, as a drinking-water reservoir is downstream of the current proposed development.

The decision makers perceive that stakeholders want the development to occur—particularly a new road, a transit center, and retail area that were planned before many current residents moved into the community. As a result, it appears that the decision makers would like to allow some development while protecting the watershed. Thus, protecting ecosystem services appears to be a constraint on the goal of allowing development.

It is arguable how the welfare of current as opposed to future residents should be weighed in current development decisions. Development will likely cause a shift in benefits from current county residents to those who move in, through reduced environmental benefits for current residents and provisioning of housing for future residents. A shift in policy or constituents can alter attitudes, baselines, and values in a region. For example, when there is a change in land use or other policy, benefits are likely to shift from those who already are present and predicated their choices on the previous set of circumstances to new stakeholders who may move into the area in response to changes. Also, the uncertainty in development trajectories that result from adaptively managing development plans generally imposes a cost to developers but provides an option value to the community.



The action under consideration is altering the location or intensity of development from what is currently proposed in the 1994 Clarksburg Master Plan for the Tenmile Creek watershed. Tenmile Creek currently is classified as a reference stream because it has a high concentration of interior forest and wetlands, stable stream channels, and a connected flood plain. These qualities would be affected by development. The Maryland Stormwater Management Act of 2007 (§4–201 et seq.) requires new development to use environmentally sensitive design, which is similar but more intensive than the BMPs previously used in Clarksburg watersheds. Environmentally sensitive design would be included in any development actions.

Modeling and data assessment are being used to analyze environmental, economic, and transportation impacts from development scenarios. The environmental impact analysis is focused on analyzing existing water-quality and natural resource conditions, as well as the potential impacts of development, and on developing recommendations for protective measures, guidance for development, and recommendations for potential mitigation and enhancement projects. The economic analyses are focused on potential market and economic impacts of development. The assessment of environmental impacts is based in part on extensive monitoring of current water quality in the focal watershed and analyses of water-quality impacts from prior development in other watersheds. Specifically, six watersheds were analyzed: a forested watershed on parkland, a built watershed with pre-2000 design, and four developing watersheds. The environmental models predict impacts of development on hydrology, geomorphology, water quality, habitat, and biology, and show that there will be a probable loss of Tenmile Creek's reference condition.

Whereas stakeholders appear to at least implicitly understand ecosystem services and have been making their living choices on the basis of these values, communicating these values to decision makers has been more challenging. The development decisions under consideration represent, in part, a choice about whether to allow water quality to move from excellent condition to good or to fair condition. Perhaps this choice would be easier if the effects of these ratings on associated values were explained. Similarly, the ecosystem service impacts presented to the Montgomery County Planning Board were largely intermediate processes without a clear connection to outputs that people directly value. A more explicit ecosystem services lens might help elucidate values that have clearer meaning to people and can be more easily traded off.

Single-loop learning in this application has focused on monitoring of water-quality impacts from past development in Clarksburg watersheds to inform development in the current watershed. Double-loop learning also may be occurring and contributing to the time required for decision making. In particular, changing decision sets (for example, new BMPs) and background conditions (that is, changes in stakeholders or values over time) may be causing decision makers to revisit the decision context, weighting of objectives, and management options. The current approach to decision making on development in Clarksburg, Md., appears to have the key components of adaptive management and ecosystem services, but the council seems to still be in search of an articulated objective that allows tradeoffs to be evaluated. While this case study is small in scale, it is nonetheless complex.

Clarksburg, Md., is a wealthy and educated area and thus represents a fairly distinct context. Its citizens are well connected, with access to resources and technical capacity, as evidenced by the numerous agencies and players involved in the process. While the approach employed by Clarksburg, Md., may not be exactly replicable elsewhere due to the distinctiveness of the area, the concept of an adaptive management zoning plan could be transferrable elsewhere, as could the specific information learned about the effectiveness of BMPs. Furthermore, innovation often happens in contexts of high capacity and resources, and then the innovation can be adopted elsewhere. As such, if this effort is successful, it may serve as an example for other regions going forward.





Whereas stakeholders appear to at least implicitly understand ecosystem services and have been making their living choices on the basis of these values, communicating these values to decision makers has been more challenging.

2

Case 2: BLM Resource Planning Across Scales— Solar Development In The West

Adaptive management and ecosystem services are being planned and piloted to improve multiscale management decisions on Federal land. In many large-scale projects within BLM and elsewhere, decision making occurs at two scales, namely a larger regional level in which infrastructure is sited and developed and a more local scale in which a facility or site is managed on an ongoing basis. For example, renewable energy facilities are located and developed within a region over time, and each is operated on a local continuing basis thereafter. Decision options at the larger scale can include the nature and size of an installation, its location on the landscape, and the design of the infrastructure for its development and operation. In contrast, decisions by land management agencies at a local scale may include specifying operating conditions and constraints for site management.

Multiscale decision making can give rise to multiscale adaptive learning. Learning accumulated over time as sites are developed can be applied to new development decisions. Similarly, learning at the site or facility level can inform site operations locally and at other sites. This form of multiscale learning is applicable across diverse management contexts.

Through this case study, workshop participants explored a combination of multiscale learning and ecosystem service management in the context of solar energy development in the Intermountain West. As described in April 2013, the BLM is working to design solar installation development and management strategies that promote multiscale learning and adaptation, encouraging lessons learned at both large and small scales to be applied across time and locations.



◆ *Learning accumulated over time as sites are developed can be applied to new development decisions. Similarly, learning at the site or facility level can inform site operations locally and at other sites.*



The BLM is mandated to protect and sustain ecological values and accommodate multiple uses. To meet this mandate while accommodating energy generation, decisions generally follow a two-phase process. First, the BLM's resource management plans (RMPs), which often cover hundreds of thousands of acres, identify at a coarse scale where a spectrum of land uses are allowed. RMP development includes an environmental impact statement (EIS) and a public comment period for consideration of the environmental, societal, and economic benefits and costs of alternative plans. The second phase of the process is triggered by either an application for the use of public lands or an agency action to offer public lands for leasing, usually in an area no larger than 3 or 4 square miles. If the action is deemed to have substantial impact, a site-specific EIS is required and a BLM-authorized officer weighs public comments and the environmental and socioeconomic benefits and costs and then authorizes or rejects the application. An authorized application is usually accompanied by a set of stipulations designed to prevent or minimize impacts at the site level, often addressing project construction, operation, maintenance, and decommissioning phases.

To increase management effectiveness, the BLM identified several opportunities to improve this process through more comprehensive consideration of ecosystem processes and services and by engaging in an adaptive decision process. Specifically, the BLM seeks to incorporate an assessment of impacts to ecological systems and services (for example, water dynamics and nutrient cycling) into impact assessments and to provide guidance for decision makers on how to reconcile conflicting demands across stakeholders, impacts of disturbance on flora and fauna, and disruption of ecosystem processes. In terms of program evaluation and adaptation, the BLM also would like to use information gained from its Assessment, Inventory, and Monitoring System to validate or revise how it estimates potential environmental, societal, and economic impacts and to assess the relative effectiveness of resource allocation strategies, project siting criteria, and stipulations. This learning would be used to update and adapt decisions and management as appropriate.

Many stakeholders could be affected by solar development, including recreationists, ranchers, energy developers, Tribes, and NGOs. Different stakeholders are likely to experience different benefits and costs as land uses change. Stakeholders are engaged in the planning process but are not decision makers. They contribute information to identify concerns and aid in the development and refinement of management questions. Some stakeholder values have been more fully addressed than others thus far. For example, renewable energy projects strictly conflict with values of some Tribes in the Southwest. While there have been numerous negotiations with Tribal governments at the consultant or project level, in some cases conflict has not been resolved. This has suggested to the BLM that there is a need for improved strategies of Tribal engagement, more thorough problem documentation, and potentially an expansion of the decision space to consider new approaches. In contrast, incentives to ranchers for participation generally have been sufficient.

The BLM's objectives for solar development focus on regulatory requirements and program needs, including land health fundamentals and standards. The solar programmatic environmental impact statement (PEIS; Bureau of Land Management, 2012) evaluates direct, indirect, and cumulative impacts to a wide range of resources, including lands and realty, rangeland, recreation, soil, water, ecological resources (including plants, wildlife, aquatic biota, and special status species), air quality and climate, visual resources, and cultural and socioeconomic resources. Although not ecosystem services as such, these resources cover many of the values likely to be affected by solar development.



The actions under consideration involve where and how to develop solar and other uses on BLM land. The guiding principle is to develop in a way that prevents impacts if possible, adapts management to minimize impacts, and mitigates unavoidable impacts. For example, implementing an invasive species management plan can minimize environmental impacts, whereas irreversible damage must be mitigated offsite. Solar installations generally result in “scorched earth,” removing all natural landscape features, including topography. To compensate, solar developers often are assessed mitigation fees to cover the costs to restore and protect another area. In addition, compliance monitoring is used to facilitate adaptation and ensure compliance on site.

◆ *The conceptual models also contribute to many aspects of the adaptive decision process, including identifying data needs, improving stakeholder engagement, and making causal relationships explicit, which can facilitate both the learning process and decision making.*

The BLM is developing ecoregional and project-specific conceptual models of ecological functioning that represent ecological components, processes, interactions, and drivers. These models are developed from existing literature and models and integrate expert opinion and local and traditional knowledge. The focus on ecological components, processes, and services facilitates management, impact assessment, and application of the adaptive decision process. Some BLM managers have found that applying an ecosystem services lens to decision-making processes benefits stakeholder engagement by more effectively communicating the values and goals of management. The conceptual models also contribute to many aspects of the adaptive decision process, including identifying data needs, improving stakeholder engagement, and making causal relationships explicit, which can facilitate both the learning process and decision making.

A framework for developing a monitoring and adaptive management plan was built into the Final Solar PEIS (Bureau of Land Management, 2012, appendix A.2.4). The aim of the framework is for learning to be accumulated through time as RMPs are implemented and specific projects are authorized, constructed, operated, and monitored. The lessons learned can then be applied as new resource allocation and project decisions are being made regarding siting, design, construction, operation, and dismantling of projects and facilities.

As of the workshop in 2013, the major intended focus of the BLM’s monitoring plan is environmental processes, including soil and site stability, hydrologic function, and habitat dispersion. Collecting data on these factors will help assess whether processes, rather than just specific species, are being maintained, further shifting management to an ecosystem focus. Monitoring results will be interpreted against defined monitoring objectives, ecological potential, land health standards, and management thresholds. Annual reports summarizing the condition and trend of each area will be developed and fed back into the monitoring planning process and solar program planning more generally. Management changes will be required if certain established objectives or thresholds are not met or are exceeded. The learning can contribute to updating models, monitoring plans, assessing if objectives are being met, evaluating the need to change actions, establishing compliance specifications for future projects, and siting decisions.

The BLM is engaging in a form of double-loop learning, or multi-iterative adaptation, by initially piloting the adaptive management process with a single solar energy zone. The pilot is meant to be used to help determine the appropriate level of stakeholder engagement, determine the key participants, and work with stakeholders to identify key management questions, objectives, and indicators. Other aspects of the process, including enhancing efficiency, also will be evaluated during the pilot process. What is learned during the pilot application will cultivate subsequent dual-level adaptive decision making at other sites.



3

Case 3: Adaptive Waterfowl Harvest Management

Each year, a federally mandated Migratory Bird Regulations Committee develops recommendations for regulating the sport hunting of waterfowl in North America. The committee includes representatives of the U.S. Fish and Wildlife Service and the waterfowl flyway councils and receives input from NGOs and the public. The framework used by the committee is built on an adaptive approach to harvest management that accounts for possible realizations of breeding population size and environmental conditions, as well as the current understanding of population dynamics and responses to harvest. Each year, personnel in the migratory bird office analyze the data and develop a decision matrix. Input from States is solicited during a number of flyway meetings. Then representatives from the migratory bird office meet with representatives from each flyway to discuss the findings and needs. Ultimately, the personnel in the migratory bird office recommend a set of harvest regulations for the year, and the Assistant Secretary of the Interior for Fish, Wildlife, and Parks makes a final decision based on the recommendations of the committee. The regulatory choices are season length (the States choose when the season opens) and bag limit, which can vary among flyways. Bird and pond numbers are subsequently monitored each year, and these postdecision monitoring data are used to update biological understanding for the next year. In this way, harvest policy evolves adaptively over time, as new knowledge is incorporated.

The objective employed in decision making seeks to maximize sustainable harvest and prevent populations from dropping too far below a threshold. Formally, this objective involves maximizing long-term, nondiscounted harvest minus a penalty that depends on how far below a threshold the population declines. This penalty term implicitly values the on-the-ground population and can be seen as accounting for some forms of ecosystem services beyond harvest. However, this objective does not account explicitly for values of nonhunter stakeholders such as birders, to the extent that these values are not satisfied by populations exceeding the specified threshold.

The decision framework employs a dynamic optimization approach that can account for the dynamic nature of populations, the uncertainty in resource status, environmental conditions, imprecise control, and uncertainty about biological processes—factors that make harvest regulation difficult. Four competing models are embedded in the dynamic optimization program: two models of survival responses to harvest and two models of reproduction responses. In addition, bird population predictions depend on the number of available ponds on the landscape. Each summer the optimization program is used to identify the optimal set of harvest regulations for the coming season. The regulations are implemented, and subsequent waterfowl population size is estimated from monitoring data collected in the following spring. This estimate of population size is compared with predictions of each of the four models, leading to increased confidence in the model(s) that predict well and decreased confidence in those that predict poorly. The program is then used to identify the optimal regulations or the current year based on the updated degrees of confidence in the models and the new estimate of waterfowl abundance from monitoring. The level of confidence in each model determines its weight or influence in the derivation of the optimal management policy. The models focus on single species and do not address species interactions. The timescales for monitoring, learning, and updating decisions have been matched to the (annual) timescale of the process being monitored (for example, duck population changes).



The importance of monitoring data to harvest decisions was recognized by the U.S. Fish and Wildlife Service well before the formal implementation of the model-based adaptive harvest management system. Thus, monitoring was already in place at the start of the adaptive harvest management program, and implementing adaptive management did not incur additional monitoring costs. However, the same model-based adaptive decision process can be applied regardless of the amount of information available at the start of the program, and a lack of information should not preclude attempting this approach. The approach has been used at the scale of single refuges, in addition to this nationwide context.

Through its adoption in 1995, this decision-making approach, which allows for learning and incorporates information from multiple competing models, helped to resolve conflict and prevent litigation. It allowed political conflict to be diverted into a conflict over ecological models of waterfowl population dynamics, and conflict was resolved by allowing the models to compete on the basis of their predictive abilities. This worked because the conflict was targeted at the science rather than the objectives. In contrast, fisheries management does not widely use modeling approaches that embed learning and competing models. Learning tends to be more informal, which may contribute to litigation being common in fisheries management but rare for waterfowl management. Other differences are that fisheries management is less transparent, catch allocations vary across individuals, and commercial interests abound.

Adaptive waterfowl harvest management represents the state of the art in adaptive management. Single-loop (technical) learning is fully integrated into the models and decision making underlying adaptive harvest management. In addition, double-loop learning is now underway as increasing focus is placed on updating the objective function to account for a wider range of values (see the discussion of case 4). The current objective does not explicitly account for a broad range of ecosystem services values beyond harvest, though some are represented implicitly in the goal of sustaining duck populations above a certain threshold. It could be that a set of values that includes more than sustainable waterfowl harvest was always affected by regulatory choices in this context but that these values previously were well aligned with the explicit objectives. However, as the hunters' objective function ceases to represent the broadening set of stakeholder values (for example, as a result of changing demographics), the objective may be revisited and additional societal values made explicit as part of the ongoing adaptive decision process. As such, double-loop learning would be at play.





Case 4: The North American Waterfowl Management Plan

In recent years, waterfowl management has begun to focus on the link between harvest regulations and hunter engagement and satisfaction, thus increasingly focusing on recreation values. In addition, waterfowl have become flagship species for a large suite of ecosystem services that wetlands provide, including nonconsumptive recreation values, flood control, biodiversity, and sustainability. Building from these expanded stakeholder concerns, an adaptive approach is being developed to address and inform management of the broad suite of ecosystem services provided by wetlands by expanding waterfowl management strategies to include habitat management as well as harvest. This approach would entail not only an expansion of management objectives and strategies but also an expansion of stakeholder and jurisdictional scope, thereby increasing management complexity.

The 2012 North American Waterfowl Management Plan (NAWMP) considers that losses of waterfowl habitat are increasing and revenues from hunters to maintain waterfowl management programs are declining. The plan thus moves from a single goal of maintaining waterfowl populations to an integration of three goals that target (1) waterfowl populations, (2) habitat conservation, and (3) societal needs and desires, including hunter satisfaction, recreational opportunities, ecological service provision, and growing the number of stakeholders that enjoy and support waterfowl and wetlands conservation. Much of the motivation for broadening the objectives and stakeholder engagement stemmed from recognition that the various goals related to waterfowl management and the likely actions to achieve them are highly interconnected. Thus, bringing them together in a single plan could enhance effectiveness and efficiency and prevent conflicting management actions—or at least acknowledge the inherent tradeoffs. For example, in 2005, a joint task group was appointed by the NAWMP Committee and the International Association of Fish and Wildlife Agencies' Adaptive Harvest Management Task Force to explore options for reconciling the use of NAWMP population objectives for harvest and habitat management. The group concluded that the separate objectives for waterfowl populations and their habitats should be “formally integrated to ensure that they support rather than act against each other” (Anderson and others, 2007; NAWMP Committee, 2012, p. iv).

A comprehensive assessment of the NAWMP from 2005 through 2007 highlighted the need to evaluate and learn from the outcomes of plan-directed conservation actions. Subsequently, in 2008, it was recommended that the next update of the NAWMP further the formal integration of harvest and habitat management and seek ways to incorporate “society’s desires for users and supporters of waterfowl and wetlands habitat” (Anderson and others, 2007; NAWMP Committee, 2012, p. iv), thus leading to the thoroughly revised goals in 2012. The plan was developed by the NAWMP Committee, and the signatories include the U.S. Secretary of the Interior, Canada’s Minister of the Environment, and Mexico’s Secretary of the Environment and Natural Resources.

Updated goals were developed through extensive consultation, including 13 stakeholder workshops, which included Federal, Provincial/Territorial, State, and NGO representatives from the continental waterfowl management community. Part of the motivation for updating the plan’s goals was concern about changes in stakeholder demographics and values, with decreasing numbers of hunters and increasing disconnectedness of people from the environment. The broadening of objectives of this plan required that a broader group of organizations and interests work together.

The updated plan moves from a single goal focused on maintaining waterfowl populations to integrating three goals, targeting waterfowl populations, habitat conservation, and societal needs and desires:

- **Goal 1:** Abundant and resilient waterfowl populations to support hunting and other uses without imperiling habitat.
- **Goal 2:** Wetlands and related habitats sufficient to sustain waterfowl populations at desired levels, while providing places to recreate and ecological services that benefit society.
- **Goal 3:** Growing numbers of waterfowl hunters, other conservationists, and citizens who enjoy and actively support waterfowl and wetlands conservation” (NAWMP Committee, 2012, p. 2).

Inherent in the third goal is a desire to maintain environmental values, a cultural value (hunting), and a revenue source and support for maintaining waterfowl and habitat more generally.

◆ *Applying an ecosystem service lens and broadening the set of objectives highlights the need to expand the management vision beyond the breeding grounds to include wintering grounds and migratory routes.*





Although adaptive management with the expanded set of objectives and potential actions had not yet been formally implemented as of our 2013 workshop, the NAWMP specifies that formal adaptive management approaches should be used to evaluate how well objectives are being met and to update understanding of the focal system. The NAWMP recognizes the need for a “[coherent management system . . .] focused on social as well as ecological matters . . . that would feature the familiar elements of an informed decision process—explicit objectives, coherent system models, targeted and focused monitoring programs, and institutional processes to adapt to new information” (NAWMP Committee, 2012, p. 24). The plan recognizes that adaptive management can be applied at a large scale so that learning can happen rapidly over space, rather than just over time.

While adaptive management in this context remains in the deliberative phase, the 2012 revision of the NAWMP itself represents a form of double-loop learning, as the plan developers stepped back to reexamine and redefine their stakeholders, goals, and management actions. They also identified that the governance supporting the enterprise should be assessed and potentially restructured to bring diverse communities together (for example, harvesters, birders, and habitat focused stakeholders). This need is amplified by waterfowl population management and waterfowl habitat conservation having evolved within distinct institutions that lack coherent, interrelated objectives. Furthermore, neither institution has formulated explicit and shared objectives for people or developed a level of adaptability that matches the pace of current environmental and societal change.

Applying an ecosystem service lens and broadening the set of objectives highlights the need to expand the management vision beyond the breeding grounds to include wintering grounds and migratory routes. Adding relevance to waterfowl conservation, a key part of the plan is recognition of the links between people and habitat, species, harvest, clean water, and so forth. By considering habitat conservation as a potential management action, multiple interacting values come to the forefront and spatial issues become important. The plan also recognizes that values vary by location.

The plan recommends strategic investments that provide people an opportunity to reconnect with nature through waterfowl. It also recommends dedicated efforts to quantify and communicate to the public the numerous environmental benefits associated with waterfowl habitat conservation. These include attenuation of floods, enhanced water quality, groundwater recharge, and numerous other ecological goods and services (Anderson and others, 2007; NAWMP Committee, 2012).

A photograph of a duck with its wings spread, floating on water. The duck is positioned on the left side of the frame, with its wings extending towards the right. The water is a light blue-grey color with gentle ripples. The background is a soft, out-of-focus landscape with a diagonal line separating the water from a lighter sky area.

Reflections on Adaptive Management- Ecosystem Services Integration: Case Study Evaluation

Although each of these case studies is useful for better understanding and exploring the challenges, benefits, and implementation of an integrated adaptive management-ecosystem services approach, none provides an ideal or complete example for replication elsewhere.

Nonetheless, discussions of four case studies during the workshop identified some lessons learned and challenges related to each component of an integrated adaptive management-ecosystem services application, as we describe next.

Stakeholders

An adaptive decision process enables dynamic engagement of stakeholders, allowing the scope and composition of stakeholder engagement to change over time. An ecosystem services lens can help identify who needs to be engaged, just as the stakeholders are critical for identifying the relevant ecosystem services to be managed.

A key challenge is deciding who should be engaged as stakeholders and how they should be engaged. The extent and type of stakeholder engagement may vary on the basis of the complexity and scale of the problem and the cost of such engagement. Also, it is important to determine how to account for the values of people far away from the management context (in time or space) and the values derived from ecological processes that sustain services over the long term. The values of individuals with little time or money for participation may be underrepresented. In some cases, defining stakeholders also can be challenging because of changing demographics or values over time. For example, in the case of Clarksburg, Md., how the values of potential future residents should be weighed relative to those of current residents has not been articulated.

There is a large empirical literature that addresses stakeholder engagement processes, including the sequencing and scale of participation and its relationship with learning and the effectiveness of management. This literature may be useful for informing stakeholder engagement across contexts.

Transforming social conflict into a technical debate can sometimes help resolve conflict. However, stakeholders nonetheless need to remain engaged, because the technical debate can become irrelevant and conflict can re-erupt if the debate becomes divorced from the stakeholder concerns.

Objectives

Objectives need to be clearly defined. Without clear specification of competing values or services, discussing how to adaptively manage for one over another is challenging at best. A variety of values can feed into objectives, including ecosystem service values, spiritual values, and economic considerations, among others. Integration of adaptive management and ecosystem service approaches can help illuminate and refine objectives. An ecosystem service lens can help identify and articulate ecosystem-based objectives, and focal objectives can be refined over time through an adaptive process that involves learning what people care about and which socially relevant outcomes are most likely to be affected by management.

There is a continuum in how much quantification of ecosystem services can be incorporated into decision making. Quantification is not needed in every instance, and quantification can be done with or without monetization (for example, see box 2 in the “Ecosystem Services” section of the introduction). Monetary valuation can facilitate evaluation of tradeoffs by putting everything in common and easily understood units, but societal outcomes also can be quantified on the basis of the measures such as the number of beneficiaries affected and the magnitude of the socially relevant biophysical change. Identifying when quantification is critical, as opposed to when it is sufficient to simply show across a set of alternatives how key ecosystem services increase or decrease according to management decisions, is a key area for continued discussion.

The case studies varied in the degree to which they articulated management objectives and accounted for ecosystem services and in terms of how objectives were measured. For example, the adaptive harvest management program is considering an expansion of objectives to explicitly consider a broader range of ecosystem services, but currently the program explicitly considers only sustainable waterfowl harvest, whereas it implicitly considers services represented by waterfowl populations on the ground. The North American Waterfowl Management Plan more explicitly considers ecosystem services in its three goals. Aspects of these goals (for example, “ecological services that benefit society”) nonetheless remain vague, likely because of the early stages of plan implementation and the plan being a high-level document rather than on-the-ground management guidance.





Local objectives can be refined over time through an adaptive process that involves learning what people care about and which socially relevant outcomes are most likely to be affected by management.



Clarksburg, Md., has brought ecosystem service consideration into its decision-making process in several ways, though some measures fall short of representing direct human values. For example, the planners described a variety of ecosystem components and processes that would be affected by development, including carbon sequestration, stream and upland habitats, terrestrial and aquatic plant and animal communities, natural soil structure and biology, infiltration of rainwater, surface-water and groundwater flows, water quality, and so forth. These represent intermediate outputs and processes rather than measures that are directly valued by people. Similarly, decisions are being made about whether to allow water quality to move from excellent condition to good or to fair condition, rather than defining what these conditions mean for specific ecosystem service values. Decisions in Clarksburg, Md., might be facilitated by a more explicit ecosystem service lens that links ecosystem changes to output that people value and that can be more easily traded off.

Similar issues could arise in the context of solar planning by the BLM. Conceptual diagrams and monitoring appear to primarily focus on ecosystem components and processes rather than the specific values that people care about. However, the BLM's solar programmatic environmental impact statement evaluated direct, indirect, and cumulative impacts to a wide range of resources, including lands and realty, rangeland, recreation, soil, water, ecological resources, air quality and climate, visual resources, and cultural and socioeconomic resources. While not ecosystem services as such, these cover many of the values likely to be affected by solar development. It seems that the approach described in the case study aims to manage for competing values by maintaining underlying ecosystem processes and improving management as understanding of the effect of management on those processes improves.





Many examples of ecosystem service management focus primarily on a single service (for example, nitrogen in the Chesapeake Bay, water quality and quantity for Water Fund projects, and waterfowl harvest for the adaptive harvest management program). When managing for a single service also protects other services that stakeholders care about, then the narrow focus may work well. However, conflicts can arise in other cases. For example, in some cases in the Chesapeake Bay, where nitrogen management has received primary focus, streams were filled in to install water-treatment strategies, and the water-treatment strategies were considered self-mitigation for the stream filling. In the context of adaptive waterfowl harvest management, managing for maximal long-term harvest has served as an adequate objective, but there is increasing desire to incorporate other values explicitly into the decision-making process. When accounting for multiple ecosystem services simultaneously, it is necessary to consider the linkages within and between natural and human systems.

Consideration of a broader set of ecosystem service values can increase the challenge of evaluating and managing tradeoffs. There can be multiple ways to define objective functions that represent multiple types of values. Weighting of different objectives often is contentious and difficult to support. A threshold approach can be useful in some contexts in which thresholds are defined for certain types of values, and the other values are then maximized to the extent possible while meeting the thresholds. Sometimes agreement on goals cannot be achieved because value conflicts are irreconcilable. Nonetheless, decisions still need to be made. In these cases it may be possible, on a temporary basis, to gain agreement on a boundary-spanning objective or on a set of actions to try.

Models

Models can range from conceptual to quantitative and can be useful for fully developing hypotheses, determining what to monitor, and evaluating management strategies. Conceptual models can help managers and stakeholders understand how actions, processes, and outcomes are linked and identify the values associated with a system. In this way, models can facilitate stakeholder engagement, as has been the case for BLM solar development planning. An ecosystem service lens can help guide the types of models needed to inform adaptive decision making by highlighting the biophysical processes likely to be affected by management and how those processes feed into the values and objectives that are being managed for. Adaptive decision making, in turn, is critical for refining the models and hence for an understanding of ecosystem service production and valuation.

In contrast to conceptual models, the adaptive harvest management program employs a quantitative model that incorporates learning and can identify management strategies that best meet the defined objectives. However, its dynamic optimization approach can be less tractable in contexts with more complexity, management choices, or types of uncertainty. Indeed, while ecosystem service identification can directly feed back into explicit identification of relevant models and the outcomes and processes that should be monitored (see the following section), a key challenge is that consideration of a broader set of ecosystem service endpoints requires consideration of more models, adding complexity to the process.



Monitoring

Monitoring is a key part of any adaptive decision process, as it enables learning about underlying system dynamics and the effects of management. This learning enables objectives to be evaluated and management to be updated. Indeed, an ecosystem service lens can help to highlight the socially relevant outcomes that should be monitored to enable evaluation of how well objectives are being met, and competing models of ecosystem service production can help to identify variables whose monitoring would help resolve key uncertainties. As such, monitoring can enable updating of models to improve our understanding of the production and valuation of ecosystem services. Availability of baseline data can speed this learning process.

Focusing only on final outcomes (for example, species abundance), without consideration of the underlying processes, can make updating models and management challenging. For example, if species populations do not respond as desired to management actions (for example, restoration) and underlying processes such as habitat changes have not been measured, then management implications may be unclear. Thus, a clear focus on ecosystem processes, in addition to the endpoints that people care about, is important for effective adaptive management.

◆ *Adaptive decision making, in turn, is critical for refining the models and hence for an understanding of ecosystem service production and valuation.*

Updating Decisions

Adaptive management will fall short if there is no mechanism for updating management on the basis of what is learned from monitoring. In such a case, when an iterative learning process suggests an alternative course of action, there may be no path for the new knowledge to be translated into a new course of action, and this absence causes adaptive management to fail. The adaptive management applications that have tended to fail have lacked institutional mechanisms for updating decisions on the basis of the learning, despite effective science being done.

Spatial-Temporal Learning

Although typically conceived of in terms of updating management decisions at a single location over time, learning and adaptive management can be applied at multiple spatial and temporal scales. For example, learning from one-off decision contexts (for example, a siting or infrastructure decision) can be used to inform other, similar one-off decisions. Likewise, ongoing learning within a given management location can inform management at other locations (for example, operations across multiple dams). Although this type of learning can be informal, explicit spatial-temporal adaptive learning may improve outcomes by formalizing monitoring, information sharing, and processes for integrating new information into decisions. The workshops explored this type of multiscale learning in the context of solar siting for the BLM, but it is likely applicable across diverse contexts, including dam relicensing and management. In addition, an ecosystem services lens may facilitate the transfer of knowledge across time and space by providing a conceptual framework for organizing information for transfer across contexts. Spatial-temporal learning also is likely to speed up learning about identification of relevant ecosystem services and their production and valuation by providing more replicates of the adaptive decision process and feedback between them.







Challenges to Adaptive Management- Ecosystem Services Integration

Although ecosystem services and adaptive management frameworks seem to be a natural fit for integration that could improve management outcomes, the integration will be challenging, as evidenced by our case studies and discussed in both workshops. In most cases, integration will face not only challenges specific to the integration, but also the institutional, cultural, and technical challenges faced by the frameworks independently. As such, few, if any, of the case studies implemented a fully developed adaptive management framework and an explicit analysis of multiple ecosystem services that includes endpoints with direct human value.

Adaptive management implementation is constrained by a variety of factors. For example, large resources generally are needed up front to initiate and design an adaptive management program, and support for long-term management and monitoring is often limited. Short-term or politically constrained budgets further limit long-term planning. Managers may hesitate in taking an adaptive management approach because of the ways in which it can increase the scope of management by moving from an agency to a collaborative context, which can increase the complexity of management and planning, exacerbate funding difficulties, and necessitate cross-jurisdictional sharing of funds. It also can be difficult to decide which stakeholders should be engaged. In the United States, Federal managers also can perceive constraints when complying with the National Environmental Policy Act (NEPA), which requires specifying, documenting, and evaluating management alternatives up front. Changes to the plan can require initiation of a new NEPA process. However, building adaptive management into the NEPA process up front can enable management to be updated in response to learning without requiring new NEPA documents. Finally, a history of projects claiming an adaptive management approach, but which fall short of applying a deliberate and structured approach to learning or are simply paying lip service to the concept, can hinder acceptance of adaptive management approaches.

Ecosystem services approaches also face a variety of constraints. One of the greatest is identification of which ecosystem services are most relevant in a particular context. In addition, incorporating ecosystem services concepts into management is challenged by incomplete understanding of the underlying biophysical production functions that link policy or management actions to outcomes that people care about. Both the economic production functions that help to value ecosystem service outcomes and the analytic frameworks for estimating these functions are evolving with new insights, research, and data. These gaps in information about relevant services and underlying production functions hinder choosing appropriate management to maximize ecosystem service benefits and again highlight the potential gains from managing for ecosystem services within an adaptive management framework. Concern also exists that ecosystem resilience and intergenerational equity may not be properly accounted for in an ecosystem services framework, particularly if values are monetized and standard discounting is employed to compare values over time. Although economic valuation is just one analytic tool for providing commensurability when considering multiple value sets, there is widespread concern that an ecosystem services approach implies commodification of ecosystem components and requires monetization of values. Finally, a management approach that seeks to maximize human well-being may not recognize the limited decision space in which managers work, in which only certain options are available.

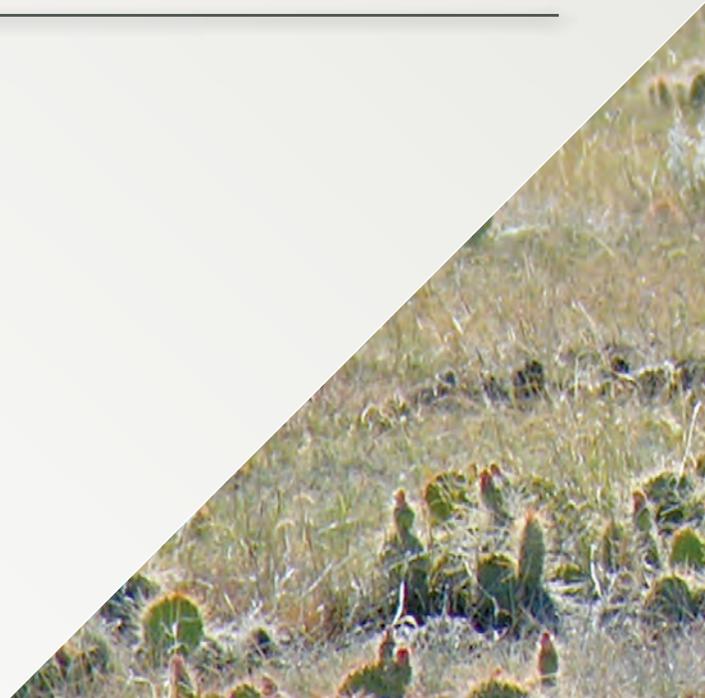
Some challenges are common to both frameworks. For example, there is a tendency to get stuck in the deliberative phase rather than moving forward with management. Also, both frameworks promote transparency, which commonly is viewed as a strength, but transparency may be resisted by stakeholders who perceive a shift in decision-making power or by lawyers concerned with vulnerability to litigation. Implementation of these approaches also necessitates demand and willing managers. In both decision-making contexts, researchers and resource managers need to work together to be most effective, but researchers can be too far separated from managers to effectively integrate science and management, in part because of cultures that identify researchers as thinkers and managers as doers. This challenge is reinforced by budget allocations that distinguish between research and management. Limitations in human resources capacity can challenge implementation of both frameworks, though boundary organizations can facilitate the integration of managerial, experiential, and scientific knowledge. Institutional or policy constraints can also constrain management and limit experimentation, and processes can be challenged by seeking stakeholder agreement.

Because integration of ecosystem services and adaptive management faces the same challenges as the approaches independently, integration may more than double the challenges. There is concern that their integration may make management too costly and complicated. The integration also requires institutional and personnel capacity and support. Governance may become more complicated with integration. For example, inclusion of ecosystem services may entail an expansion of the objectives and decision context (for example, moving beyond recovery of a species to consider management of an entire water system, such as on the Platte River). This complexity entailed by integration has implications for who is at the decision table and the scope of stakeholder involvement, which in turn affect decision processes and invite demand for more collaborative decision making. These factors can present challenges for effective management.

Integration can also involve technical challenges. As the diversity of objectives and processes considered expands, the numbers and types of uncertainties also are likely to expand. Developing models, identifying key uncertainties and features for monitoring, evaluating tradeoffs, and selecting management actions can become complex conceptually and technically as objectives broaden. Figuring out how to combine qualitative and quantitative aspects of adaptive management and ecosystem services will be an important area of future development.

Finally, new concepts often meet institutional resistance, which also can hinder adoption.

◆ *Inclusion of ecosystem services may entail an expansion of the objectives and decision context (for example, moving beyond recovery of a species to consider management of an entire water system, such as on the Platte River).*







Future Directions and Needs

Although challenges face both independent and integrative application of adaptive management and ecosystem services concepts, integration has the potential to substantially improve outcomes. Progress in uniting these approaches will require that the joint framework that links the two concepts be as sleek and simple as possible, without losing account of socioecological processes and uncertainties. Neither ecological complexity nor societal values can be neglected. Thus integrating the approaches is a difficult balance of simplicity and complexity.

A reviewer of this report (Michael Runge, USGS) noted that multicriteria decision analysis (MCDA) could provide a useful link between ecosystem services and adaptive management for facilitating their integration. MCDA is a formal structure for decision making and analysis that can be used to address problems involving multiple criteria, or objectives, as they arise when considering ecosystem services, and, similar to adaptive management, MCDA would bring a disciplined decision analysis structure to ecosystem service analysis. In addition, the key terms within adaptive management and ecosystem services map well into MCDA framing concepts. Future work could explore the usefulness of MCDA as a means for helping to integrate adaptive management and ecosystem service approaches.

Replicable examples of where adaptive management-ecosystem services integration has been done well are needed. As examples of successful adaptive management have become more prevalent (though still uncommon), it has been considered and applied in more contexts. A key example is the adaptive harvest management approach that has been applied repeatedly, across scales and species. If an approach can be seen working in one context, then strategies, lessons learned, and general principles can be drawn upon to scale up its application or apply it elsewhere.

Although the case studies explored in the second workshop were useful for exploring the benefits and challenges of integrating adaptive management and ecosystem services approaches, it is not clear that any replicable example of an approach to integrated adaptive management-ecosystem services yet exists that considers a diverse array of ecosystem service outcomes. The adaptive harvest management case study provides an important example of a well-designed and well-implemented application that manages explicitly for harvest and implicitly for those ecosystem services represented by maintenance of waterfowl populations on the ground. However, to date, the application considers a narrower range of services than may be desired in other decision contexts and thus does not yet incorporate the complexity of processes and tradeoffs that might ultimately be managed in this type of framework. Other management applications that may ultimately serve as examples of adaptively managing a broader suite of ecosystem services include the solar siting by the BLM, but most applications are too early in their implementation to evaluate.

Although not available at the time of the focal workshops for this report, another example may be the Glen Canyon Dam Long-Term Experimental and Management Plan, which also considers the integration of ecosystem services and adaptive management. In particular, plan development included an extensive and detailed decision analysis (including MCDA and the expected value of information) that considered a broad array of ecosystem services and other objectives and considered the utility of adaptive management for resolving uncertainties (Runge and others, 2015). The continued development of example applications likely will depend on decision makers being convinced that the integration will solve a real problem that they are facing. However, once managers consciously work to integrate the two concepts, they may find that integration makes both processes easier, because individually the approaches frequently leave out key components.



Applying an ecosystem services-adaptive management approach in a context gridlocked by conflict would target challenges most likely to be helped by the approach and could turn management in a more productive direction.

One approach for enhancing application could be to identify a set of demonstrations within the Department of Interior. These could be selected by identifying situations where inaction is resulting from conflict and where an integrated approach could help resolve the conflict. Applying an ecosystem services-adaptive management approach in a context gridlocked by conflict would target challenges most likely to be helped by the approach and could turn management in a more productive direction. In conjunction with a Secretarial directive to apply the approach more widely, this approach could initiate a diffusion strategy. Those who benefit from the process would likely become champions of the approach.

Two additional features that could facilitate wider application of an integrated adaptive management-ecosystem services approach are (1) showing people that their values are represented in the process and that those values alter decisions, and (2) ensuring the decisions that managers have to make and the constraints that they face are central when developing the model. These features can help bring relevance to the people involved, making the approach accessible.

Continued development of practical guidance for applying an ecosystem services approach may provide an important foundation for integrating ecosystem services evaluation into an adaptive management framework. This includes developing accepted measures for different ecosystem service values (for example, human well-being) to overcome the pigeonholing of ecosystem services as an approach that requires monetization; this would require combined efforts of ecologists, economists, and stakeholders.



Political and institutional contexts need to be considered when implementing and designing an integrated adaptive management-ecosystem services approach, including recognition of the political constraints, financial and talent capacity constraints, information or incentives to get approaches implemented, cultural context and values, hurdles of administrative law, and relevant governance structure. The choices of framing, scale, and context determine capacity needs, and it may be necessary to adjust scale on the basis of capacity. Applying an integrated adaptive management-ecosystem services approach places a premium on being able to explain its importance simply and on the approach making the process easier or providing substantial net benefits.

Adaptive management and ecosystem services are evolving areas of both knowledge and application. This, in itself, makes their integration challenging. For example, methods for measuring and valuing ecosystem services lack accepted guidance and application. Integration with adaptive management thus requires both learning about the integration and reaching into the frontiers of ecosystem service analysis and evaluation. Nonetheless, adaptive management is a response to uncertainty that seeks to improve management outcomes through learning. Thus, the uncertainty and dynamism in managing ecological processes and their societal dimensions suggests an important role for adaptive management. Greater interaction among expertise, methods, models, and data would benefit both communities of practice.

Application of an ecosystem service lens implies an expansion of the objectives, and such an expansion has implications for which stakeholders to engage, the choice of management actions, the models that are developed, and what should be monitored. However, a potentially useful approach for expanding the integration of adaptive management and ecosystem services may be to look to examples where successful adaptive management is underway or is beginning and to apply an ecosystem service lens in those contexts, either in the initial deliberative phase or in the context of double-loop learning when objectives and models are being revisited.

Alternatively, an adaptive management approach could be brought formally into a context where ecosystem services already are being managed explicitly. A key example might be application of spatial-temporal learning in the context of The Nature Conservancy's Water Fund projects or in payment for ecosystem service programs.

Development of a boundary organization that brings together expertise in both ecosystem services management and adaptive management may be a fruitful means for providing capacity and guidance for forging this integration on the ground.

Indeed, although this report explores the benefits and challenges of integrating adaptive management and ecosystem services approaches to natural resource management, in addition to examining how they conceptually link together, further research is needed to move implementation forward. In particular, research is needed on how to reduce costs of implementation and to better understand how the benefits of integration relate to costs. In addition, we need to better understand the management contexts for which the benefits of this type of integration are most likely to outweigh the capacity, time, and resource costs.

Furthering this integrative approach depends on continued interaction and collaboration between researchers and practitioners. Application of the approach is needed to further develop conceptual understanding, and we hope that the conceptual framework explored here will help to move the integration forward in practice and research. The feedback between concept and application is integral to the development of a usable framework and for enhancing adoption of this approach.



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Conclusion

In summary, careful and deliberate integration of adaptive management and ecosystem services approaches has the potential to substantially improve management outcomes in a variety of contexts. Workshop discussion identified substantial costs and obstacles that need to be addressed to facilitate this integration. Indeed, fully applying the conceptual approach laid out (fig. 3) is not practically feasible, but the conceptual approach highlights ways for reorienting management to better incorporate both ecosystem service concepts and adaptive decision processes and provides a conceptual foundation for moving the integration forward. Jointly pursuing concept development and application would further this integration: continued conceptual development of the framework would help to inform application, and application in practice is needed to push and refine the framework. This report is the first to explore the explicit integration of ecosystem services and adaptive management, and it is intended as the start of a long but valuable process of learning and application development.

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Appendix 1. List of Workshop Participants

Workshop 1. Integrating Ecosystem Services and Adaptive Management— Developing a Framework, Resources for the Future, Washington, D.C., June 14–15, 2012

Facilitator: Steven Courtney, *Director of Science, RESOLVE*

Bernard Bormann, *Research Forest Ecologist, U.S. Department of Agriculture (USDA) Forest Service, Pacific Northwest Research Station, and Professor of Forest Ecology, College of Forestry, Oregon State University*

Jim Boyd, *Senior Fellow and Director, Center for the Management of Ecological Wealth, Resources for the Future*

David Cleaves, *Climate Change Advisor to the Chief, USDA Forest Service*

Robert Costanza, *Professor and Director, Institute for Sustainable Solutions, Portland State University*

Rebecca Epanchin-Niell, *Fellow, Resources for the Future*

Anne Guerry, *Lead Scientist, Natural Capital Project*

Lance H. Gunderson, *Professor of Environmental Studies, Department of Environmental Studies, Emory University*

Kai Lee, *Program Officer, Conservation & Science, The David and Lucile Packard Foundation*

James D. Nichols, *Senior Scientist, U.S. Geological Survey (USGS)*

Bryan G. Norton, *Professor of Philosophy, Science and Technology, Georgia Institute of Technology*

Paul A. Sandifer, *Senior Science Advisor, National Oceanic and Atmospheric Administration*

Lynn Scarlett, *Visiting Scholar and Codirector, Center for the Management of Ecological Wealth, Resources for the Future*

Carl Shapiro, *Codirector, Science and Decisions Center, and Senior Economist, Energy, Minerals, and Environmental Health, USGS*

Beatrice Van Horne, *Program Manager, Ecological Process and Function, U.S. Forest Service, Pacific Northwest Research Station*

Byron Kenneth Williams, *Codirector, Science and Decisions Center, and Chief, Cooperative Research Units, USGS*

Workshop 2. Integrating Ecosystem Services and Adaptive Management—Case Study Evaluation, Resources for the Future, Washington D.C., April 25–26, 2013

Facilitator: Olivia Barton Ferriter, Deputy Director, Office of Policy Analysis, U.S. Department of the Interior

Jim Boyd, *Senior Fellow and Codirector, Center for the Management of Ecological Wealth, Resources for the Future*

Charles Curtin, *Core Faculty, Antioch College*

Michael Dwyer, *Project Manager, U.S. Department of Interior, Bureau of Land Management*

Rebecca Epanchin-Niell, *Fellow, Resources for the Future*

Dianna Hogan, *Research Physical Scientists, U.S. Geological Survey (USGS)*

Dale Humburg, *Chief Scientist, Ducks Unlimited*

Kai Lee, *Program Officer, Conservation & Science, The David and Lucile Packard Foundation*

Molly Macauley, *Vice President for Research and Senior Fellow, Resources for the Future*

James D. Nichols, *Senior Scientist, USGS*

Stephen Polasky, *Fesler-Lampert Chair in Ecological/Environmental Economics, University of Minnesota*

Lynn Scarlett, *Visiting Scholar and Codirector, Center for the Management of Ecological Wealth, Resources for the Future*

Carl Shapiro, *Director, Science and Decisions Center, and Senior Economist, Energy, Minerals, and Environmental Health, USGS*

Jeremy Sokulsky, *Chief Executive Officer, Environmental Incentives*

Gordon Toevs, *National Program Lead, Bureau of Land Management, Assessment, Inventory, and Monitoring program (AIM)*

Byron Kenneth Williams, *Executive Director, The Wildlife Society*

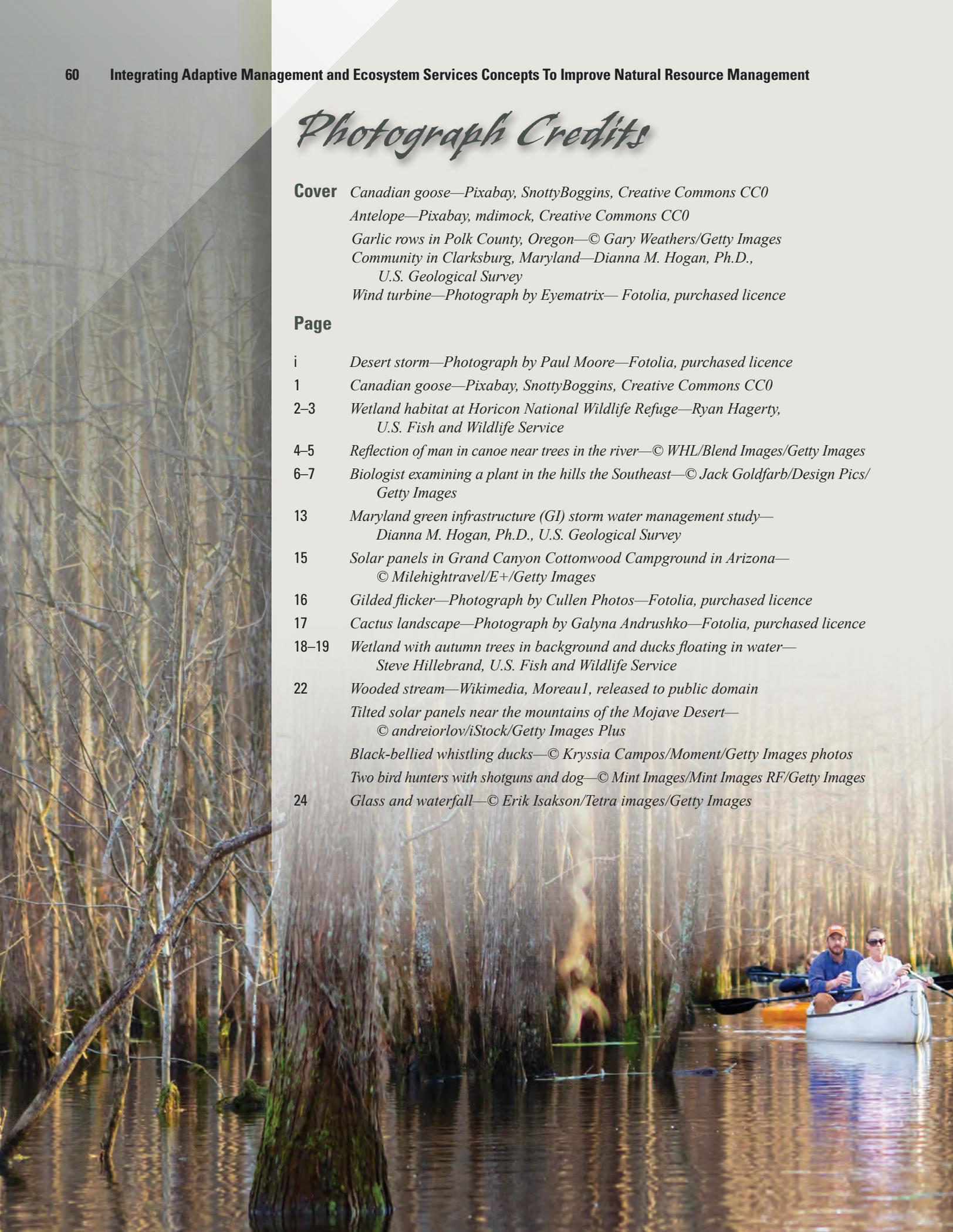
Robert Winthrop, *Senior Social Scientist, Department of the Interior's Bureau of Land Management*

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18–19 Wetland with autumn trees in background and ducks floating in water—
Steve Hillebrand, U.S. Fish and Wildlife Service
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Tilted solar panels near the mountains of the Mojave Desert—
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- 62–63 *River—Photograph by B Jefferson Bolender—Flickr, Creative Commons, Share Alike, 2.0*

Figure 2

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Prepared by the USGS Science Publishing Network,
Reston, Pembroke, and Denver Publishing Service Centers
Editing by Jonas Casey-Williams
Design and layout by Carol Quesenberry
Web support by Angela E. Timms and Mari Kauffmann
Printing support by Cathy Y. Knutson



