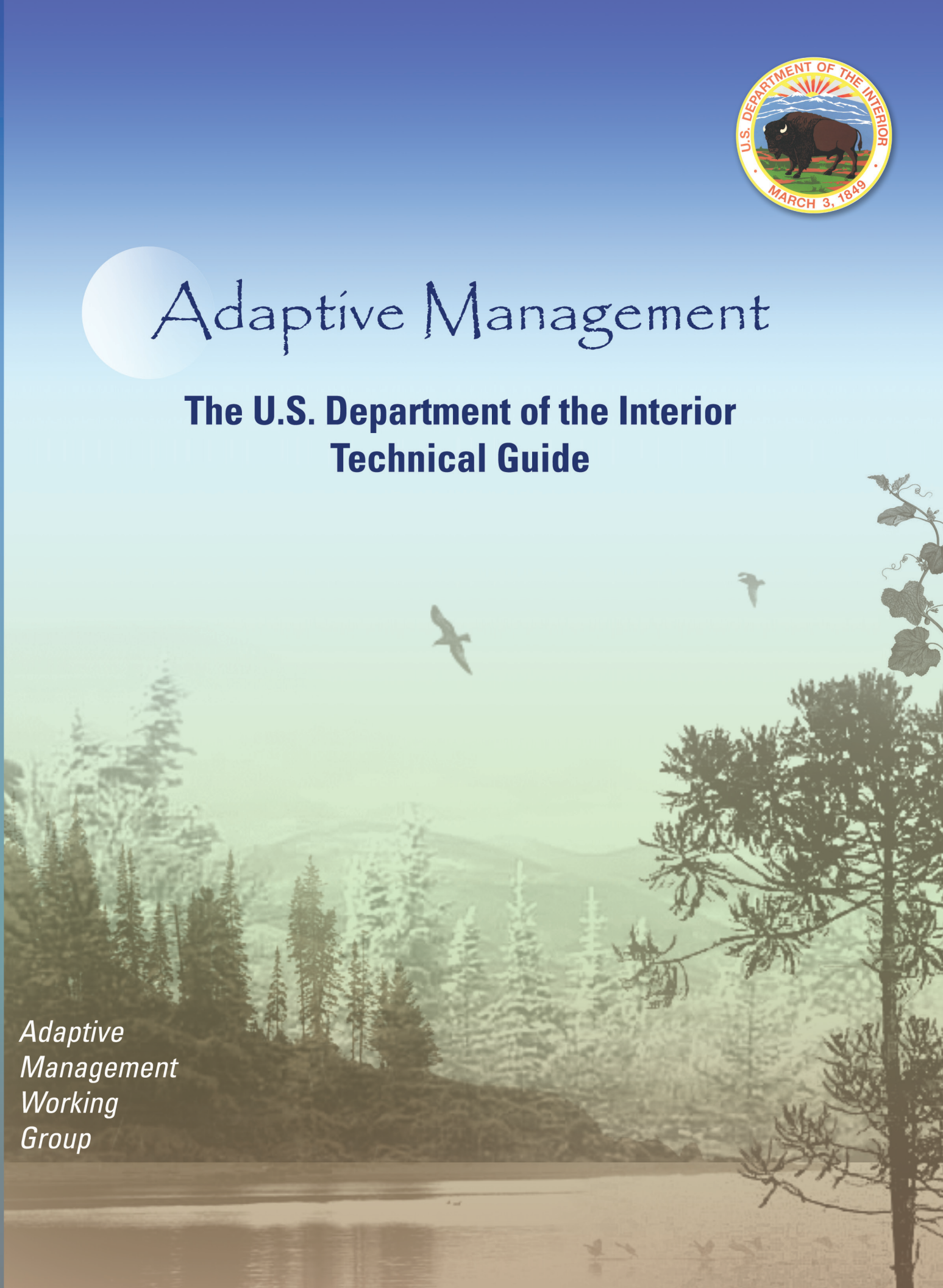

Adaptive Management

The U.S. Department of the Interior Technical Guide

Adaptive Management Working Group

Adaptive Management

The U.S. Department of the Interior Technical Guide

Adaptive Management Working Group
Chair: Olivia Barton Ferriter
Director, Conservation, Partnerships & Management Policy

Lead Authors
Byron K. Williams, Robert C. Szaro, and Carl D. Shapiro

Other Contributors
Robert Adamcik, Mary Boatman, Sarah Bransom,
Jeremy Casterson, John Fay, Scott Florence,
Douglas Growitz, Caroline Hermans, Fred A. Johnson, James Kendall,
Dennis Kubly, Michael Mayer, Susan Moyer, Malka Pattison,
Randall Peterson, Laura van Riper, Michael Runge, Robert Snow,
Christine Turner, and Rich Whitley

Book Design
Vitmary Rodriguez

U.S. Department of the Interior

For more information on the Technical Guide, please visit:
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Preface

The Department of the Interior (DOI) Adaptive Management Working Group (AMWG) sponsored the development of this technical guide to clearly and consistently define adaptive management and describe conditions for its implementation. AMWG membership includes representatives from across DOI's bureaus and offices.

A writing team of resource managers, technical experts, and other specialists worked with AMWG to address four basic questions concerning adaptive management: (1) What is adaptive management? (2) When should it be used? (3) How should it be implemented? (4) How can its success be recognized and measured? These questions were used to organize both the writing effort and the structure of the guide itself, with individual chapters addressing each of the questions.

The authors sought to describe adaptive management at an appropriate level of technical detail, while remaining focused on its definition, operational components, and conditions in which it applies. A key challenge was to provide sufficient detail for clarification, while limiting the length and complexity of the document.

The authors gratefully acknowledge the efforts by the many people who participated in developing this guide, including Maryanne Bach, Donna Brewer, Tara Conrad, John Dennis, Mike Ferguson, Larry Finfer, Gary Fraser, Ken Havran, Jacob Hoogland, Rick Lemon, Kim Magraw, Chris Pease, Steve Tyson, Ben Tuggle, John Vitello, Suzanne Weedman, and Tom Weimer. The authors also thank the people who provided valuable comments as reviewers, including Charles Baxter, Robert Fisher, Scott Florence, Clint Moore, Roger Sayre, and Brent Uilenberg.

Contents

Problem-Scoping Key for Adaptive Management

The following key can help in dissecting a particular management problem and determining whether adaptive management is an appropriate approach to decision making. If the answer to any question in the key is negative, then an approach other than adaptive management is likely to be more appropriate.

1. Is some kind of management decision to be made?
   (see Sections 1.1, 2.1, 2.3, 3.1, and 5.5)
   No – decision analysis and monitoring are unnecessary when no decision options exist.
   Yes – go to step 2.

2. Can stakeholders be engaged?
   (see Sections 1.1, 1.2, 2.1, 3.1, and 4.2)
   No – without active stakeholder involvement an adaptive management process is unlikely to be effective.
   Yes – go to step 3.

3. Can management objective(s) be stated explicitly?
   (see Sections 1.2, 2.1, 2.2, 2.3, 3.1, 4.2 and 5.1)
   No – adaptive management is not possible if objectives are not identified.
   Yes – go to step 4.

4. Is decision making confounded by uncertainty about potential management impacts?
   (see Sections 1.1, 1.2, 2.1, 3.1, 4.1, 4.2 and 5.2)
   No – in the absence of uncertainty adaptive management is not needed.
   Yes – go to step 5.

5. Can resource relationships and management impacts be represented in models?
   (see Sections 1.2, 3.1, 4.2, and 5.1)
   No – adaptive management cannot proceed without the predictions generated by models.
   Yes – go to step 6.

6. Can monitoring be designed to inform decision making?
   (see Sections 2.1, 2.3, 3.1, and 4.2)
   No – in the absence of targeted monitoring it is not possible to reduce uncertainty and improve management.
   Yes – go to step 7.

7. Can progress be measured in achieving management objectives?
   (see Sections 1.1, 3.1, 4.1, and 4.2)
   No – adaptive management is not feasible if progress in understanding and improving management is unrecognizable.
   Yes – go to step 8.

8. Can management actions be adjusted in response to what has been learned?
   (see Sections 1.2, 2.1, 3.1, 4.1, 4.2, 5.3, and 5.4)
   No – adaptive management is not possible without the flexibility to adjust management strategies.
   Yes – go to step 9.

9. Does the whole process fit within the appropriate legal framework?
   (see Sections 2.3, 2.4, 3.2, 4.1, and 4.2)
   No – adaptive management should not proceed absent full compliance with the relevant laws, regulations, and authorities.
   Yes – all of the basic conditions are met, and adaptive management is appropriate for this problem.

Executive Summary

The purpose of this technical guide is to present an operational definition of adaptive management, identify the conditions in which adaptive management should be considered, and describe the process of using adaptive management for managing natural resources. The guide is not an exhaustive discussion of adaptive management, nor does it include detailed specifications for individual projects. However, it should aid U.S. Department of the Interior (DOI) managers and practitioners in determining when and how to apply adaptive management.

Adaptive management is framed within the context of structured decision making, with an emphasis on uncertainty about resource responses to management actions and the value of reducing that uncertainty to improve management. Though learning plays a key role in adaptive management, it is seen here as a means to an end, namely good management, and not an end in itself. The operational definition used in the guide is adopted from the National Research Council, which characterizes adaptive management as an iterative learning process producing improved understanding and improved management over time:

> Adaptive management [is a decision process that] promotes flexible decision making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood. Careful monitoring of these outcomes both advances scientific understanding and helps adjust policies or operations as part of an iterative learning process. Adaptive management also recognizes the importance of natural variability in contributing to ecological resilience and productivity. It is not a 'trial and error' process, but rather emphasizes learning while doing. Adaptive management does not represent an end in itself, but rather a means to more effective decisions and enhanced benefits. Its true measure is in how well it helps meet environmental, social, and economic goals, increases scientific knowledge, and reduces tensions among stakeholders.

Adaptive management as defined here involves ongoing, real-time learning and knowledge creation, both in a substantive sense and in terms of the adaptive process itself. It is described in what follows in a series of 9 steps, as summarized in section 4.1, involving stakeholder involvement, management objectives, management alternatives, predictive models, monitoring plans, decision making, monitoring responses to management, assessment, and adjustment to management actions. An adaptive approach actively engages stakeholders in all phases of a project over its timeframe, facilitating mutual learning and reinforcing the commitment to learning-based management. Adaptive management in DOI is implemented within a legal context that includes statutory authorities such as the National Environmental Policy Act (NEPA), the Endangered Species Act, and the Federal Advisory Committee Act.

For many important problems now facing the resource management community, adaptive management holds great promise in reducing the uncertainties that limit the effective management of natural resource systems. For many conservation and management problems, utilizing management itself in an experimental context may be the only feasible way to gain the system understanding needed to improve management.

Though it is commonly thought that an adaptive approach can produce results quickly at low cost, the opposite is more likely to be true. An initial investment of time and effort will increase the likelihood of better decision making and resource stewardship in the future, but patience, flexibility, and support are needed over the life of an adaptive management project. For these reasons it is important to carefully consider the potential use of an adaptive approach, and to engage in careful planning and evaluation when adaptive management is used.

Chapter 1: What is Adaptive Management?

Adaptive management is a systematic approach for improving resource management by learning from management outcomes (1). Its origin can be traced back to ideas of scientific management pioneered by Frederick Taylor in the early 1900s (2,3). Various perspectives on adaptive management are rooted in parallel concepts found in business (total quality management and learning organizations [4]), experimental science (hypothesis testing [5]), systems theory (feedback control [6]), and industrial ecology (7). The concept has attracted attention as a means of linking learning with policy and implementation (8,9). Although the idea of learning from experience and modifying subsequent behavior in light of that experience has long been reported in the literature, the specific idea of adaptive management as a strategy for natural resource management can be traced to the seminal work of Holling (10), Walters (11), and Lee (12).

Adaptive management as described here is infrequently implemented, even though many resource planning documents call for it and numerous resource managers refer to it (13). It is thought by many that merely by monitoring activities and occasionally changing them, one is doing adaptive management. Contrary to this commonly held belief, adaptive management is much more than simply tracking and changing management direction in the face of failed policies, and, in fact, such a tactic could actually be maladaptive (14). An adaptive approach involves exploring alternative ways to meet management objectives, predicting the outcomes of alternatives based on the current state of knowledge, implementing one or more of these alternatives, monitoring to learn about the impacts of management actions, and then using the results to update knowledge and adjust management actions (15). Adaptive management focuses on learning and adapting, through partnerships of managers, scientists, and other stakeholders who learn together how to create and maintain sustainable resource systems (3).

The purpose of this technical guide is to present an operational definition of adaptive management, identify the conditions in which adaptive management should be considered, and describe the process of using adaptive management for managing natural resources. The guide is not an exhaustive discussion of adaptive management, nor does it include detailed specifications for individual projects. However, it should aid both U.S. Department of Interior (DOI) managers and practitioners in determining when and how to apply adaptive management.

Examples of decision making in natural resource management include the control of water releases from a dam, direct manipulation of plant or animal populations through harvesting, stocking, or transplanting, and manipulations of ecosystems through chemical or physical changes to habitats.

1.1. Decision Making and Natural Resource Management

A context for resource management involves a decision making environment characterized by multiple (often competing) management objectives, constrained management authorities and capabilities, dynamic ecological and physical systems, and uncertain responses to management actions. Management thus involves not only predicting how ecological or physical systems are likely to respond to interventions, but also identifying what management options are available, what outcomes are desired, how much risk can be tolerated, and how best to choose among a set of alternative actions. The challenge confronting managers is to make "good" decisions in this complex environment, recognizing that the quality of decision making in the face of uncertainty should be judged by the decision making process as well as progress towards desired outcomes.

A common problem in natural resources management involves a temporal sequence of decisions, in which the best action at each decision point depends on the state of the managed system. Because management actions at each point in time can influence change in the resource system from that time forward, the goal of management is to prescribe objective-driven strategies that account for both the current and future impacts of decisions. A key issue is how best to choose management actions, recognizing that the most appropriate management strategy is obscured by limited understanding.

Often the uncertainty about management impacts is expressed as disagreements among stakeholders who have differing views about the direction and magnitude of resource change in response to management. An adaptive approach explicitly articulates these viewpoints, incorporates them into the decision making process, and uses management itself to help identify the most appropriate view about resource dynamics. In this way, understanding of the resource can be enhanced over time, and management can be improved.

Examples of this kind of decision problem include the control of water releases from a dam, direct manipulation of plant or animal populations through harvesting, stocking, or transplanting, and manipulations of ecosystems through chemical or physical changes to habitats.

The following management issues exemplify sequential decision making in natural resources in the face of uncertainty:

- In a newly established meta-population of wolves, how many animals (if any) should be relocated periodically to maximize the probability that the meta-population will persist over the long term?
- What amount and timing of water release from a dam will maintain downstream water quality, water quantity, and living resources, including people and communities?
- How can an area be managed to minimize the impacts of recreational use on flora and fauna?
- When and how much should water levels be raised or lowered in an impoundment to maximize abundance and availability of invertebrates for foraging shorebirds?
- How can plant communities in an area be managed so as to protect and sustain archeological resources in the area at minimum cost?
- How much forest should be cut each year as part of a pine regeneration program to maximize old-growth pine for use by red-cockaded woodpeckers?
- How can fuel loads be decreased while minimizing effects on forested ecosystems?
- Should annual hunting-season regulations be restrictive or moderate to maximize the longterm cumulative harvest of mallards?
- How much and how often should herbicide be applied to minimize the proliferation of the invasive plant hydrilla in a group of southern lakes?
- In what order should patches of isolated bull trout habitat be reconnected in a network of tributaries to maximize the probability of population persistence while minimizing costs?
- When and where should prescribed burns be used in a collection of management units to maximize the probability that Florida scrub-jays will persist at a refuge over the long term?

Management of problems like these increasingly involves a systems approach with explicit and agreed-upon objectives, management alternatives, and analytical approaches that can identify the most appropriate management strategies. Adaptive management exemplifies such an approach; however, its focus is not only on making good decisions in the present, but also on gaining experience and knowledge so that future management decisions can be improved.

Adaptive management as an example of structured decision making

The move toward accountability and explicitness in natural resource management has led to a growing need for a more structured approach to decision making. Improved clarity about key elements in a decision making process can help decision makers focus attention on what, why, and how actions will be taken. Activities in a structured approach to decision making include the following:

- Engaging the relevant stakeholders in the decision making process
- Identifying the problem to be addressed
- Specifying objectives and tradeoffs that capture the values of stakeholders
- Identifying the range of decision alternatives from which actions are to be selected
- Specifying assumptions about resource structures and functions
- Projecting the consequences of alternative actions
- Identifying key uncertainties
- Measuring risk tolerance for potential consequences of decisions
- Accounting for future impacts of present decisions
- Accounting for legal guidelines and constraints

In the ensuing chapters it will be clear that adaptive management is itself a structured approach to decision making, in that it includes the key elements listed above. The distinguishing features of adaptive management are its emphasis on sequential decision making in the face of uncertainty and the opportunity for improved management as learning about system processes accumulates over time.

Embracing uncertainty

Making a sequence of good management decisions is more difficult in the presence of uncertainty, an inherent and pervasive feature of managing ecological systems (16,17). Uncertainties arise with incomplete control of management actions, errors in measurement and sampling variation, environmental variability, and an incomplete understanding of system dynamics (see Section 5.2). These uncertainties potentially degrade management performance and contribute to acrimony in the decision making process.

Perhaps not surprisingly, managers have sometimes been reluctant to acknowledge uncertainty in environmental assessments and management strategies (18). Often there is a perception that asserting certainty as to management impacts is more convincing, and acknowledging uncertainty increases the likelihood that recommended actions will be ignored. Acknowledgement of uncertain management outcomes is sometimes seen as an invitation for confrontation among different interest groups, resulting in an inability to reach timely agreement on a proposed action.

Adaptive management forces stakeholders to confront unresolved uncertainties that can significantly influence management performance. An adaptive approach provides a framework for making good decisions in the face of critical uncertainties, and a formal process for reducing uncertainties so that management performance can be improved over time.

1.1 Key Points

- Resource management involves decision making in an environment of multiple management objectives, constrained management authorities and capabilities, dynamic resource systems, and uncertain responses to management actions.
- Resource management increasingly involves the articulation of objectives and management options and the use of analytical techniques to identify optimal management strategies.
- Adaptive management is a structured approach to decision making that emphasizes accountability and explicitness in decision making.
- Adaptive management is useful when there is substantial uncertainty regarding the most appropriate strategy for managing natural resources.

1.2. Operational Definition of Adaptive Management

For the U.S. Department of the Interior to effectively implement adaptive management in a consistent and coherent manner across all bureaus, an operational definition is needed that will be applicable for all of DOI. The definition used in this technical guide is adopted from the National Research Council (19):

> Adaptive management [is a decision process that] promotes flexible decision making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood. Careful monitoring of these outcomes both advances scientific understanding and helps adjust policies or operations as part of an iterative learning process. Adaptive management also recognizes the importance of natural var ability in contributing to ecological resilience and productivity. It is not a 'trial and error' process, but rather emphasizes learning while doing. Adaptive management does not represent an end in itself, but rather a means to more effective decisions and enhanced benefits. Its true measure is in how well it helps meet environmental, social, and economic goals, increases scientific knowledge, and reduces tensions among stakeholders.

This definition gives special emphasis to uncertainty about management impacts, iterative learning to reduce uncertainty, and improved management as a result of learning. Key points in the definition are discussed in more detail below:

Adaptive management openly acknowledges uncertainty about how ecological systems function and how they respond to management actions (20,21). However, adaptive management is not a random trial-and-error process. Instead, it involves formulating the resource problem, developing conceptual models based on specific assumptions about the structure and function of the resource system, and identifying actions that might be used to resolve the problem. Through the monitoring of outcomes following management interventions, adaptive management promotes improved understanding about which actions work, and why.

Adaptive management is designed to improve understanding of how a system works, so as to achieve management objectives (20,21). Models are used in adaptive management to embed hypotheses about system behaviors and enable managers to predict the impacts of their activities. These predictions are the basis for learning later on. Once activities are implemented, the testing of underlying model assumptions against monitoring data provides the foundation for learning and the improvement of management based on what is learned.

Adaptive management is about taking action pursuant to desired outcomes (21). In adaptive management, the outcomes of decisions, assessed through followup monitoring, are compared against explicit predictions of those outcomes (20), with the comparative results fed back into decision making to produce more effective decision making (11,22,23,24). Actual and expected results can differ for many reasons: underlying assumptions are wrong, actions are poorly executed, environmental conditions have changed, monitoring is inadequate, or some combination of these problems. An adaptive approach helps isolate inadequacies in a management application, allowing adjustments to be made and management to be improved.

Adaptive management requires the participation of stakeholders. Stakeholders include people and organizations who use, influence, and have an interest, or "stake," in a given resource (25). Stakeholders should be involved early in the adaptive management cycle, to help assess the problem and design activities to solve it. Stakeholders also can help to implement and monitor those activities, and participate in the evaluation of results. Involvement

of stakeholders from the beginning increases management effectiveness and the likelihood of achieving agreed-upon outcomes (25).

There are many definitions in the literature on adaptive management, but a common theme shared by them all is that adaptive management is a learning-based process (26). The definition used in this guide was chosen because it emphasizes the use of learning to improve management decisions and because it is germane to resource management in DOI.The sequence of activities shown in Fig. 1.1 is often used to characterize adaptive management. Additional structure can be incorporated into this sequence, by recognizing an embedded feedback loop of monitoring, evaluation, and management adjustments that focuses specifically on learning about the impacts of management. Multiple iterations of this loop may occur within each iteration of the overall cycle, accelerating learning about ecological process within the more comprehensive cycle that includes learning about the adaptive process itself (through periodic problem reassessment, design, and implementation). Learning at both levels is discussed in more detail in Section 3.1.

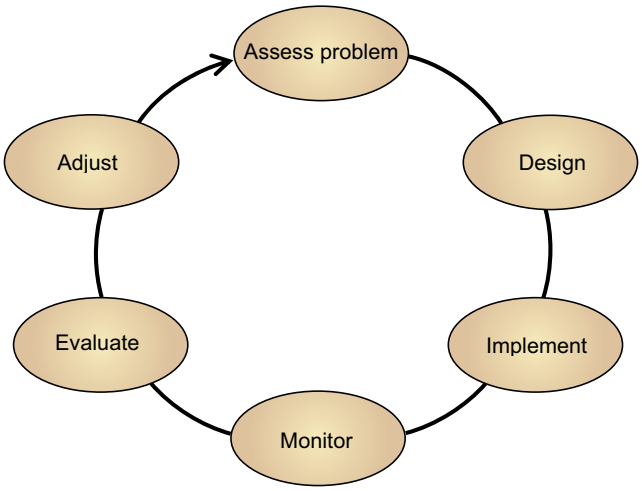


Figure 1.1. Diagram of the adaptive management process.

Other approaches to resource management

Learning from the experience of management is certainly not a new idea, but the purposeful and systematic pursuit of knowledge as an explicit part of management has rarely been practiced. The term "adaptive management" has been used to describe a broad array of approaches that involve learning while doing, but the phrase is not always appropriate. For example, management by trial and error is sometimes described as adaptive management, but at best it is likely to be inefficient, and at worst it can retard the institutionalization of experience and learning. Nor should adaptive management be confused with conflict resolution, which focuses on negotiating tradeoffs among competing interests. Management approaches that primarily depend on expert opinion and advice for decision making are not by themselves adaptive. Finally, in the absence of additional structure in a decision making process, monitoring a managed resource system does not itself make an application adaptive. A great many resource systems are monitored in some manner, but in most cases the resulting data are not used systematically for learning and improvement in a context of objective-driven management.

More formal approaches to decision making can be identified, depending on the amount of uncertainty facing managers and the capacity to influence the system being managed (Fig. 1.2). In an ideal situation in which system controllability is high and management impacts are predictable, formal optimal control approaches can be used to identify optimal management strategies. If one's ability to control the system is limited, hedging strategies or scenario planning can be useful, depending on how well the effects of management can be predicted. As indicated in Fig. 1.2, adaptive management is appropriate if management can strongly influence the system but uncertainty about management impacts is high (27).

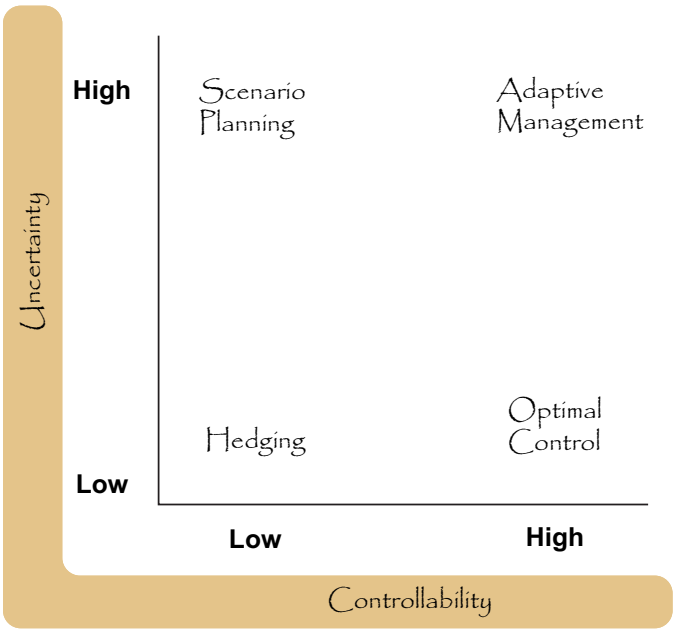


Figure 1.2. Approaches to decision making in a natural resource system. The appropriate approach depends on the influence decisions can have on system behavior and the amount of uncertainty about management impacts (27).

Adaptive management requires stated management objectives to guide decisions about what to try, and explicit assumptions about expected outcomes to compare against actual outcomes. It is important to know what the available management options and alternative assumptions are, in case the action that is tried does not work as expected. The linkages among management objectives, learning about the system, and adjusting direction based on what is learned distinguish adaptive management from a simple trial and error process. In the chapters that follow, we describe adaptive management formally in terms of objectives, management options, and models that embed alternative hypotheses about management responses. But in essence, adaptive management will be seen to be learning by doing, and adapting based on what is learned (28). A comparison of adaptive management with some other approaches to natural resource management is presented in Section 5.1.

1.2 Key Points

- Adaptive management acknowledges uncertainty about how natural resource systems function and how they respond to management actions.
- Adaptive management is designed to improve understanding of how a resource system works, so as to achieve management objectives.
- Adaptive management makes use of management interventions and followup monitoring to promote understanding and improve subsequent decision making.

Adaptive management requires stated management objectives to guide decisions about what actions to take, and explicit assumptions about expected outcomes to compare against actual outcomes.

Chapter 2: When Should Adaptive Management be Used?

In this chapter we describe the conditions under which adaptive management is applicable, and highlight some challenges, limitations, and benefits of an adaptive approach to resource management.

2.1. Conditions that Warrant an Adaptive Management Approach

Not all decisions can or should be adaptive. In some cases there is no opportunity to apply learning; in others, there is little uncertainty about what action to choose; and in still others, there is disagreement about objectives. But the concept of adaptive management is so intuitively appealing that the phrase has been applied indiscriminately, with the result that many management applications fail to achieve the improvements expected from adaptive management. In many instances, that failure may have less to do with the approach itself than with the inappropriate contexts within which it is purported to apply (29). An important question is which decision problems are appropriate for the application of adaptive management.

There is a considerable literature that explores reasons why the practice of adaptive management has not lived up to its promise, and extensive documentation of some of the more prominent failures. But only recently has attention focused proactively on those attributes of resource management that make a problem amenable to adaptive management. The following discussion draws from published sources as well as the experiences of management agencies within the Department of the Interior.

There are two key conditions that are mentioned in all thoughtful analyses. First, "there must be a mandate to take action in the face of uncertainty" (12,24). That is, the problem must be important enough to require action of one sort or another. Situations without this imperative can result in either delayed action as more information is acquired or action foregone altogether. Second, there must be the institutional capacity and commitment to undertake and sustain an adaptive program. This condition includes an institutional stability for long-term measurement and evaluation of outcomes, which should allow the early investment in an adaptive approach to pay off in long-term management. Together, these two conditions imply that decision makers must be motivated and patient, that is, they must care about improving management over extended time frames (12).

In addition to these two overarching conditions, six more conditions can be identified directly from the meaning and context of adaptive management, as described in the previous chapter. Adaptive management is warranted when there are consequential decisions to be made, when there is an opportunity to apply learning, when the objectives of management are clear, when the value of reducing uncertainty is high, when uncertainty can be expressed as a set of competing, testable models, and when a monitoring system can be put in place with a reasonable expectation of reducing uncertainty.

A real management choice is to be made

As described in Chapter 1, adaptive management is first and foremost an approach to the management of natural resources and not simply an opportunity to learn. Thus, an application of adaptive management must involve a real choice among management alternatives that affect resource systems. The variability among alternatives must be consequential (i.e., different alternatives produce substantively different management impacts), and the alternatives must be ecologically, economically, politically, and legally feasible.

The genesis of alternatives should be multidisciplinary and participatory. They can arise from within the management agency, from scientists or engineers working for, with, or in opposition to the management agency, from the regulated community, or from other stakeholders. Some decisions are particularly difficult because a suitable range of alternatives cannot be easily identified. In such cases, a collaborative approach in identifying alternative actions is especially useful.

Because natural resource systems operate at multiple spatial and temporal scales and involve interactions among many component systems, the development of alternative actions should account for multiscale responses. One consequence of this complexity is that several pathways may exist to achieve similar outcomes, with alternative pathways differing enough in some relevant aspects (feasibility, cost, public acceptance) to be considered as bona fide alternatives.

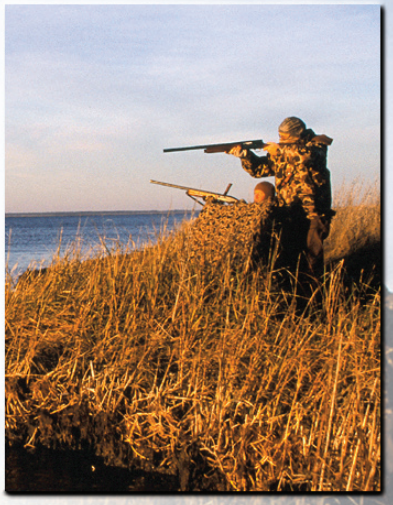
The alternatives considered in adaptive management are constrained by existing laws, regulations, and policies, both substantive and procedural. A number of substantive laws govern natural resource decision making (for example, Clean Water Act, Clean Air Act, Endangered Species Act, etc.). Of the procedural laws, the National Environmental Policy Act (NEPA) and its implementing regulations provide considerable guidance about developing and considering alternative management actions. An emerging view discussed in Section 3.2 sees the NEPA process as a powerful and potentially effective way to embody adaptive management (30).

There is an opportunity to apply learning

A condition of adaptive management is that resource management decisions can be revisited and modified over time or that multiple decisions of a similar nature can be made over time. That is, decision making needs to be iterative over time and possibly space; otherwise, learning cannot be applied. Many examples of adaptive management treat a single management unit (for example, a single river or a continental population of ducks) over time, applying the learning derived from earlier actions to decisions made at later times. But equally appropriate are situations where similar management units are each treated only once, and the learning accrued from treatments of some units is used in decisions about how to treat other units at a later time (31).

Besides iterative decision making, several other considerations affect the opportunity to apply learning. First, perhaps obviously, the adaptation of actions must be possible. That is, there must be flexibility in the decision making process to adjust management actions in response to measured outcomes (32). This requires both flexibility in the actions themselves as well as flexibility within the management institutions to adopt the change. Second, management institutions must have the stability to measure outcomes and use the results at later times. Adaptive management sometimes has failed because institutions managing the process dissolved before the learning could be applied (33). Third, it must be possible to acquire understanding quickly enough to apply it to subsequent management decisions. Some ecological processes respond very slowly to management (for example, forest systems). If learning can occur only after observing slow response variables, many iterations of decision making may have passed before the new knowledge can be applied.

Ideally the response to previous management actions can be assessed before a decision about the next management action is made. For example, the response of waterfowl populations to hunting regulations in one year can be assessed in time to inform the setting of hunting regulations in the following year (34). On the other hand,



Ideally the response to previous management actions can be assessed before a decision about the next management action is made. For example, the response of waterfowl populations to hunting regulations in one year can be assessed in time to inform the setting of hunting regulations in the following year.

applications of adaptive management in forestry can be limited by the fact that the relevant response variables may not be measurable until decades after a management action is taken (35).

Clear and measurable management objectives can be identified

An adaptive approach requires explicit and measurable objectives. As described in the next three conditions, uncertainty about how to achieve objectives is what motivates adaptive management and drives the design of the monitoring system. To address this uncertainty stakeholders must agree on the objectives. Although an adaptive management framework can serve to structure dialogue among stakeholders, adaptive management itself is not designed to resolve conflicts about management objectives. If the objectives are not clear and measurable, the adaptive framework is undermined.

Objectives need to be measurable for two purposes: first, so progress toward their achievement can be assessed; second, so performance that deviates from objectives may trigger a change in management direction. Explicit articulation of measurable objectives helps to separate adaptive management from trial and error, because the exploration of management options over time is directed and justified by the use of objectives.

Objectives must be relevant to the project or program to which they apply. An example of a project objective might be to increase biodiversity of amphibians by 25 percent in a local watershed. An example of a program objective is that used by the U.S. Fish and Wildlife Service for adaptive harvest management, namely the maximum long-term harvest of waterfowl consistent with population goals in the North American Waterfowl Management Plan (36, 37). In both cases, the objectives are measurable, relevant to the management problem, and useful for decision making, evaluation, and learning. The nature and use of objectives are discussed in more detail in Section 3.1.

The value of information for decision making is high

The fundamental motivation for adaptive management is that the impact of management actions on resources is uncertain, and the reduction of that uncertainty will accelerate progress in meeting management objectives over time (34). Although uncertainty can be identified in almost any resource management problem, its reduction does not automatically lead to better decision making. An adaptive management application should target learning that will change management actions and improve the ability to achieve management objectives.

The "value of information" refers to how much better the expected performance of a managed system would be if uncertainty were reduced. A high value of information means that the decision maker will potentially choose different alternatives if the system is better understood. With improved understanding comes better decisions, so that success in achieving objectives becomes more likely. The prospect of substantially improved decision making justifies the cost of monitoring and assessment (24) in adaptive management. Conversely, an adaptive approach is not warranted if the value of information is low, essentially because the potential improvement in management does not justify its costs. Sometimes the tradeoffs between costs and benefits can be made explicitly, particularly in applications in which an economic value can be ascribed to learning.

Provided careful thinking, analysis, and modeling are undertaken prior to implementation, one of the advantages of an adaptive approach is that surprises can be anticipated (29). Preparing for the unexpected means fully acknowledging uncertainty, articulating the ways in which assumptions might be wrong, exploring the consequences to management of uncertainty, and having the appropriate monitoring in place to recognize and benefit from unexpected outcomes.

Uncertainty can be expressed as a set of testable models

A formal approach to adaptive management uses the tools of structured decision analysis to inform and analyze the problem. A key step is to predict the effects of management actions that are relevant to the objectives. But predictions require models, whether conceptual or quantitative. Adaptive management utilizes multiple models, each imbedding a particular hypothesis about how the natural resource system responds to management. These models are tested with monitoring data to determine which model best represents system responses. In this way the hypotheses underlying management decisions can be expressed and tested.

Models are critical in an adaptive management process, if only as a means to encourage managers, scientists, and other stakeholders to think carefully about the structure and dynamics of the systems they are managing. When there is contention among stakeholders about how the system will respond to management, modeling forces stakeholders to express these differences as alternative hypotheses, which then can be tested. The models embodying the hypotheses in question also can be used to identify critical monitoring variables to use for comparing hypotheses, and they provide a framework for interpreting monitoring results and evaluating alternative actions to best achieve management objectives.

Models can be qualitative and conceptual, quantitative and highly detailed, or anywhere in between. In all cases, their function in an adaptive management context is to make predictions about how a natural system will respond to management actions and to evaluate the consequences of uncertainty. A common complaint used to justify not undertaking an adaptive program is that the data are sparse and there is too much uncertainty to build models. But this is precisely where adaptive management is most valuable—in expressing and reducing uncertainty. The alternative to building models of system dynamics is to allow the assumptions of decision makers and stakeholders—essentially, the models that exist in the minds of a few individuals—to remain unexpressed and untested.

A monitoring system can be established to reduce uncertainty

Monitoring is fundamental for adaptive management, as a source of data with which to test alternative models and measure progress toward accomplishing management objectives. Simply put, adaptive management is not possible without effective monitoring (see Section 3.1 for a more detailed discussion of monitoring).

There are important details, however, that influence whether a monitoring system will help reduce uncertainty to any useful degree, and these should be considered when evaluating whether to undertake an adaptive program. For example, anticipated effects of alternative actions need to be substantial, because field monitoring can seldom detect subtle differences. Thus, management experiments must be dramatic enough to produce an observable response from the ecosystem, or they will not facilitate learning (32). It is useful here to recall that the statistical power to distinguish among hypotheses is influenced by sample size and the magnitude of treatment effects, and these factors apply as well to an adaptive monitoring system. Poor monitoring precision does more than simply slow the rate of learning; imprecise monitoring can produce misleading evidence that supports inappropriate management. Inaccurate or imprecise monitoring can actually be counterproductive to the goals of management (38).

Learning is accelerated when the principles of experimental design—replication, randomization, and control—are used. Attention to these principles, and their incorporation where possible, will lead to more rapid improvements in management. The amount of temporal and/or spatial replication is an especially important design feature because it determines the

necessary sampling intensity. All other things being equal, management actions that can be replicated many times at different locations will reduce uncertainty more quickly. Replication over time is also valuable (and more common), but typically the sample size is necessarily lower, and information accrues more slowly.

A realistic assessment of the potential for monitoring is a critical condition for adaptive management. This assessment should include not only the power of the monitoring system and the efficiency of its design, but also the institutional resources needed to sustain the monitoring (and analysis of the resulting data) over the time frame required to inform management.

2.2. Institutional Context for Adaptive Management

There are a number of factors associated with management problems that can encourage the use of adaptive management. These include not only certain characteristics of the management situation itself, but also the nature and commitments of implementing organizations.

Using pre-existing institutional structures

Certain characteristics of the record of management may help to determine whether adaptive management is appropriate for a particular situation. One is a history of decision making that indicates a willingness to address the risk of unintended and/or undesirable natural resource impacts. Others include previous stakeholder involvement in a collaborative group environment, cost sharing of collaborative efforts, and a demonstrated commitment to evaluation and scientific rigor. The existence of these characteristics prior to the creation of a formal program is a strong indication that adaptive management is potentially useful.

An example of designing around pre-existing conditions is the U.S. Fish and Wildlife Service adaptive harvest management (AHM) program, which was built upon a series of features that were already in place when it was first initiated. Thus, stakeholders were already involved in harvest management, well developed models were available, a decision making process was in place that involved federal, state, and public interests, and extensive, long-term monitoring programs were ongoing (39). AHM was designed from the outset to take advantage of these preadaptations, recognizing that considerable uncertainty still remained about the impacts of harvest regulations.

Commitment of executive leadership

Adaptive management involves an ongoing commitment of leadership and support. Soon after the initiation of an adaptive management project, executive leadership may anticipate a reduction or elimination of stakeholder conflict, a rapid reduction in the amount of scientific investigation that is needed, and early declines in funding needs. But adaptive management activities require management involvement and funding throughout the life of the project, not just at its inception.

From a financial perspective, long-term funding highlights the commitment of implementing organizations to adaptive decision making, and it promotes the planning and implementation of the monitoring and evaluation needed for adaptive management. Conversely, a lack of long-term support limits progress in reducing uncertainty.

The support required for an adaptive approach may include not only funding for monitoring and evaluation, but also an investment in more inclusive and robust decision making processes. It is essential that executive leadership be aware of uncertain outcomes and be prepared to make the necessary changes as adaptive management progresses through implementation.

Finally, executive leadership is needed to support an institutional culture and the organizational arrangements that will acknowledge uncertainty and promote learning. Adaptive management flourishes in a learning organization that encourages experimentation, rewards risk taking, and embraces the lessons learned from experimentation. To successfully employ an adaptive approach in management, a philosophical shift from “expert” to collaborative

learning will likely be necessary. Executive leadership must play a critical role in the transition to a learning organization and in sustaining it thereafter. These issues are discussed in more detail in section 5.4.

Consensus on management objectives

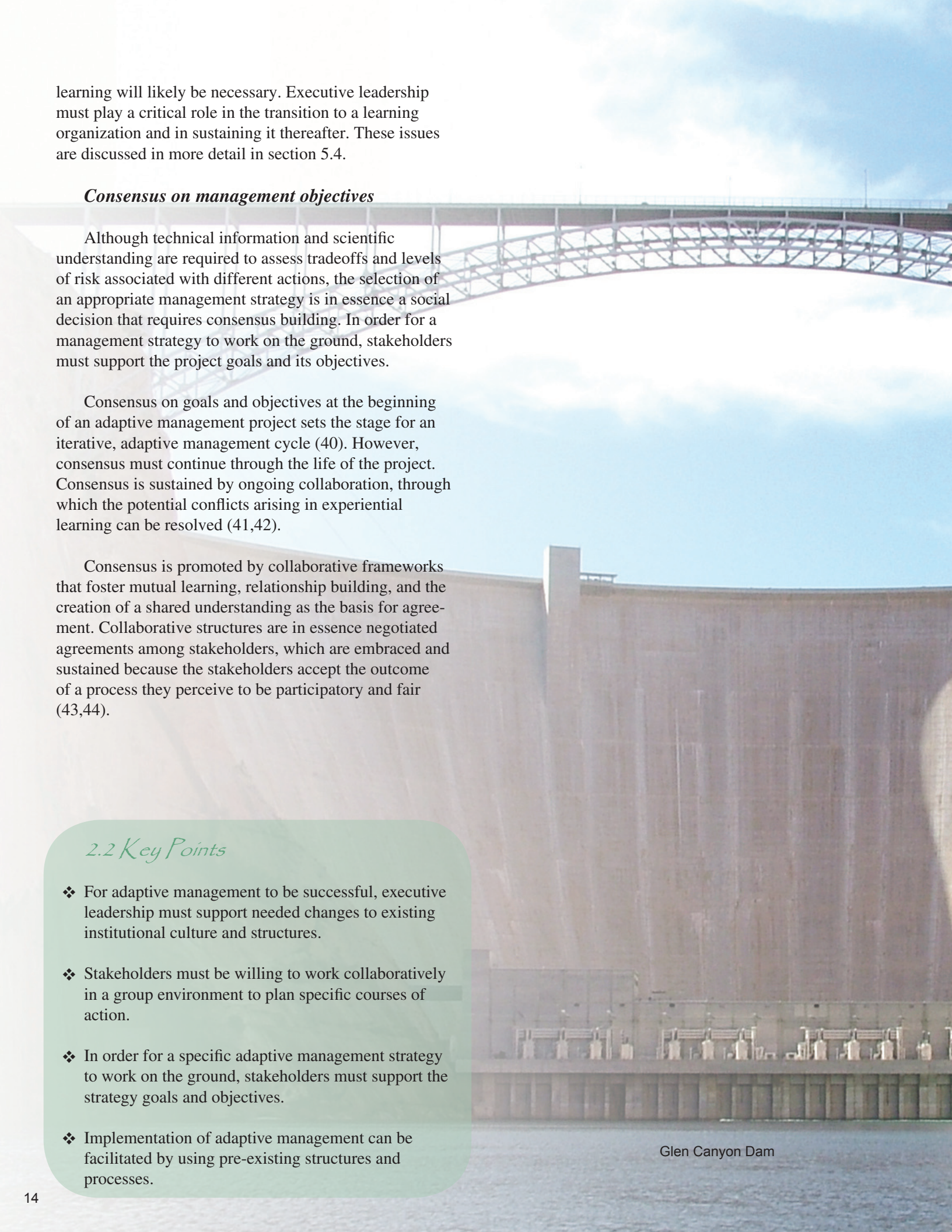
Although technical information and scientific understanding are required to assess tradeoffs and levels of risk associated with different actions, the selection of an appropriate management strategy is in essence a social decision that requires consensus building. In order for a management strategy to work on the ground, stakeholders must support the project goals and its objectives.

Consensus on goals and objectives at the beginning of an adaptive management project sets the stage for an iterative, adaptive management cycle (40). However, consensus must continue through the life of the project. Consensus is sustained by ongoing collaboration, through which the potential conflicts arising in experiential learning can be resolved (41,42).

Consensus is promoted by collaborative frameworks that foster mutual learning, relationship building, and the creation of a shared understanding as the basis for agreement. Collaborative structures are in essence negotiated agreements among stakeholders, which are embraced and sustained because the stakeholders accept the outcome of a process they perceive to be participatory and fair (43,44).

2.2 Key Points

- For adaptive management to be successful, executive leadership must support needed changes to existing institutional culture and structures.
- Stakeholders must be willing to work collaboratively in a group environment to plan specific courses of action.
- In order for a specific adaptive management strategy to work on the ground, stakeholders must support the strategy goals and objectives.
- Implementation of adaptive management can be facilitated by using pre-existing structures and processes.



Glen Canyon Dam

2.3. Limitations of Adaptive Management

Although adaptive management often can enhance an agency's ability to achieve resource objectives, there are situations where its application may not be appropriate. An agency considering the employment of adaptive management should ensure that its use is suitable for the particular situation. Adaptive management should not be employed if one or more of the following limitations apply.

Decision making occurs only once

If resource management decisions cannot be revisited and modified over time, then adaptive management cannot be meaningfully employed. Many decisions are essentially irreversible in that follow-up adaptation is either infeasible or impossible. An example is the removal of a dam on a large river where the decision can be made only once. Of course, such a decision may be part of a larger decision making program, for example the management of a watershed that includes many dams, where learning that follows from the removal of one dam informs subsequent decisions about other dams.

Monitoring cannot provide useful information for decision making

A suitable monitoring strategy is a key requirement for any adaptive management approach. Data collected from monitoring are used to test alternative models and measure progress toward management objectives. There are several situations in which an effective monitoring program cannot be established:

- The frequency of monitoring cannot keep pace with changes in the natural system. If monitoring is too infrequent or the system changes at too rapid a pace, monitoring data may be unrepresentative of the resource system by the time a decision is to be made.

- A design for experimental management and monitoring cannot be developed to test hypotheses. If understanding of the resource system is so limited (or management is so constrained) that designing a meaningful experiment becomes problematic, adaptive management may not be appropriate. This problem is most likely to occur when the geographic scale of the problem is extensive, replication is difficult or impossible, or there are many potentially confounding environmental factors that combine to influence outcomes.

- A firm commitment to funding and institutional support for monitoring is lacking. Adaptive management should not be employed without a clear commitment to monitoring over the life of the project. If a commitment for monitoring is in question, it may be necessary to take another approach to decision making that does not rely on monitoring, such as expert systems, management intuition, or non-technical understanding of the system.

There are irresolvable conflicts in defining explicit and measurable management objectives or alternatives

If explicit and measurable management objectives cannot be identified or alternatives cannot be determined, then adaptive management is not feasible. Conflicts may arise in a collaborative process in which stakeholders with different interests fail to agree upon these components. One alternative in this situation is conflict resolution. Collaborative management is never easy, and agencies and stakeholder groups should not abandon the approach until the possibility of agreement on the key components of adaptive management is exhausted.

Decisions that affect resource systems and outcomes cannot be made

Adaptive management should only be considered in situations where management actions substantially influence the outcome. In certain situations, a management agency can only partially influence the resource system. For example, if an agency manages a relatively small area surrounded by private land, and the adaptive management project applies only to the agency-managed land, management activities on the private lands may well dominate the effect of agency actions. In such a situation, adaptive management is unlikely to be useful.

Some resource decisions are essentially irreversible in that follow-up adaptation is either infeasible or impossible. An example is the removal of a dam on a large river where the decision can be made only once.

Risks associated with learning-based decision making are too high.

It is sometimes considered inadvisable to use adaptive management when the "worst case scenario" resulting from a management action would be unacceptable to stakeholders. An example of such a situation might arise when management actions can lead to the extinction of extremely rare, threatened, or endangered resources. In this particular situation one approach might be to include management thresholds that prevent the worst-case scenario from occurring.

The limits of acceptable risk can vary substantially among applications, so adaptive management should not automatically be discounted even when dealing with rare or fragile resources. The relevant issue here is the value of information (see Section 2.1), taking into account the risks associated with learning-based decision making. In assessing risks, it is important to analyze the risk of the "do nothing" alternative, because the risk associated with maintaining the status quo may well be as high or higher than that of the alternatives.

In fact, an adaptive management approach often can alleviate the level of risk through a careful articulation of objectives, management alternatives, and other elements of the resource problem. If the levels of uncertainty and risk are high, an adaptive approach that includes pessimistic alternatives and very high penalties for negative outcomes may well be the preferred approach to management.

Each of the limitations listed above is often encountered in natural resource management. In addition, other conditions can undermine adaptive management, for example an inability to reach agreement about the key elements of structured decision making, or a mismatch between the rate of change in system process and the frequency of management interventions. When such limitations are encountered, decision makers should question whether the use of adaptive management is appropriate, and perhaps consider other approaches to manage public lands and resources.

An example of high-risk management involves management actions that can lead to the extinction of extremely rare, threatened, or endangered resources.

2.3 Key Points

- Adaptive management is not appropriate for single-time decision making.
- It is not appropriate if monitoring information is unavailable to decision makers.
- It is not appropriate if there are irresolvable conflicts about objectives or decision alternatives.
- It is not appropriate if management interventions cannot influence system behaviors in ways that affect management returns.
- It is not appropriate if there is not a commitment to sustained funding for monitoring and assessment.

2.4. Benefits and Challenges in using Adaptive Management

Benefits

An adaptive approach provides flexibility to act in the face of uncertainty

Adaptive management helps managers address resource issues by providing the flexibility to adjust management actions as additional understanding is gained. It can help determine whether management actions are having desired effects and whether mitigation measures are cost effective. The flexibility of adaptive management to respond to changing environmental conditions and improved understanding can result in better decision making.

An adaptive management approach is learning based

The concept of learning is central to adaptive management (8), with learning seen as a means to good management. Learning within the context of adaptive management derives from evaluation of previous management actions, the results of which are used to inform subsequent actions (8). The premise of an adaptive management approach is that the behavior of resource systems is uncertain but management is required anyway, and the reduction of uncertainty over time can lead to better management.

Adaptive management specifies what actions are to be taken and when

Adaptive management produces management strategies that specify what management actions are to be taken and how and when they should be adjusted. These strategies are based in turn on an explicit articulation of the management problem, what is known (and not known) about the resource system being managed, and the objectives of management (8). This explicitness makes it possible for stakeholders to focus on the key attributes involved in learning-based resource management, while avoiding the confusion and controversy that typically results when key management elements are not open to discussion and negotiation.

Adaptive management encourages long-term collaboration among stakeholders

Adaptive management brings resource managers, researchers, and other stakeholders together and encourages long-term collaboration through the development and strengthening of institutional ties (45). These ties are important in maintaining the level of support needed to successfully implement adaptive management. Through strengthened collaboration, stakeholders can be encouraged to remain involved over the life of an adaptive management project.

Adaptive management promotes optimal decision making with the information available

Adaptive management fosters the acquisition of new knowledge and understanding by specifying hypotheses and designing management alternatives to test them against field data (8, 46). The information accumulated through this process is used to adjust strategy periodically on the basis of what has been learned. In this sense, adaptive management allows decision makers at each juncture to make the best decisions they can with the information available at that time (41).

Challenges

Institutional reluctance to change

For adaptive management to be embraced on an institutional level, refinements in existing approaches to natural resource management are needed (8,47). An example might involve new ways of dealing with overlapping responsibilities and authorities among agencies, so as to reduce or eliminate resistance to one agency's adaptive management project by another agency that has regulatory oversight.

Some barriers to implementation go beyond the operational level. One such barrier is an inadequate recognition that the targets of resource management are rapidly becoming more inclusive. For example, ecosystem management traditionally is approached by targeting only one or a few system attributes, failing to account for the broader resource context and its implications for resource management. A framework for adaptive management allows the resource problem to be identified in a more inclusive context that includes issues like system viability and sustainability.

Another institutional barrier is a lack of the resource planning and design capacity that are required for adaptive management (see Section 3.1). For example, agency programs often have an inadequate capacity for the outcome-based monitoring needed for adaptive management. The problem here is not so much an inability to understand the process and procedures of adaptive management, as it is that program operations focus on tracking and assessment of activities and outputs rather than resource outcomes.

Implementation of adaptive management will require a shift in focus toward resource sustainability as a strategic target, with resource planning and design, decision-based monitoring, and assumption-driven research as central activities. In essence, adaptive management will require refinements to the resource management business model and adjustments in the organizational and institutional arrangements that support it. See Section 5.4 for further discussion on organizational roles and implications.

Commitment to monitoring and evaluation over the life of the project

In times of shrinking funding, managers must carefully assess the cost of the monitoring and assessment that inform decision making in an adaptive approach. The costs of timely monitoring and assessment over extended time scales are substantial, and often appear to be especially high at the outset of a project when compared with the costs of trial and error with only incidental monitoring (8). Agencies must be willing to make a commitment to cover the costs of monitoring and evaluation over the life of an adaptive management project; otherwise, discontinuing the monitoring effort will lead quickly to the cessation of adaptive decision making. Agencies also need to commit to a schedule for monitoring, analysis, and re-examination of decisions as understanding accumulates. In the absence of a commitment of resources for timely monitoring and evaluation over the life of the project, the use of adaptive management becomes problematic.

Significant time lags between management actions and their impacts

Time itself is a challenge in implementing adaptive management (48). In many cases, the overall costs associated with adaptive management are tied as much to the timeframe of the project as they are to its complexity. Some adaptive management plans require years of monitoring in order to be able to ascertain the results of an initial action. Of course, models that forecast some future endpoint as a consequence of a decision or series of decisions should also be able to predict resource status at various intervals prior to that endpoint, allowing management assessments to be performed on the predicted status over an abbreviated interval. The problem of time lags is further complicated by the fact that individual decision makers and/or managers rarely remain in the same position over the needed timeframes (8).

Implementing adaptive management in a complex legal environment

Legal issues must be weighed when deciding whether to implement an adaptive management strategy. In many cases, a NEPA decision process is required of federal agencies.

Depending on the resource problem and the scope of the project, requirements under other federal laws may also be triggered. Some laws may constrain or even preclude the use of adaptive management (see Section 3.2); on the other hand, legal considerations sometimes can be successfully integrated with it. Indeed, the case studies included on the enclosed CD suggest that adaptive management might make NEPA compliance more effective and efficient in some instances.

Collecting enough information to evaluate progress

The amount of data required for adaptive management depends on the system being managed, the actions being implemented, the objectives of management, and the amount of uncertainty (49,50). Project costs obviously increase for applications that require more frequent monitoring and the collection of larger amounts of data during each monitoring event.

Projects should be assessed individually, with each project tailored to the resource being managed, the environmental conditions of the project area, the project objectives, and the capabilities of the manager to implement decisions and carry out the subsequent monitoring and assessment. A considerable amount of up-front planning may be required; however, an initial investment of time and effort increases the likelihood of better decision making and resource stewardship in the future.

Projects should be tailored to the resource being managed, the environmental conditions of the project area, the project objectives, and the capabilities of the manager to implement decisions and carry out the subsequent monitoring and assessment.

2.4 Key Points

- Adaptive management promotes cooperative decision making in the face of uncertainty about the impacts of management interventions.
- Adaptive management produces management strategies consisting of actions that are tied to resource status and current understanding.
- Adaptive management brings resource managers, researchers, and other stakeholders together and encourages long term collaboration.
- Resistance to institutional change and a complex legal environment can be impediments to adaptive management.
- Agencies must be willing to commit to monitoring and evaluation over the life of an adaptive management project.

Chapter 3: How Should Adaptive Management be Implemented?

From an operational point of view, adaptive management simply means learning by doing (i.e., learning through management) and adapting what one does based on what is learned (i.e., adjusting management as understanding improves). Learning contributes to management by providing information on which to base management strategies, and management reinforces learning by implementing actions that are useful in investigating the resource system. A sequential application of these component activities should produce both improved understanding of resource dynamics and improved resource management (51).

As noted earlier, the emphasis in an adaptive approach is first and foremost on resource management. The value of understanding, and the monitoring and analysis that produce understanding, is inherited from their contributions to the objectives of resource management. Although the focus is on learning, the ultimate goal of the effort is smart management.

This chapter focuses on the implementation of adaptive management. The actual process of using adaptive management is discussed in terms of its key structural elements and the integration of these elements into an iterative cycle of management, monitoring, and assessment. Also highlighted are some legal issues that focus on compliance with the relevant environmental and administrative laws.

3.1. Operational Sequence for Adaptive Management

Implementation of adaptive management can be described in terms of two phases: a set-up phase in which its key components are developed, and an iterative phase in which the components are linked together in a sequential decision process. The set-up phase has five structural elements, namely stakeholder involvement, management objectives, potential management actions, predictive models, and monitoring plans. The iterative phase uses these elements in an ongoing cycle of learning about system structure and function, and managing based on what is learned.

Although adaptive management is described here by a series of steps in the set-up and iterative phases, it is important to recognize that adaptive management is a complex endeavor that includes much more than simply following a sequence of steps. Properly executed, the process involves ongoing, real-time learning, both in a technical sense and in terms of process itself. Stakeholders need to be engaged at the stage of initial problem formulation and remain engaged throughout implementation. By implication, an adaptive approach to management improves on the traditional communications approach in which scientists create knowledge and then pass it on to practitioners, with other stakeholders acting as passive observers (51). Instead, an adaptive approach actively engages parties in all phases of the project, facilitating mutual learning and reinforcing the commitment to learning-based management.

Set-up phase

Adaptive management prescribes the integration of decision making, monitoring, and assessment into an iterative process of learning-based management. To implement the process, certain elements must be put in place, and then used in a cycle of iterative decision making.

Step 1 - Stakeholder involvement

Ensure stakeholder commitment to adaptively manage the enterprise for its duration

Of particular importance in adaptive management is that stakeholders assess the resource problem (see Fig. 1.1) and reach agreement about its scope, objectives, and potential management actions, recognizing that differences of opinion about system responses may exist even when there is consensus on these issues. Clearly, agreement about scope, objectives, and interventions is not possible in the absence of stakeholder involvement in establishing them. Thus, a first step in adaptive management is to engage the appropriate stakeholders (See Case Study 1 and BLM Collaboration Desk Guide on CD for a discussion of stakeholder involvement).

Case Study 1: For decades, there has been concern about the ecological impacts of the operation of Glen Canyon Dam on downstream resources, particularly the riparian areas along the Colorado River in the Grand Canyon, Arizona. In recent years efforts have been made to evaluate and adapt management actions for resource protection through experiments that are monitored for their effects in the Grand Canyon. (See included CD for additional information on this project).

Several activities are involved. First, stakeholders must be identified and encouraged to participate. This might involve personal contacts, public announcements, formal consultations, or other means. Second, a process must be implemented that solicits stakeholder input in the design of the adaptive management project and, in particular, the identification of management objectives and potential management actions. Depending on the project, this may require formal or informal consultations, legally mandated and administered procedures, or other approaches. In any case, stakeholder involvement in identifying key components of the project should be open and transparent. Third, stakeholders must commit to an agreed-upon process of reducing uncertainties and/or disagreements about the effects of management. That is, having reached agreement on the scope of the management problem and its objectives and potential interventions, stakeholders must then commit to an iterative process of objective-driven decision making.

In general, the group of stakeholders should be broad enough to express the uncertainty (perhaps through disagreement) that is the focus of adaptive management. However, adaptive management is not prescriptive about who the stakeholders are, how many there are, or what their perspectives or values are. The scale and complexity of stakeholder involvement can vary greatly among projects and is influenced by the scale and complexity of the application itself. Many adaptive management projects involve only one or a few stakeholders, as with a refuge manager who is unsure how to manage water control structures on the refuge, or a farmer who is unsure how to seed and cultivate some of his farmland, or a fish hatchery manager who is uncertain about how long to age fish stocks before releasing them in a reservoir. Other projects may involve a large number of disparate stakeholders, as with the seasonal release of water from a dam on a large river, or the production of timber on a large regional forest, or the management of a coastal fishery. As a general rule, the number of stakeholders, and the breadth of their perspectives and values, will vary with the geographic, ecological, administrative, and political scale of the adaptive management project.

Stakeholders should play a role in identifying the scope of the project as well as the objectives and potential management actions. Within a context of legal and institutional boundaries, stakeholders help to define the operating environment of an adaptive management project, and they influence both decision making and the opportunity to learn. All too frequently, a decision making process is undertaken without agreement about scope, objectives, and management alternatives. Without this agreement, any management strategy likely will be viewed as reflecting unshared objectives and inappropriate or unnecessary limitations on management. The prospects for conflict increase dramatically in such a situation.

The success of an adaptive management project requires an adequate understanding of the resource issues and the dedication to stay abreast of new information. The interface between scientific investigation and stakeholder understanding becomes increasingly difficult as proposed actions become more technical, and it is not uncommon for both scientists and stakeholders to become impatient and frustrated. Engagement and communication among stakeholders is critically important if arguments on the meaning of science are to be minimized.

Of particular concern in adaptive management is the asymmetry between management interventions, which often must be implemented in a relatively short amount of time, and their impacts, which sometimes require years or even decades to be recognized. This asymmetry imposes special demands on stakeholders to remain engaged over an adequate timeframe for learning to occur. Among other things, it may be useful, and even necessary, to design monitoring and assessment programs at different scales, so as to build understanding incrementally while anticipating unexpected results that may require adaptations in the project. Otherwise, premature interruption of monitoring efforts, or stakeholder pressure to terminate the application of adaptive management, could short-circuit the expected benefits of improved decision making.

Recognizing stakeholder interests and ensuring their involvement for the duration of the management enterprise are requirements for learning–based management in general. But involvement is more than passive participation in information sharing and other stakeholder prerogatives. Adaptive management involves the commitment of time, resources, and active engagement of stakeholders. These requirements often are underestimated. If stakeholders are unwilling to dedicate sufficient time and effort, group deliberations have the potential to devolve into value-based arguments, minimizing the positive impacts of monitoring and evaluation. Program documents should explicitly state the responsibilities of the stakeholders, and every effort must be made to ensure that stakeholders will meet those responsibilities over the life of the project.

Step 1 - Key Points

- A strong effort must be made to identify and engage the appropriate stakeholders.
- All phases of the adaptive management process must be open, transparent, and accessible to stakeholders.
- Stakeholders must strive for agreement on scope, objectives, and management alternatives for the adaptive management application.
- Stakeholders must commit to a process for adjusting management strategy over time, based on resource status and learning.
- Stakeholder organizations must be encouraged to commit time and energy to adaptively manage the resource over the agreed-upon timeframe.
- Stakeholders must commit resources for monitoring and assessment, in addition to decision making.

Bemidji Crude-Oil Research Project; measuring crude-oil thicknesses during the aquifer test.

Step 2- Objectives

Identify clear, measurable, and agreed-upon management objectives to guide decision making and evaluate management effectiveness over time

Objectives, resource status, and learning all influence the choice of management interventions in adaptive management. But objectives also play a crucial role in evaluating performance, reducing uncertainty, and improving management through time. It therefore is important to have clear, measurable, and agreed-upon objectives at the outset, to guide decision making and assess progress in achieving management success (See Case Study 2 for a discussion of setting objectives).

The term "objective" is used here to mean some desired outcome or performance measure that can be used to guide decision making and measure success. Objectives typically are expressed in terms of management performance over the timeframe of a project. For example, measures might be harvest yield, population size, water flows, or the probability of a negative impact on resource status, with an objective of maximizing accumulated harvest, achieving a desired population size, maintaining water flow, or minimizing a probability of extinction.

Because management objectives are used to guide decisions in managing (and often changing) certain aspects of a target resource through time, they should be more specific than common, "broad-brush" statements or overall program purposes that appear in many project documents. For example, generic statements such as "provide public access and recreational opportunities" or "improve water quality to enhance and restore commercial fishing" are purpose statements indicating why management is to be undertaken, rather than objectives that can help to guide decision making.

Objectives should address the resource issue or problem that initially motivated management, and reflect the social, economic, and/or ecological values of stakeholders. Underlying an adaptive approach is the recognition that stakeholders influence what is to be managed and under what circumstances. Finding common ground among disparate and often contentious parties is not an easy task when there are differences in understanding about the resource system and differences in ideas about the desired focus and direction of management. For objectives to be realistic and mutually acceptable, parties must work toward an agreement on the purpose and approach to resource management and seek a common basis for recognizing management success. In particular, objectives should be defined cooperatively through a dialogue among managers, scientists, and other stakeholders.

In the context of adaptive management, objectives must be relevant to the decision making process and possess a number of attributes that render them useful as guides to management (52). To be useful for decision making and evaluation, objectives need to exhibit the following technical features:

- **Specific:**
Objectives should be unambiguous, with specific metrics and specific target conditions. Specificity can be encouraged by articulating objectives with Who, What, Why, and/or Where phrases.

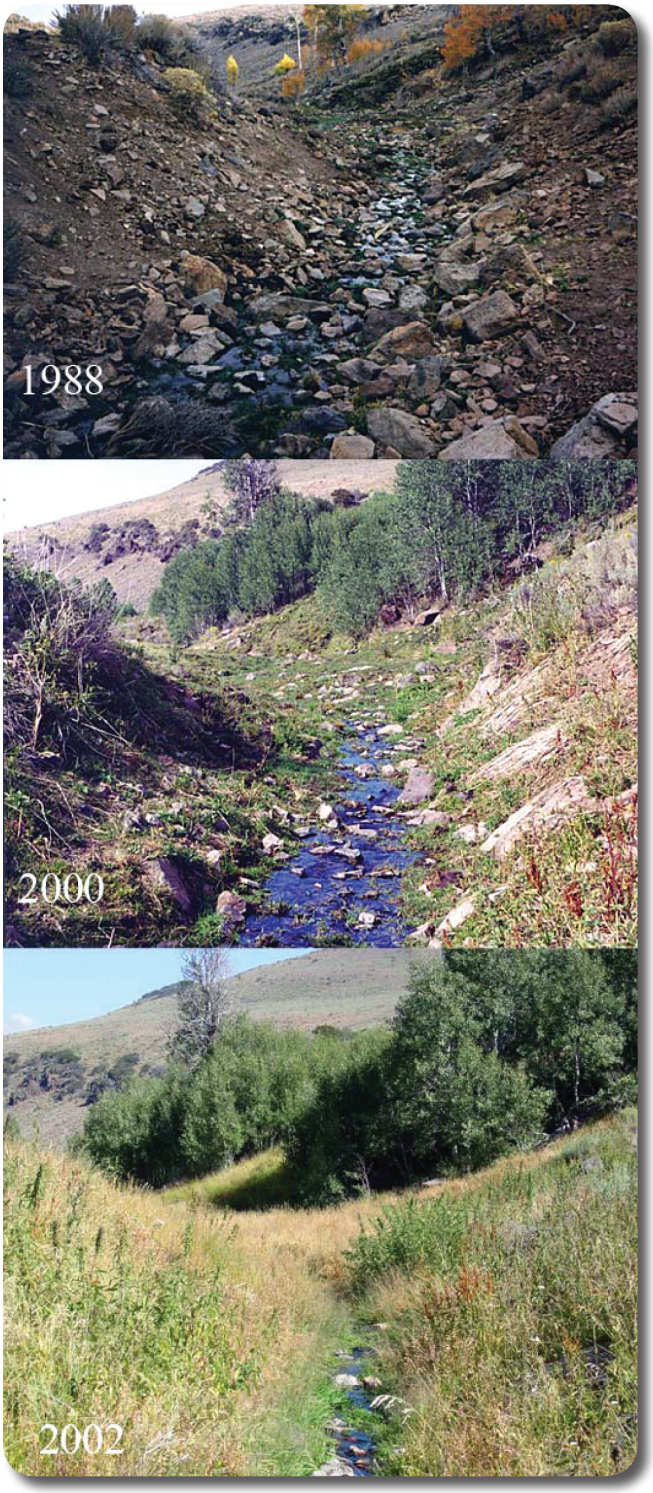
- **Measurable:**
Objectives should contain elements that can be readily measured, so as to promote the evaluation of management actions and recognize their contributions to successful management.

- **Achievable:**
Objectives should be based on the capacities of the natural resource system being managed and the political or social system within which management occurs.

- **Results-oriented:**
Objectives should contain for resource endpoints and/or conditions representing their achievement. For example, a results-oriented habitat objective might describe the habitat conditions expected when the objective is achieved.

- **Time-fixed:**
Objectives should indicate the timeframe for achievement, consistent with the duration of the project. Project implementation may be in stages, but the overall timeframe should be clear.

It is often the case in adaptive management that there are multiple objectives for resource management. For example, one might seek to sustain species richness in a refuge, while attempting to maximize visitor use, maintain a harvest program for one or more species of wildlife, and allocate resources to these activities so as to minimize costs. In such a situation it is important to be able to weigh different objectives in terms of their perceived importance, so as to facilitate the comparison and prioritization of management alternatives.



Step 2- Key Points

- Objectives substantively influence decisions and management strategies.
- Objectives should incorporate the social, economic and/or ecological values of stakeholders, and reflect the value of learning over time.
- To be useful as guides for decision making and evaluation, objectives should be specific and unambiguous, measurable with the appropriate field data, achievable but challenging, results-oriented, and applicable over the timeframe of the enterprise.

Case Study 2: The Trout Creek Mountain Restoration focuses on compatibility between livestock grazing and critical habitat for listed Lahontan cutthroat trout within the Trout Creek and Oregon Canyon Mountains, Oregon. This time sequence shows the dramatic changes along Cottonwood Creek, V Pasture, looking downstream starting in 1988. Until 1989 this pasture was grazed during the summer every year. Despite changes in the timing and intensity of grazing, chronic trespass prevented acceptable levels of riparian improvement. Enforcement, changes in permittees, and fence repairs since then have allowed 2 years of actual rest. Note the increased reproduction in aspen by 2002. (See included CD for additional information on this project).

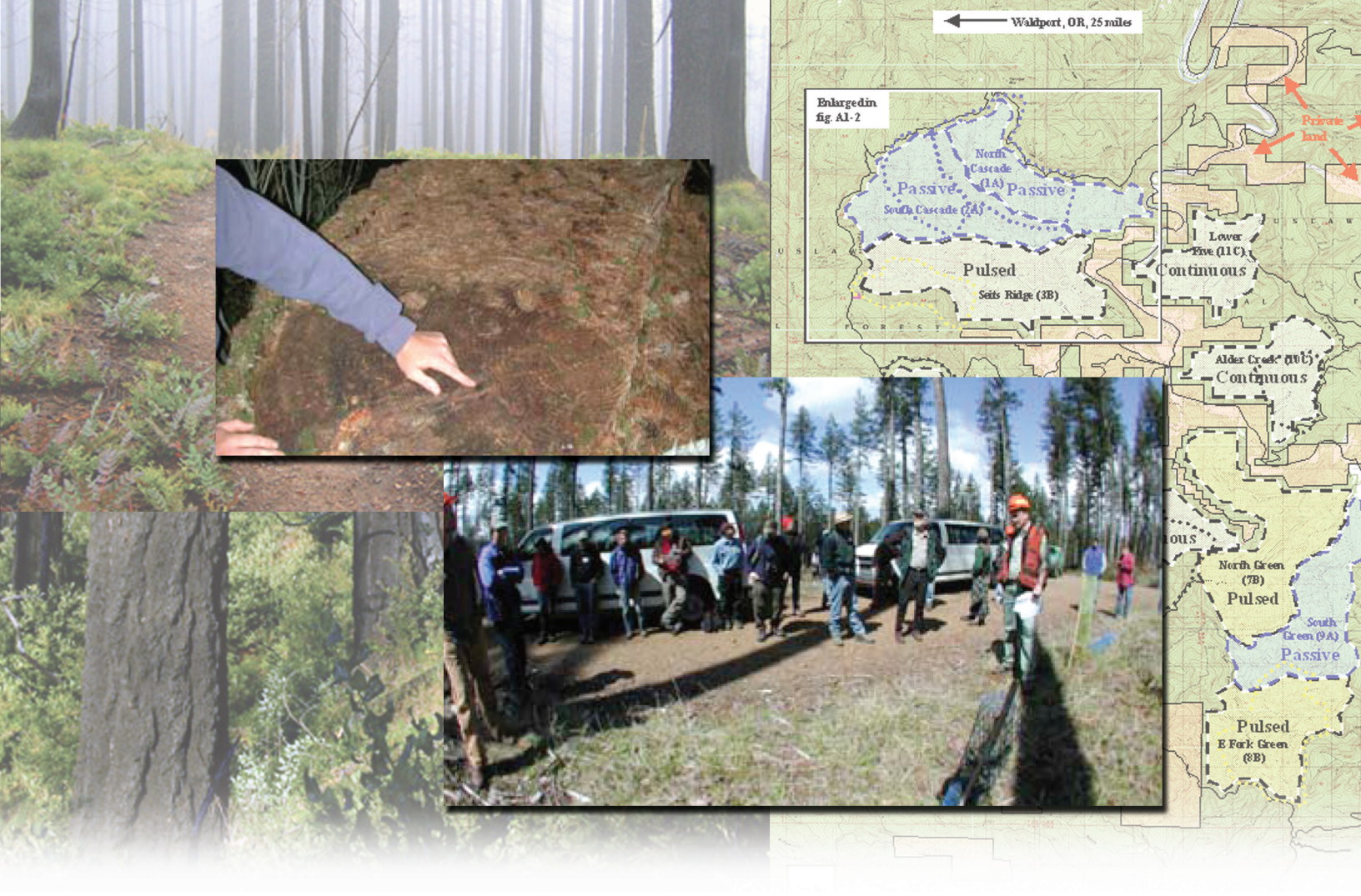
Step 3- Management actions

Identify a set of potential management actions for decision making

Like any iterative decision process, decision making in adaptive management involves the selection of an appropriate management action at each point in time, given the status of the resources being managed at that time. Resource managers and stakeholders, typically working with scientists, have the responsibility of identifying the set of potential actions from which this selection is made (See Case Study 3 for a discussion about identifying management actions).

The management alternatives in an adaptive management project constitute a key element in its operating environment, and they can strongly influence the selection of a management strategy (see Section 5.1). Just as the choices made in daily life depend on one's available options, so too are strategy choices in an adaptive management project constrained by the set of available options. If these options fail to span a reasonable range of management activities or fail to produce recognizable and distinct patterns in system responses, adaptive management will be unable to produce effective and informative management strategies. This argues for careful thinking about the potential actions to be included in a project.

Case Study 3: The Sonoita Valley Planning Partnership is an ad hoc, volunteer association of Federal, State, and local agencies, user groups, organizations, and individuals with a common interest in the upper Cienega watershed, which includes the 42,000 acres of public lands within the Las Cienegas National Conservation Area, Arizona. The goal of the partnership is to perpetuate naturally functioning ecosystems while preserving rural grasslands for future generations. (See CD for additional information on this project).



Case Study 4: The Five Rivers Landscape Management Project began in 1998 as an attempt to apply adaptive management at large scales. The project was designed for 32,000 acres of productive Siuslaw National Forest land in coastal Oregon. (See CD for additional information on this project).

Management alternatives in adaptive management often focus on a potential change in resource status or the alteration of process rates. Examples of the former include culling a livestock herd to maintain a population at carrying capacity, stocking a lake to sustain a fishery, or withdrawing water from a reservoir to maintain an appropriate volume of water in it. Examples of the latter include harvest regulations that target an acceptable mortality rate, alteration of nesting habitat to enhance population reproductive rate, or control of the amount and timing of visitor disturbance so as to influence avian migration patterns positively.

In designing an adaptive management project, management alternatives should be included that will produce different responses and thereby promote learning. One way to structure alternatives for this purpose is to limit their number, and maximize differences among them. An example is the Five Rivers Landscape Management Project (See Case study 4), which used three different management alternatives: (1) passive management in which plantations are allowed to develop into old growth with no intervention other than road closures; (2) frequent light-touch thinning and road maintenance; and (3) heavy thinning followed by 30-year road closures. Another example involves the impact of harvest, which is likely to be easier (and less costly) to recognize with a few widely spaced harvest rates rather than many that are closely spaced. In both examples a smaller number of alternatives helps to reduce implementation costs, minimize problems that otherwise can arise with partial controllability (see Section 5.2), and highlight differential responses of the resource.

Because of natural variation, resource systems often are extraordinarily difficult to control with management actions, and "cause and effect" relations are usually unclear and difficult to recognize. It is important to include options that can help to reduce these difficulties, though this sometimes leads to a broader range of

potential actions than otherwise would be desireable. In any case, the options under consideration should always be designed to achieve specific objectives.

To ensure clarity and transparency it is important to make the management options explicit. Too often the set of options is unstated, and simply assumed to be recognized and understood by managers and other stakeholders. Ambiguity as to the alternatives under consideration can lead to conflict among stakeholders and the possibility of legal challenges to the decision making process.

The identification of management options is often a greater challenge than some anticipate. Just as different stakeholders see the resource system differently and identify different objectives for its management, so will they recognize differences in the feasibility and acceptability of management options. Even when there is rough agreement on their nature and extent, there still may be different perspectives about the appropriate number and composition of management alternatives. It is important to take the necessary time and effort to think carefully about these issues, so as to reach agreement on a realistic and politically acceptable set of alternatives.

Because of natural variation, resource systems often are extraordinarily difficult to control with management actions, and "cause and effect" relations are usually unclear and difficult to recognize.

Step 3- Key Points

- Potential actions consist of activities under management control (for example, harvest, stocking, restoration).
- Alternatives typically focus on alterations of resource status or process rates.
- The suite of available actions should be designed to promote learning.
- The alternatives should be explicit and documented.
- Stakeholders should participate in the identification of alternatives.

Step 4- Models

Identify models that characterize different ideas (hypotheses) about how the system works

Models play an important role in virtually all applications of structured decision making, whether adaptive or otherwise. In order to make smart decisions, it always is important to compare and contrast management alternatives in terms of their costs, benefits, and resource consequences. Models typically express benefits and costs as outputs of management through time. More importantly, they allow one to forecast the impacts of management.

The term "model" is used here to mean a plausible representation of a dynamic natural resource system (See Case Study 5 for a discussion of model development). Models can be as informal as a verbal description of system dynamics (for example, a simple description of reservoir size that is positively influenced by runoff and negatively influenced by water release), or as formal as a detailed mathematical expression of change (for example, an age-structured multi-species model with density-dependent vital rates that are affected by random environmental changes). The models used in an adaptive management project are not restricted to a particular kind. In many instances only a few models are required to capture contrasting views about the system, and these often can be described with limited technical detail.

Case Study 5: In 1995, the U.S. Fish and Wildlife Service implemented an approach known as adaptive harvest management, in which managers seek to maximize sustainable harvests against a background of various sources and degrees of uncertainty. (See CD for additional information on this project).

Although model complexity can vary widely depending on the ecological and management scale of the application, the models used in adaptive management generally share certain attributes (53):

- Resources are described as changing though time, so as to allow learning to occur and management to adapt to learning (Fig. 3.1).
- The resource system is characterized by key components of interest (for example, population size, resource biomass or volume, biodiversity) that are the focus of management and the targets of monitoring.
- Resource changes often are described in terms of processes (for example, reproduction, mortality, spatial movement) that are thought to be directly influenced by management.
- Fluctuating environmental conditions are incorporated as needed to characterize resource dynamics.
- Management impacts are described in terms of costs, benefits, and influences on resource components or processes that are highlighted in the model.
- Models are calibrated with available data and knowledge, to ensure compatibility with current understanding about resource structures and functions.

Models play a key role in representing uncertainty. In adaptive management, structural or process uncertainty is captured in contrasting hypotheses about system structure and function, and the hypotheses are imbedded in the suite of models used to forecast resource changes through time. At any point, the available evidence will suggest differences in the adequacy of each of these models to represent resource dynamics. As evidence accumulates over time, the confidence placed in each model (and its associated hypothesis) evolves, through a comparison of model predictions against monitoring data.

To be useful, the models in a particular project must meet certain conditions, including a requirement that different models predict different outcomes in response to management. However much two models may differ in the way they describe system dynamics, if both predict the same responses to management, then recognizing which is more scientifically credible will be of little use in improving management.

An example that highlights many of these points is the modeling framework used for adaptive harvest management of waterfowl. Adaptive Harvest Management (AHM) was initiated in 1995 as a process for setting annual regulations for the sport hunting of waterfowl in North America (37). For AHM, a simple model was used to account for associations among fall harvest, seasonal survivorship, and spring reproduction (Fig. 3.2). Contrasting hypotheses about the impact of harvest on annual survivorship were easily incorporated into different versions of the model, by describing different functional relations between harvest rates and post-harvest survival. In addition, contrasting hypotheses about the importance of density dependence in recruitment were incorporated by describing recruitment in terms of spring population size. In combination, these hypotheses define four models, each with its own predictions about harvest impacts and each with its own measure of confidence that evolves over time (54). The models and their measures of confidence characterize structural or process uncertainty, which is reduced over time as harvest actions are taken and post-harvest monitoring data are used to update the confidence measures.

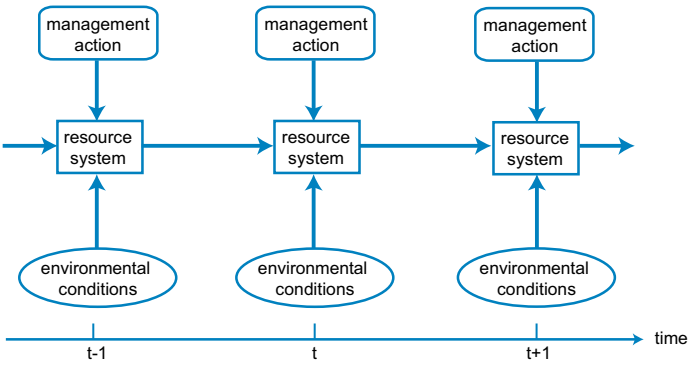


Figure 3.1. Change in resource system as influenced by fluctuating environmental conditions and management actions. Management produces immediate returns (costs and/or benefits) and longer-term changes in resource status.

Like the management options in an adaptive management application, models can strongly influence the identification (and acceptability) of management strategies. If the models fail to incorporate meaningful hypotheses, or fail to produce recognizable differences in population dynamics, an adaptive approach may be unable to produce useful and informative strategies. This argues for engaging managers, resource scientists, and other stakeholders in a thoughtful and deliberate process of selecting the models to be used in an application.

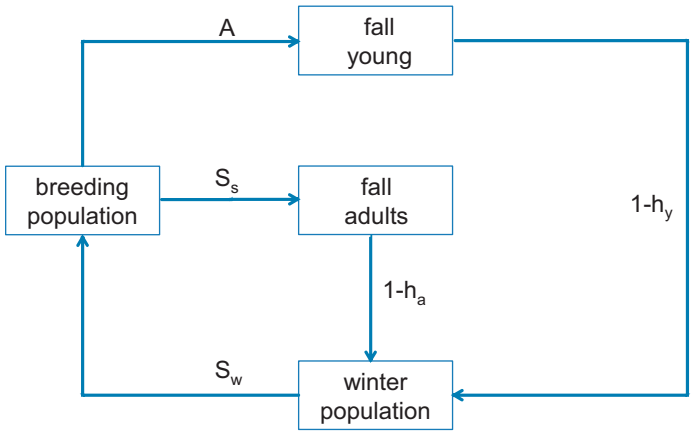


Figure 3.2. Conceptual model of the annual cycle of mallard population dynamics. Model includes survival rates for spring-summer (S_s) and fall-winter (S_w), along with harvest rates for young (h_y) and adults (h_a) and age ratio (A) for reproduction/recruitment.

Step 4- Key Points

- Models in adaptive management should characterize system behaviors and responses to management actions.
- Models should incorporate different ideas (hypotheses) about how the resource system works and how it responds to management.
- The suite of models should capture key uncertainties (or disagreements) about resource processes and management effects.
- Models must be compatible with, and calibrated to, available data and knowledge.

Step 5- Monitoring plans

Design and implement a monitoring plan to track resource status and other key resource attributes

The learning that is at the heart of adaptive management occurs through a comparison of model-based predictions against estimated responses based on monitoring data. It is by means of these comparisons that monitoring is used to understand resource dynamics, and thus to confirm the most appropriate hypotheses about resource processes and their responses to management. By tracking useful measures of system response, well designed monitoring programs facilitate evaluation and learning in adaptive management.

In general, monitoring provides data in adaptive management for four key purposes:

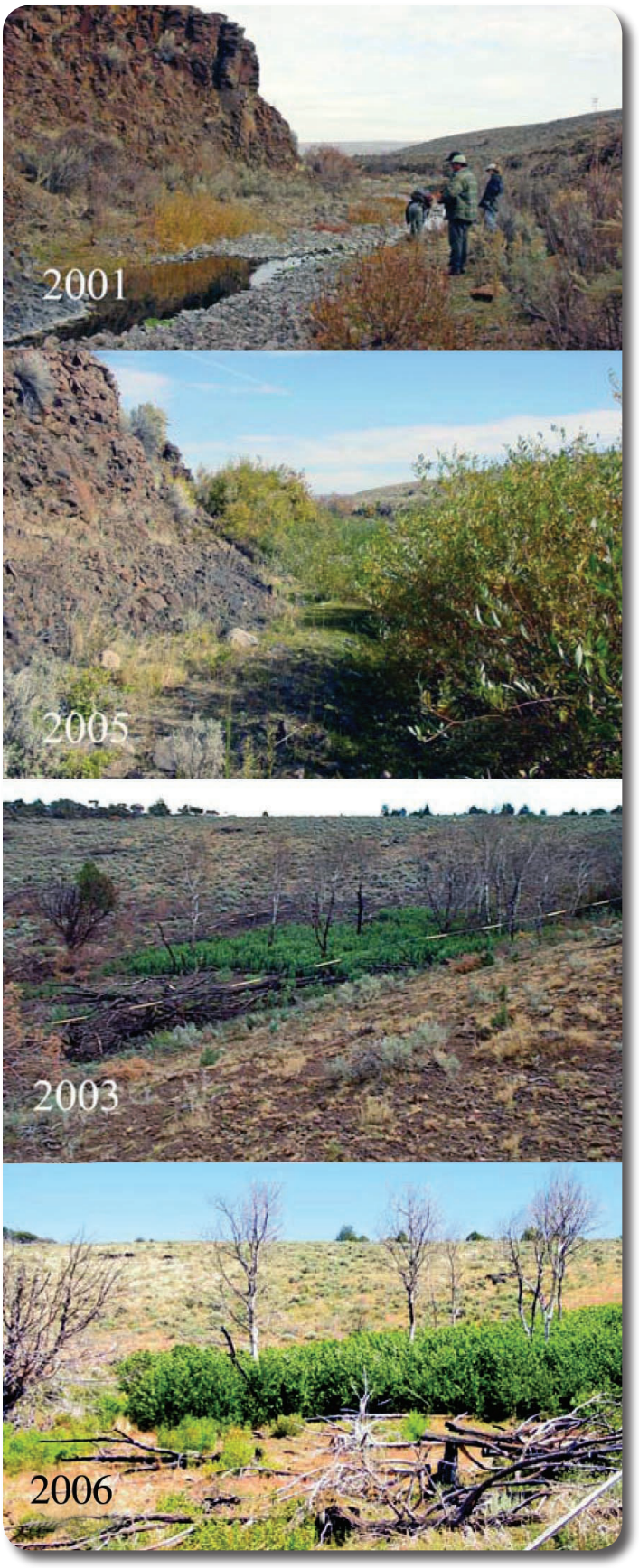
(i) to evaluate progress toward achieving objectives;

(ii) to determine resource status, in order to identify appropriate management actions;

(iii) to increase understanding of resource dynamics via the comparison of predictions against survey data; and

(iv) to enhance and develop models of resource dynamics as needed and appropriate.

Monitoring programs should be designed from the outset to inform decision making with data that are relevant to the management issues in the adaptive management project (55,56). For example, variables such as survival, harvest, stocking, and reproduction rates can be estimated with properly designed monitoring efforts and used to adaptively manage a biological population. Surveys producing such information can be invaluable as sources of longterm data with which to develop the adaptive management project (See Case Study 6 for a discussion about developing a monitoring plan).



Monitoring in adaptive management inherits its focus and design from the larger management context of which it is a part. Thus, field surveys are not motivated by scientific curiosity, nor are survey data gathered with only a vague hope that somehow they will prove useful for management. Instead, monitoring programs are designed to focus on the information needed to make management decisions and evaluate their impacts. There may be scientific or other values in broad-scale surveillance monitoring, and data collected in this way can sometimes prove useful for resource conservation. But monitoring in the context of adaptive management is much more efficient and effective if it targets specific attributes for the specific purposes listed above. Simply put, the value of monitoring in adaptive management is derived from its contribution to adaptive decision making, and monitoring efforts should be designed with that goal in mind (57).

Step 5- Key Points

- A monitoring plan should be designed to estimate system state and other attributes needed for decision making and evaluation.
- The plan should promote learning through a comparison of estimates against model-based predictions.
- The plan should be efficient, in that it produces estimates that have maximum precision for a given cost, or minimum cost for a given level of precision.

Case Study 6: The Bully Creek Landscape Area Management Project of the Bureau of Land Management is within the Malheur Resource Area, Vale District, Oregon. The project represents ground-level resource planning for public lands. On the top are views of Allotment #3 on a tributary of Cottonwood Creek in 2001 (first year after change in riparian management) and 2005 (after 5 seasons of riparian management). On the bottom are views of the Muir Spring aspen stand (with protective fencing) in 2003 (first year after treatment), and 2006, which shows a close-up of the same site with continued aspen regeneration. (See CD for additional information on this project).

Iterative phase

At this point in the operational sequence of adaptive management it is assumed that the key elements are in place. Thus, the appropriate stakeholders have been engaged in articulating the scope and nature of the resource issue. The objectives and management alternatives of the project have been identified. Forecasting models that capture uncertainty (or disagreement) about the impacts of management have been identified. And a monitoring effort has been designed that targets the resource attributes needed for learning, evaluation, and decision making. The stage is now set to incorporate these elements into an iterative decision process that will lead to improved understanding and management.

Step 6- Decision making

Select management actions based on management objectives, resource conditions, and understanding

At each decision point in the timeframe of an adaptive management project, an action is chosen from the set of available management alternatives. The management objective identified in Step 2 is used to guide this selection, given the state of the system and the level of understanding when the selection is made. The appropriate action is likely to change through time, as understanding evolves and the resource system responds to environmental conditions and management actions. That is, management is adjusted both to changing resource status and to learning. It is the influence of reduced uncertainty (or learning) on decision making that makes the decision process adaptive.

There are many ways to design the actual process of selecting an alternative. For example, formal optimization methods can be used to select from the available management alternatives an option that best accounts for current and future consequences (53,58,59). Alternatively, less computation-intensive search procedures can be used to produce suboptimal (but in many cases quite acceptable) management strategies. Finally, one sometimes can rely on less structured approaches or common sense to identify acceptable strategies. Irrespective of the approach, decision making should be driven by the management objectives and informed by resource status and process uncertainties.

Step 6- Key Points

- ❖ At each point in time, selection of a management action is made from the set of possible alternatives.
- ❖ The selection of a management action is guided by objectives, which are used to evaluate alternatives and identify an action that contributes to meeting the objectives.
- ❖ The appropriate action depends on resource status and the current level of understanding about resource dynamics.
- ❖ Management is adjusted over time as resource conditions change and understanding evolves.

Step 7- Followup monitoring

Use monitoring to track system responses to management actions

Monitoring is used in adaptive management to track system behavior, and in particular to track the responses to management through time. In the context of adaptive management, monitoring is seen as an ongoing activity, producing data after each management intervention to evaluate the intervention, update the measures of model confidence, and prioritize management options in the next time period (See Case Study 7 for a discussion of follow-up monitoring).

Field surveys, banding programs, remote sensing, and other monitoring approaches can generate the data needed to estimate key indicators of resource dynamics (20). The information thus produced is used to compare data-based estimates of system components against expectations, and thus to measure performance in achieving management objectives. Monitoring information also factors directly into the learning process, through the comparison of estimates against model predictions. Subsequent decision making reflects the increasing degree of credibility earned by the most appropriate model(s), and management performance is adaptively improved.

Monitoring data play into these assessments in multiple ways. For example, estimates of system state typically are used in the process of identifying state-

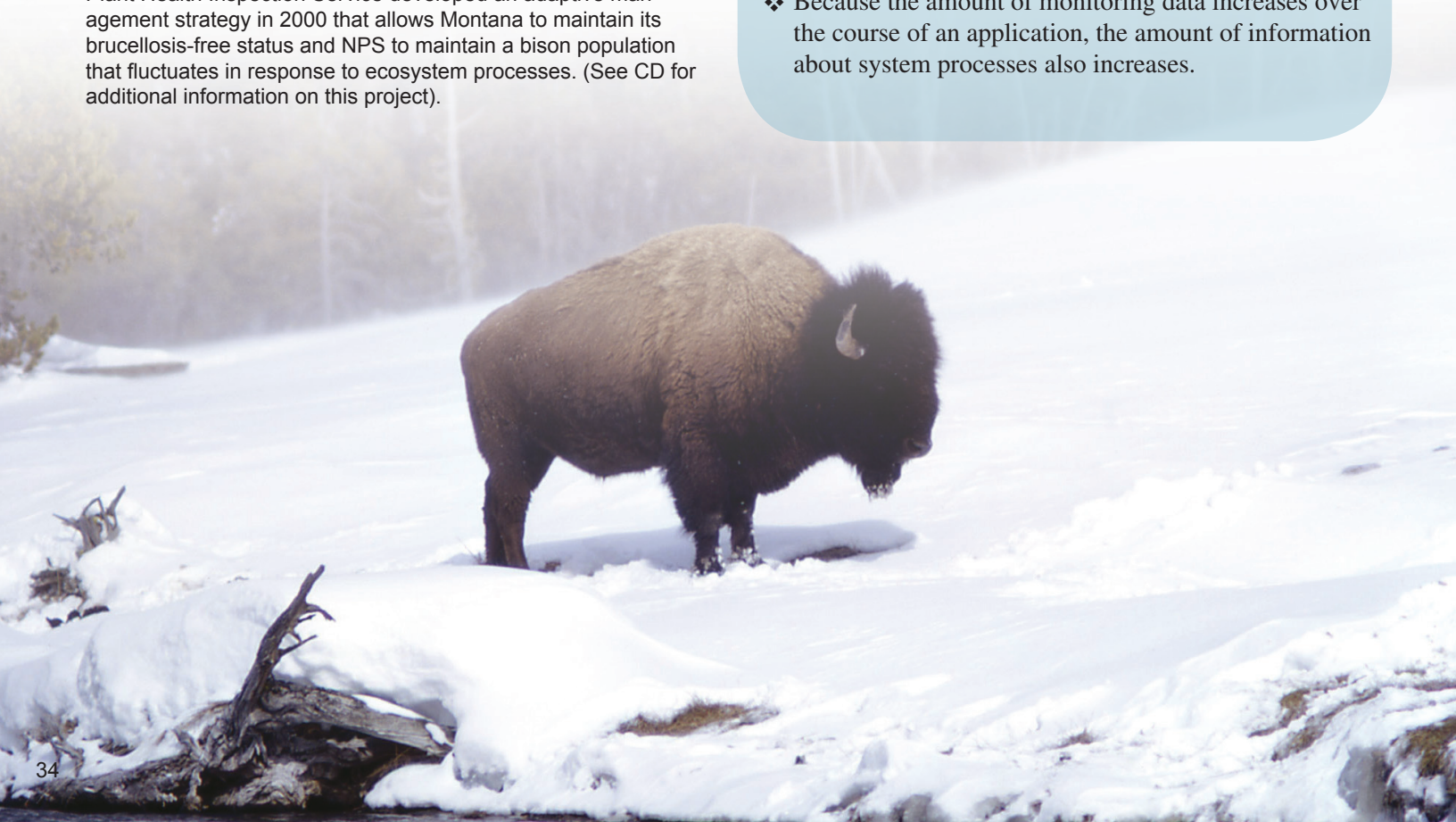
specific decisions. In some cases, estimates of resource status are directly included in the objectives, and thus are needed to assess the expected benefits, costs, and consequences of particular decisions. Of particular importance in adaptive management is the use of estimates of status and perhaps other attributes for comparison against model predictions so as to improve understanding of resource dynamics.

In many but not all instances, it is useful to collect data prior to initiating management. For example, if the management objective is to increase the size of a previously unperturbed population over some time period, a "baseline" population size prior to any management intervention can be used to compare population size before and after the initial intervention. On the other hand, an objective of maximizing harvest may not require baseline conditions prior to the start of management. In the latter case, decision making pursuant to the objective is not informed by a comparison of resource status against a starting value. The point here is that the design of a monitoring effort, and in particular the need for initial "baseline" information, is determined by the nature of the project and its objectives. Even when baseline information is needed, its comparative value declines rapidly as the project proceeds through time, essentially because monitoring after each intervention establishes new "baselines" throughout the life of the project.

Step 7- Key Points

- Monitoring typically occurs after management interventions.
- Resource status and other key indicators of impacts are estimated with monitoring data.
- Estimates based on monitoring data are used to evaluate management impacts and inform decision making at the next decision point.
- Because the amount of monitoring data increases over the course of an application, the amount of information about system processes also increases.

Case Study 7: The National Park Service (NPS), State of Montana, USDA Forest Service, and the USDA Animal and Plant Health Inspection Service developed an adaptive management strategy in 2000 that allows Montana to maintain its brucellosis-free status and NPS to maintain a bison population that fluctuates in response to ecosystem processes. (See CD for additional information on this project).



Step 8- Assessment

Improve understanding of resource dynamics by comparing predicted and observed changes in resource status

The information produced by monitoring folds into assessments of decision making, performance evaluation, and learning. For example, the comparison of model predictions against estimates of actual responses is a key element of learning, with the degree of coincidence between predicted and observed changes used as an indicator of model adequacy. Confidence is increased in models that accurately predict change, and confidence decreases for models that are poor predictors of change. In this way evidence accumulates over time for the most appropriate hypothesis about resource dynamics, and understanding of the resource system is thereby advanced.

As important as it is, learning is not the only role played by analysis and assessment in adaptive management. Thus, an assessment of desired against actual outcomes can be used to evaluate the effectiveness of management and measure its success in attaining management objectives. In addition, an assessment of management alternatives as to their projected costs, benefits, and resource impacts contributes to the selection of a management option in the next time period.

Step 8- Key Points

- Assessment/analysis includes parameter estimation, comparative assessments, and prioritization of management alternatives.
- Comparison of predicted and actual responses is used to update understanding of management impacts.
- Comparison and ranking of projected outcomes for management alternatives is used in selection of management actions.
- Comparison of desired and actual outcomes is used to evaluate management effectiveness.

Step 9- Iteration

Cycle back to Step 6

The gain in understanding from monitoring and assessment in Steps 7 and 8 is used to inform the selection of a management action at the next decision point. As understanding evolves, so too does the decision making that is influenced by improved understanding. In this way, the iterative cycle of decision making, monitoring, and assessment leads gradually to improved understanding of resource dynamics, and improved management as a consequence of improved understanding.

As shown in Fig. 3.3, the iterative cycle can begin with any of the Steps 6 to 8. However, it is useful to think of it as starting with a management decision, which is followed by post-decision monitoring and the subsequent assessment of monitoring data. This sequence of activities is repeated over the course of the application, during which learning occurs continuously and the management strategy is continuously adjusted based on what is learned.

The cycle typically terminates at the end of the time-frame with a final management action that is informed by assessment of the data collected just prior to the terminal time. It is also possible, if unlikely, that all uncertainty about ecological structure and function can be eliminated at some point, whereupon the learning-based adaptive approach can give way to non-adaptive resource management for the remaining time.

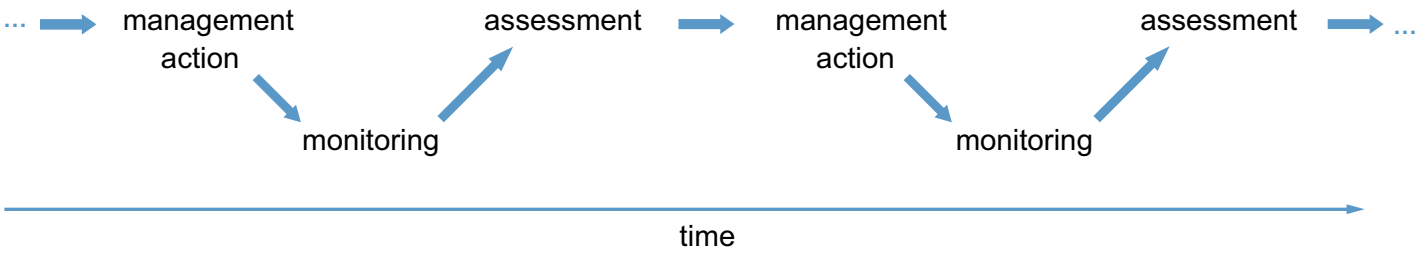


Figure 3.3. Iterative cycle of adaptive management. Management actions are based on objectives, resource status, and learning. Data from followup monitoring are used to assess impacts and update understanding. Results from assessment guide decision making in the next time period.

Step 9- Key Points

- The cycle of Steps 6 through 9 is iterated until the end of the timeframe.
- Iterations can begin at any point in the cycle; however a natural entry point is with decision making.
- The direct linkage from assessment to management action in Fig. 3.3 expresses the contribution of learning to decision making, by providing information on which to base smart decisions.
- The two-step linkage from management action to assessment in Fig. 3.3 expresses the contribution of management to learning, through interventions that are useful in investigating the resource system.

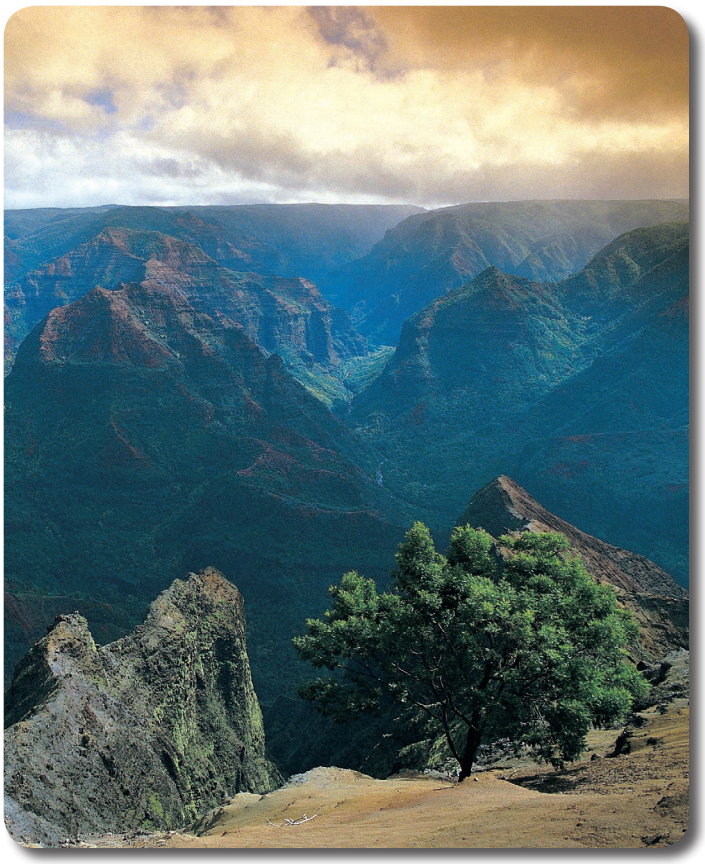
Technical and process learning in adaptive management

The operational sequence described above provides a framework for implementing adaptive management, with a focus on reducing structural or process uncertainty and thereby improving management. However, adaptive management involves much more than simply following the sequence of steps outlined here.

Just as adaptive management can be described in terms of two phases, learning with adaptive management can be seen to occur at two levels. Thus, adaptive management provides an opportunity to learn not only about ecological processes, but also about the adaptive process itself. In Chapter 1, adaptive management was described in terms of a cycle that included not only monitoring, evaluation, and adjustment of management actions, but also problem assessment and design (Fig. 1.1). The latter elements focus on problem formulation, stakeholder involvement, identification of objectives, and the other elements included in the setup phase of adaptive management. In fact, it is useful to think of adaptive management not only in terms of an ongoing sequence of decision making, post-decision monitoring, and assessment as described here, but also in terms of periodic but less frequent recycling through the elements in the setup phase and adjustment of these elements as needed to account for evolving stakeholder perspectives and institutional arrangements (Fig. 3.4). The broader context of learning that focuses on the components of adaptive management as well as technical uncertainty is sometimes called "double-loop" learning (12).

In many applications of adaptive management, both kinds of learning are of key importance. For example, it can be as important to understand and track the social and institutional relations that influence adaptive management elements and stakeholder perspectives, as it is to resolve technical issues about system structure and process (54). Although the motivation of an adaptive approach is to improve resource management by reducing structural uncertainty, its success can be impeded by a failure to adapt to social and institutional changes that inevitably occur over time. Because these changes can themselves be a result of early successes in reaching objectives, it is important to recognize and if possible account for them as decision making moves forward.

The need to better understand and characterize the elements of adaptive management often becomes more pressing as the iterative process of adaptive management rolls forward. Thus, stakeholder perspectives and values can shift as the adaptive process unfolds, and previously unanticipated patterns in resource dynamics can arise that require an adjustment of objectives, alternatives, and other elements of the process. In this sense, learning about the adaptive management process extends the context of adaptive learning to include changes in institutional arrangements and stakeholder values as well as changes in the resource system.



An emphasis on both technical and process learning has important implications for the institutional framework for resource management. Many managers contend that adaptive management is simply common business practice in their organizations and that they have been using adaptive management all along (51). In fact, the use of adaptive management in resource management almost always requires a fundamental shift from the status quo. For example, it typically is necessary to rethink the nature of risk aversion that characterizes decision making in most Federal agencies, and to explicitly recognize uncertainty as a key attribute of natural resource management. Without a willingness to embrace uncertainty, adaptive management is unlikely to succeed (47).

In addition, adaptive management requires a much more open process of decision making, in which stakeholders are directly engaged and decision making authority is shared among them. It also requires that objectives, assumptions, and the other elements of the decision making process be explicit, and therefore amenable to analysis and debate. Finally, it requires a strong commitment by managers to the necessary monitoring and assessment that underlie adaptive management, not as marginal activities but as essential elements of the process. It is undoubtedly true that many, perhaps most, projects in DOI involve monitoring, and in some cases management actually considers the results of monitoring. But that by itself is a long way from structured, adaptive decision making in a learning-based environment.

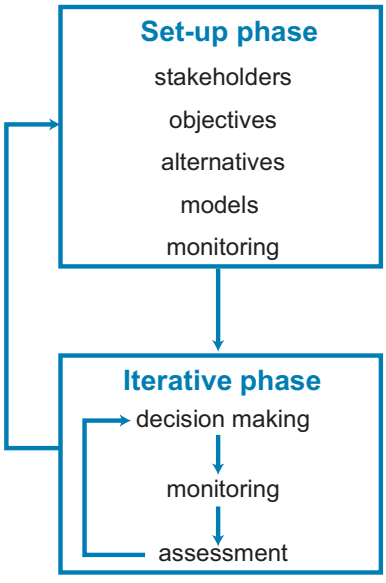
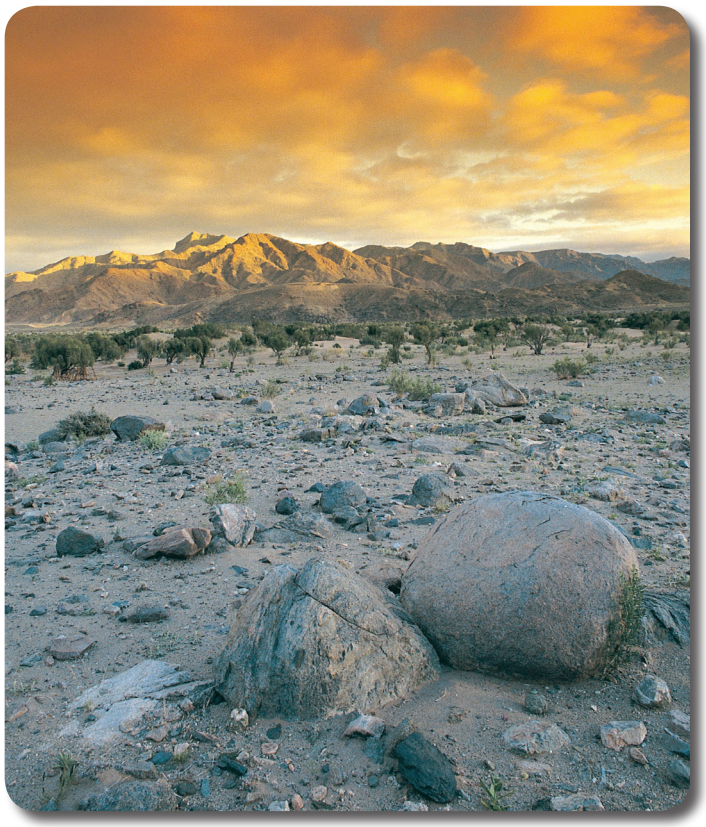


Figure 3.4. Two-phase learning in adaptive management. Technical learning involves an iterative sequence of decision making, monitoring, and assessment. Process and institutional learning involves periodic reconsideration of the adaptive management set-up elements.

3.2. Legal Considerations when Applying Adaptive Management

In addition to ecological and societal factors, a number of legal considerations influence adaptive management and potentially constrain its success. The Federal government is often criticized for the length of time it takes to plan and implement a particular action, and public concerns increase when an agency reconsiders its action and begins planning and compliance activities all over again. Well-designed and executed adaptive management strategies can help to alleviate this concern.

Agency officials should invest significant effort on legal issues at two critical stages of adaptive management: (1) at the time a decision is made to utilize adaptive management for a particular project and (2) at the time the agency seeks to adjust management decisions based on the information derived from monitoring and assessment. Knowing what federal laws and regulations require, and what limitations apply prior to agency decisions, allows stakeholders to anticipate the legal requirements and integrate them into the adaptive management process. However, agency officials should recognize that some laws and implementing regulations prescribe specific activities and assessments in ways that could limit or even preclude the use of adaptive management.



Application of adaptive management will vary depending on geographic setting, ecological complexity and participating stakeholders, as well as the specific statutory provisions authorizing and sometimes constraining actions. Some examples include:

- National Park Service Organic Act of 1916 (applicable to the National Park Service).

- Reclamation Act of 1902 (applicable to the Bureau of Reclamation).

- Surface Mining Control and Reclamation Act of 1977 (applicable to the Office of Surface Mining).

- Federal Land Policy Management Act of 1976 (applicable to the Bureau of Land Management).

As a general matter, statutes of this type impose obligations on a particular agency. In addition, a number of statutes apply to all Federal agencies and serve to either limit agency actions or require certain tasks before an agency takes action. Regulations issued by other Executive Branch agencies can also limit agency actions.

The use of adaptive management within the Department of the Interior does not alter the legal context that applies to Federal agency actions. Simply put, all of the applicable laws, regulations, and polices continue to apply to agency actions whether or not adaptive management principles are used in a particular context.

Statutory and other authorities that apply to Interior agencies

The first place to look for the authorized boundaries of agency activity is in the statutory foundation or appropriations authority that supports the activity. Although few useful generalizations can be made about statutory requirements, the importance of identifying underlying authorities cannot be overstated. Employees working on an adaptive management project should understand the authority under which they are entering into the project and be sure to embark on it only when there is clear statutory authorization.

The statutes discussed here are not intended to provide an exhaustive accounting of applicable law. However, they are some key authorities that agency personnel should consider regarding adaptive management. Many other statutes such as the Clean Air Act, the Clean Water Act, and the National Historic Preservation Act may be involved in particular applications of adaptive management.

One of the benefits of clean water in the Cold River, a salmon stream in Massachusetts

Native American wickiup structures were listed in 2003, on Colorado's Most Endangered Places List by Colorado Preservation, Inc. The Wickiup Project is supported by the Bureau of Land Management, Dominquez Archaeological Research Group and the Colorado State Historic fund.

In the examples below, Departmental employees are assumed to be actively working with non-Federal stakeholders on an adaptive management project. Most projects of adaptive management involve such interactions at some level of the application.

Statutory authorities that apply directly to adaptive management

National Environmental Policy Act. One of the most important statutes for an agency to consider as it implements adaptive management is the National Environmental Policy Act (NEPA). The primary goal of this statute is to ensure that agency decision makers and the public recognize and account for environmental and other related impacts of proposed agency actions.

Compliance with NEPA generally requires a series of procedural steps, and certain NEPA processes involve public participation and public review and comment. In complex or controversial situations, NEPA potentially involves the preparation of a Notice of Intent to prepare an Environmental Impact Statement (EIS), as well as a Draft EIS, a Final EIS, and a Record of Decision assessing environmental impacts of major Federal actions. In less complex or controversial actions, environmental compliance often can be accomplished with a simpler Environmental Assessment (EA) that culminates in a Finding of No Significant Impact. In some cases, an action can be categorically excluded from the requirement for NEPA compliance.

The NEPA requires an EIS of proposed "major Federal actions significantly affecting the quality of the human environment." An EIS must include an analysis of alternatives to a proposed action. The activities resulting from a particular adaptive management process may rise to the level of a major Federal action requiring an EIS, and in any event they likely will need to be analyzed for NEPA compliance. Less complex or controversial actions may be addressed by a less comprehensive EA. Under NEPA, following the completion of an EA the agency will either identify significant impacts (and prepare an EIS), or prepare a Finding of No Significant Impact. Of course, some actions can be categorically excluded from NEPA's documentation requirement.

As an example, a proposal resulting from collaboration between a DOI agency and an environmental nonprofit organization might call for the nonprofit to conduct habitat improvement for a protected species. It is possible that this undertaking could be considered a major Federal action. In such a circumstance, the collaborative activities resulting in a Federal action covered by NEPA must comply with NEPA's documentation and procedural requirements. Given that many Federal actions may be challenged in Federal court, non-Federal stakeholders should be made aware of the possibility of litigation inherent in Federal actions.

An EIS incorporating adaptive management, whether as a "stand-alone" alternative or part of another alternative, needs to clearly describe how the approach would be implemented. This not only includes what types of actions are proposed initially, but also the results that are expected from monitoring and assessment, and future actions that may be implemented based on those results. Decision makers and the public must be able to see how the adaptive management approach would be implemented, including potential future actions and anticipated impacts on the environment.

One common challenge to making adaptive management work in natural resource decision making is that ongoing monitoring may reveal "new, significant information" that requires an agency to prepare a Supplemental Environmental Impact Statement. This requirement is triggered when "[t]he agency makes changes in the proposed action that are relevant to environmental concerns; or [t]here are significant new circumstances or information relevant to environmental concerns and bearing on the proposed action or its impacts" (40 CFR § 1502.9 (c)). If management adaptations that could occur in light of new information are fully documented and analyzed at the beginning of a NEPA process, the need to supplement NEPA documents may be reduced. Put differently, if an EIS anticipates significant information that can arise from monitoring and assessment, the agency may not need to supplement the EIS when invoking management changes based on the newly acquired information.

An important statute for an agency to consider as it implements adaptive management is the National Environmental Policy Act . The primary goal of this statute is to ensure that agency decision makers and the public recognize and account for environmental and other related impacts of proposed agency actions.

Endangered Species Act. The Endangered Species Act of 1973 (ESA) provides a broad, comprehensive approach to the conservation of threatened and endangered species. By Congressional direction, the ESA is administered by the U.S. Fish and Wildlife Service (FWS) and the NOAA-Fisheries (National Marine Fisheries Service). In general, the FWS deals with terrestrial and fresh water species, while NOAA-Fisheries deals with anadromous fish and marine species. As part of their administration of the ESA, these agencies:

- "List" endangered and threatened species
- Designate critical habitat for listed species
- Publish plans to identify actions needed to assist in the recovery of listed species
- Consult with other federal agencies whose actions may affect listed species
- Work with non-federal entities to develop and approve habitat conservation plans
- Work cooperatively with other nations to conserve listed species
- Administer international agreements to limit trade in endangered and listed species

Of particular relevance to Federal agencies engaged in activities that may affect listed species is Section 7 of the ESA. Section 7 enlists agencies of the Federal government to support species conservation and avoid actions that would contribute to species extinction.

Given the importance of conserving endangered and listed species, the complexity associated with protecting these imperiled species, and the impacts the ESA may have on society and agency decision making, any adaptive management program that may affect listed species or critical habitat is more likely to be successful if it involves FWS and/or NOAA early in the process. Key to efficient and effective consultation is an initial description of the range of potential adaptations and effects of those actions on listed species and their designated critical habitats. Re-initiation of consultation is far less likely to be needed if the initial consultation clearly considers the action to be adaptive and addresses the full range of possible adaptations and their associated potential effects.

In some cases involving large-scale Federal programs, consultation is appropriate at both a broad programmatic level as well as the level of individual projects or actions that may affect listed species. Careful consideration of effects and alternatives can set the stage (for example, through adoption of best management practices or design standards) for expedited consultation on later individual actions.

Agencies whose actions may affect listed species should design monitoring programs with input from FWS and/or NOAA-Fisheries. Learning by doing - the critical centerpiece of adaptive management - is particularly important in ESA situations, where cause and effect can be particularly difficult to ascertain. New information on listed species, or the effects of actions on listed species, may require re-initiation of Section 7 consultation by a Federal agency, or may trigger changes in habitat protection pursuant to approved Habitat Conservation Plans (HCP). Knowing and understanding the ESA and its requirements will be essential to successfully integrating the elements of an adaptive management program with efficient ESA procedural compliance.

Integration of adaptive management principles has been utilized by the FWS in the context of HCPs under Section 10 of the ESA. The FWS has developed guidelines regarding this aspect of HCP planning (included in the reference CD). Particular attention should be given to the issue of which party is to be responsible for any required changes in mitigation and/or minimization of "take" to listed species as a result of monitoring programs. Any effort in this regard must take into consideration the No Surprises assurances that a permittee can receive pursuant to the regulations that implement Section 10(a)(1)(B).

The Endangered Species Act's purposes include providing a means to conserve the ecosystems upon which endangered and threatened species depend, and providing a program for the conservation of the species

Federal Advisory Committee Act ("FACA"). Under FACA, Department officials may not receive advice from a group that the Department has established or that it uses (i.e., manages or controls) unless the Department complies with the provisions of FACA. The FACA requires certain actions to set up and operate a committee or similar group to provide advice to Federal officials. FACA does not require any particular outcome regarding the substance of advice on a particular matter. Rather, it establishes a number of actions and approaches to ensure balanced consideration and input. These actions include filing a charter, providing public notice of meetings in the Federal Register, and making advisory committee information publicly available.

Federal officials who receive advice from non-federal stakeholders should be aware of FACA's potential applicability. However, FACA does not apply to every situation in which a Departmental official receives advice, but only to those situations in which the advice comes from a group that the Department has established or utilized. This means that FACA does not apply to advice received from individuals, even in a group setting (such as "town hall" meetings). Nor does it apply to advice received from preexisting groups, or groups that the Government neither manages nor controls. It does not apply to groups that simply exchange facts or information; or groups that are authorized to carry out operational functions; or groups consisting of only Federal, state, local, and tribal government employees exchanging views, information, or advice on programs with shared intergovernmental responsibilities. Finally, under some circumstances groups may be exempted from the requirements of FACA by another statute (such as the ESA for Recovery Implementation Teams). For more information on FACA, employees should consult FACA regulations in 41 C.F.R. Part 102-3.

Funding authorities

Annual Appropriations Acts and Funding. Agency activities cannot be undertaken without available funds that are allocated for a particular purpose. Occasionally, Congress may insert specific limitations in annual appropriations acts that could affect agency activities. For example, Congress may enact a provision stating that no Federal funds may be spent to map natural gas deposits off the coast of California or to study decommissioning of the Glen Canyon Dam. In these situations, any Departmental effort to map deposits or undertake such a study would be impermissible, even if a non-Federal stakeholder thought the activities would assist a particular adaptive management process or a non-Federal partner donated the necessary resources and/or data for the efforts.

Antideficiency Act. The Antideficiency Act contains a series of controls over the use of Federal appropriated funds to ensure that Federal agencies "pay as they go." Government officials are prohibited (without specific authority) from making payments, or committing the United States to make payments at some future time, unless there are available agency funds to cover the cost in full. The Antideficiency Act applies to applications of adaptive management just as it does to all other Federal activities. In essence, no agreement should be entered into that commits an agency to the payment of funds in the future, in advance of available appropriations to fund activities under the agreement. For example, an agreement by an agency that commits $100,000 in grant funds to a particular organization for each of the next 5 years will likely be improper under the Antideficiency Act, unless there are sufficient agency funds that are available for the grant for more than one year.

Other relevant statutes and authorities

Administrative Procedure Act (APA). The APA provides a procedure by which Federal agency actions may be challenged in court. Although there are several ways to challenge an agency action under APA, the most commonly employed is the claim that an agency action is "arbitrary, capricious, an abuse of discretion, or otherwise not in accordance with law." This standard applies equally to adaptive management projects as to other activities, so agency decisions in a particular adaptive management application may ultimately be reviewed by a court. To survive a court challenge, agency decisions must therefore be rational, reasonable, and carefully articulated.

APA challenges are usually decided on the basis of the administrative record (the materials upon which the agency officials relied in taking action). Challenges to activities in adaptive management applications are no different. Departmental employees must therefore ensure that their decisions and actions are based on, and supported by, a complete and thoroughly documented administrative record. Finally, the APA may also provide the basis for challenges under NEPA, the ESA, and other statutes.

Substantive Statutory Authority. Often a statute that authorizes an activity will also contain specific limitations. For example, a statute that authorizes the Secretary to establish a wildlife refuge in cooperation with a State may also require the Secretary to ensure that State laws apply on the refuge. Conversely, Congress may enact statutes that forbid a particular activity. For example, Congress has forbidden Federal agencies from creating business corporations.

Lobbying Activities. Under 18 U.S.C. § 1913 and related authorities, most Department employees may not expend appropriated funds for "grass roots" lobbying that is designed to influence a member of Congress or official of any government (Federal, State, local, tribal) regarding his or her position on legislation. That is, Federal employees may not engage in lobbying. This restriction prohibits encouraging a stakeholder to undertake lobbying activities in support of the Department.

Freedom of Information Act. The Freedom of Information Act (FOIA), codified in 5 U.S.C. § 552, provides members of the general public potential access to any information created or obtained by the Department and under the Department's control at the time of a FOIA request. Department personnel should keep in mind that documents generated during adaptive management activities will generally be agency records that are subject to release under the FOIA. However, the Department may withhold documents from the public that fall within one of nine specified FOIA exemptions. Agency personnel will want to consider how they intend to gather, store and publish information developed as part of the adaptive management process, and work with their agency's FOIA offices when responding to requests for information.

Data Quality Act. Although relatively new, the Data Quality Act (DQA) is increasingly affecting the work of Interior agencies. Passed in 2001 as part of the Treasury and General Government Appropriations Act, the DQA directs the Office of Management and Budget to publish guidelines applicable to Federal agencies, and provide policy and procedural guidance to Federal agencies for ensuring and maximizing the quality, objectivity, utility, and integrity of information (including statistical information) disseminated by Federal agencies. Each agency should assess the applicability of the DQA to new or ongoing adaptive management projects.

Governmental Integrity. Because agency decisions, whether products of adaptive management or not, will only stand up if they comport with the law and are not "arbitrary and capricious," agency officials must constantly work to ensure that the agency's decisions are supportable based on the information that is available to the agency. In carrying out agency activities, Departmental employees should always act in an unbiased, fair, and equitable manner, so as to ensure that the public will not have cause to question the integrity of the Federal government. All Federal employees should endeavor to act impartially and to avoid giving preferential treatment, or the appearance of preferential treatment, to any private entity.

Making Adaptive Management Work: The Importance of Integrating Adaptive Management and NEPA

NEPA serves as a pre-decisional requirement and analytical process with the goal of ensuring that both the public and Federal decision makers are fully aware of the potential impacts of a discretionary Federal action. Expanding the NEPA framework to accommodate the iterative, data-driven process of adaptive management requires the integration of learning-based strategies into the existing framework of NEPA requirements and the implementing regulations. Of course, compliance with other environmental statutes, regulations, and Executive Orders is also necessary.

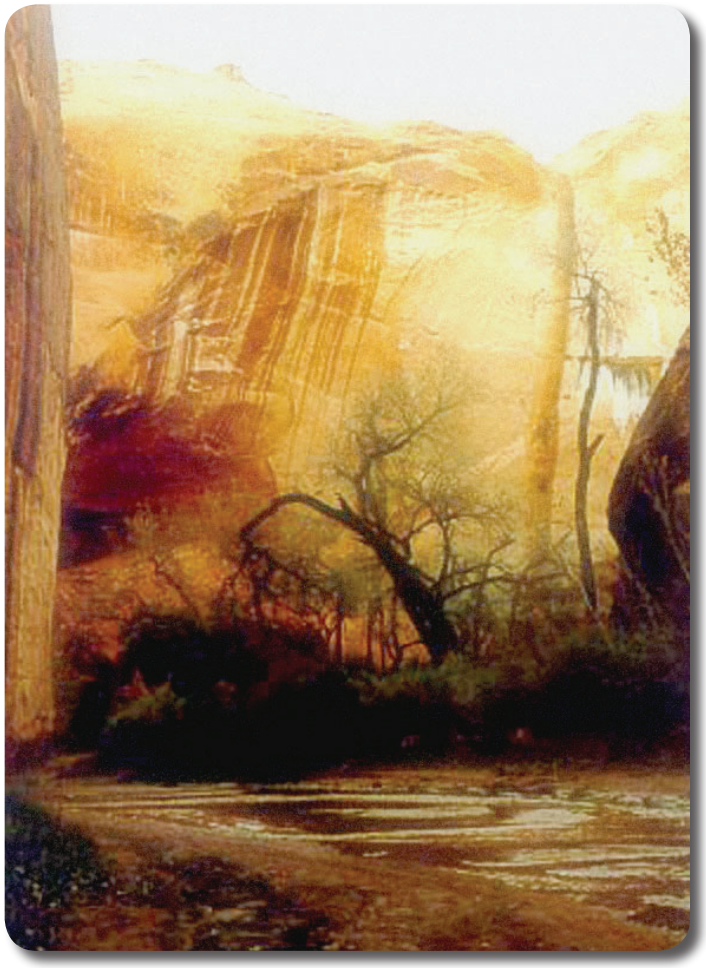
Federal agencies are encouraged to use adaptive management as part of the NEPA planning process, particularly in circumstances where long-term impacts are uncertain and informed decisions in the future will depend on monitoring and assessment at that time. Any adaptive management alternatives in an Environmental Impact Statement can be crafted to allow the necessary flexibility for strategy adjustment as learning advances through monitoring and assessment. Agencies are encouraged to build this flexibility into their management alternatives and NEPA compliance activities. Training of NEPA practitioners in this important environmental concept is paramount.

Because NEPA analysis and compliance is procedural and predictive, and includes the evaluation of "all reasonable alternatives," it is important to include a sufficiently broad range of management options to ensure a comprehensive environmental analysis and a "NEPA coverage" that is adequate for whatever contingencies are anticipated. The idea is to satisfy the NEPA requirements for scientific analysis of potential impacts, and provide full disclosure of those impacts. Thoughtful and carefully structured alternatives should avoid the triggering of additional NEPA compliance later.

Alternatively, another approach to NEPA compliance that has proven successful for adaptive management programs is to prepare a "programmatic" EIS at the start, which broadly covers the likely range of actions that may be taken under the particular adaptive management program. Later, any NEPA compliance needed for subsequent shifts in the management actions as a result of the adaptive management process can then "tier" off of the initial programmatic EIS, saving considerable time and work.

Where appropriate, greater use of Environmental Assessments could help to integrate NEPA and adaptive management, especially if environmental analyses will be needed subsequent to an initial EIS and impacts are not expected to be significant. An Environmental Assessment is generally much easier to prepare than an EIS.

If an agency is constantly undergoing NEPA compliance and documentation, it may be because the original NEPA process failed to fully consider a broad range of potential adaptive management modifications. Frequent follow-up NEPA compliance can erode the public's perception of the integrity of the process, and impede the ability to react to new, relevant information. NEPA is first and foremost a public process, and its credibility and successful implementation is predicated on the public's perception that it is transparent and involves full disclosure of the potential environmental effects of Federal actions.



Coyote Gulch

3.2 Key Points

- Adaptive management must be integrated with all existing legal obligations of the agency; it is not a replacement for environmental compliance.

- Adaptive management must comply with NEPA and other environmental laws. Integration of adaptive management and other legal obligations requires thoughtful "up-front" planning, and involves an investment of time and resources by the agency and other stakeholders.

- Integrating environmental review procedures with adaptive management requires consideration of the range of adaptive actions and attendant environmental effects that can reasonably be anticipated at the time of the environmental review.

- The management alternatives and effects considered in an adaptive management application must be reviewed in light of the relevant environmental laws and regulations, so that environmental compliance applies not only for the initial action, but also for adaptive redirections that may be needed in the future.

- For some adaptive management applications, it may be appropriate to assess environmental effects of future adaptive actions on a case-by-case basis using streamlined environmental assessments or informal consultations. Such an approach may serve to strengthen the case for compliance when uncertainty exists regarding the environmental effects of future adaptive actions.

- Key to successful integration of NEPA and adaptive management is a well planned and thorough up-front consideration of the range of potential actions and their effects, so as to ensure that future actions and their effects are within the scope of the initial analysis and do not require subsequent environmental analysis.

Chapter 4: When is Adaptive Management Successful?

4

Chapters 1 and 2 address the context and conditions for adaptive management to be applicable to resource management, and Chapter 3 describes adaptive management in operational and legal terms. In these chapters we referred to the successful implementation of adaptive management without ever explicitly defining success. Here we offer a definition, criteria, and steps to promote successful implementation.

4.1. Recognizing Success in Adaptive Management

In general, the implementation of adaptive management is defined as successful if progress is made toward achieving management goals through a learning-based (adaptive) decision process. This definition contains two essential elements. First, it requires progress toward achieving objectives, a primary indicator of success with any management strategy, whether adaptive or not. Second, it requires learning-based management, as described in the nine-step operational sequence in Chapter 3. Specifically, stakeholder involvement, an effective monitoring program, and agreed-upon objectives, management alternatives, and models must be integrated into an iterative learning cycle (see Fig. 3.4). Of course, the decision making process must be framed in a context of applicable laws, authorities, and regulations.

Based on this definition, we suggest the following four criteria for recognizing success in adaptive management (Fig. 4.1):

- Stakeholders are actively involved and committed to the process.
- Progress is made toward achieving management objectives.
- Results from monitoring and assessment are used to adjust and improve management decisions.
- Implementation is consistent with applicable laws.

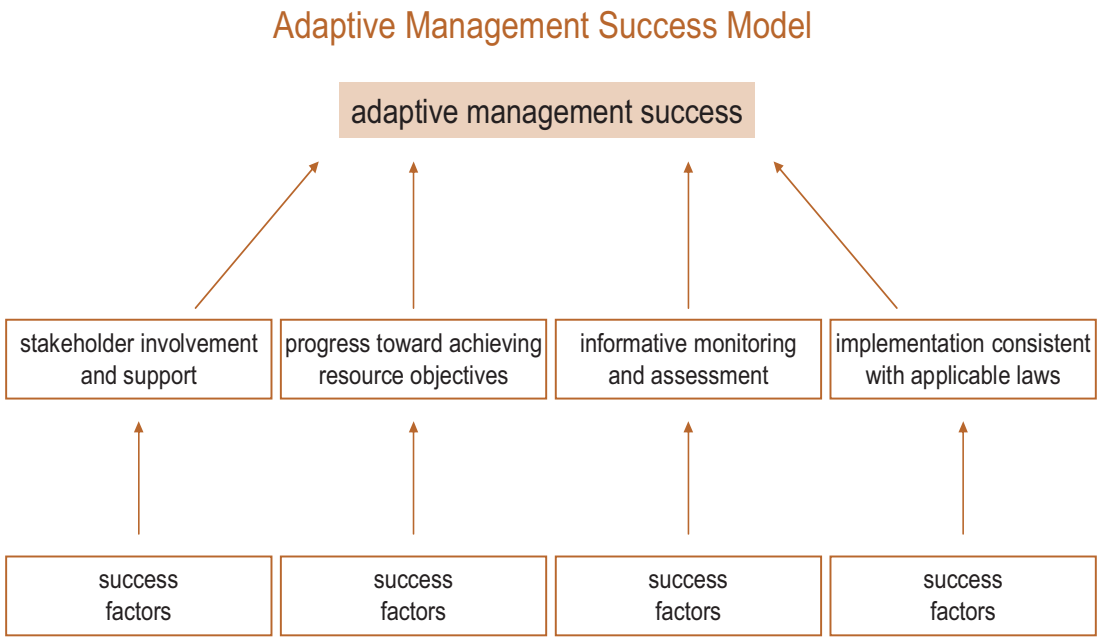


Figure 4.1. Adaptive management success model, with four success criteria. Success factors for each criterion are addressed by a series of questions that help practitioners increase the likelihood of success.

These criteria integrate the structural elements and processes described in the preceding chapters. They are interrelated and interdependent, and should be viewed collectively as indicators of success.

For an adaptive management project to be successful, all four criteria must be met over the project timeframe. For example, an adaptive management project is not considered fully successful if stakeholders do not see the resource management process as legitimate. Likewise, results from monitoring and assessments must be used to inform adjustments in management practices for it to be fully successful.

Stakeholders are actively involved and committed to the process

Broad stakeholder involvement is critical for adaptive management success. Recall from Chapter 3 that engaging stakeholders is one of the key steps in adaptive management. Ideally, stakeholders are engaged in every aspect of adaptive management, from the initial problem formulation to the identification of objectives and the design of monitoring and assessment. The fact that stakeholders play a role in all aspects of the process argues for singling out stakeholder involvement as a key success criterion.

Including stakeholders in the adaptive management process reinforces stakeholder perceptions of adaptive management as a legitimate process, which in turn encourages cooperation and reduces the likelihood of conflict. Stakeholder involvement in problem identification, process design, monitoring and assessment, and other elements of the adaptive management process builds support for the process and provides a foundation for learning-based resource management. It also provides opportunities for resource managers to obtain additional information about the natural system and priorities for its management before decisions are made. Conversely, a lack of stakeholder involvement can by itself cause the process to fail.

Progress is made toward achieving management objectives

In structured decision processes, clear and measurable objectives guide decision making and serve as metrics for assessing management performance. Because adaptive management by design pursues management benefits as expressed in the management objectives, progress toward achieving objectives is a natural criterion of success.

Two points about objectives are emphasized here. First, the objectives in natural resources management often are multidimensional, and thus involve tradeoffs. Improving an outcome associated with one objective may involve tradeoffs with outcomes associated with other objectives. When multiple management objectives are identified, it is important to recognize and account for the relationships among them, so that potential tradeoffs can inform decision making. In this way, consistent and achievable resource management goals and thresholds can be established.

Second, it is important to recognize that management objectives may change. In many cases, success in attaining objectives can be an ongoing process that involves refinement of objectives as understanding accumulates and stakeholder perspectives change. That is, the adaptive management system is itself dynamic, including its objectives. Adaptive management needs to include not only the cyclic evaluation of project performance, but also a periodic reassessment of the project objectives.

Results from monitoring and assessment are used to adjust and improve management decisions

The accumulation of understanding and subsequent adaptation of management strategy depends on feeding monitoring and assessment results back into the decision making process. Monitoring and assessment efforts should be designed to ensure that key resource parameters are adequately measured and appropriately focused, so as to contribute to achieving success. In Chapter 3 these key process elements were seen to factor directly into the operational sequence that defines adaptive management.

Here we emphasize the importance of monitoring resource responses and using the resulting information to assess system models, update their confidence measures, and reduce system uncertainty. Scientists, managers, and stakeholders should collaborate in an interdisciplinary assessment of what is known and what is learned about the system being managed. Success in adaptive management ultimately depends on effectively linking monitoring and assessment to objective-driven decision making.

Implementation is consistent with applicable laws

It is almost axiomatic that implementation of adaptive management must be consistent with applicable laws to be considered successful. The use of adaptive management in a manner that is not consistent with applicable laws will eventually lead to distractions from the project objectives, or to a breakdown in trust among stakeholders, or to a litany of official – and unofficial – sanctions.

Ensuring that an adaptive management application complies with applicable laws, regulations, and policies can be challenging because of the many legal considerations and complexities that may be involved. Thoughtful, detailed planning and constant attentiveness to the requirements of laws, regulations, and policies are needed to ensure the success of an adaptive management project.

This criterion should not be assessed in isolation. In large measure, success with the previous criteria will affect stakeholder assessments of whether an adaptive management project remains in compliance with applicable legal considerations. For example, if serious disagreements persist among stakeholders regarding the appropriateness of monitoring protocols and results, one or more of the stakeholders may challenge the validity of the program's results. This in turn can lead to withdrawal of stakeholder support, loss of continued funding, and even litigation.

Using the success model

A key success metric that adaptive management shares with all management strategies is progress toward the achievement of management objectives. As an adaptive management project moves forward in time, it should be possible to compare management performance against expectations, to get some idea of the progress made up to that time in achieving objectives. In the absence of at least some indication of progress over a reasonable period, there is little justification for continuing a project in its current form.

All four success criteria need to be met for successful implementation of adaptive management. They should be considered when initially developing an adaptive management project, and reviewed periodically over the life of the project to evaluate project implementation and assess the likelihood of achieving objectives. In fact, the success criteria can themselves be used adaptively, to determine where changes are needed in order to achieve success.

The success model provides a framework for both technical and process learning, as described in Section 3.1. The focus is on adaptation not only at the technical level, through an iterative application of decision making, monitoring, and assessment, but also at the institutional and process level, through periodic assessments of stakeholder perspectives, management objectives, and other process elements. The successful application of adaptive management potentially involves learning and adaptation at both levels. The following section includes questions that can be useful in implementing and evaluating the success of an adaptive management project.

Avian Influenza Sampling Project 2006

USGS scientist is measuring various water-quality conditions in Holes Creek at Huffman Park in Kettering, Ohio.

4.2. Key Questions for Successful Implementation

The following questions can be used to increase the likelihood of successful adaptive management, and to evaluate progress in achieving objectives. The questions address each of the criteria identified in Section 4.1 and are tied to the operational steps discussed in Section 3.1 and shown in Box 4.1. The questions should be considered throughout the timeframe of an adaptive management project, to ensure that success is continually considered and evaluated as the project progresses. A particular adaptive management project may not be able to address all of the issues outlined in the following questions. However, the questions encompass an important set of issues that should be considered, so as to increase the likelihood of success.

Box 4.1 Adaptive Management Operational Steps

Set-up phase

- *Step 1 - Stakeholder involvement*
  Ensure stakeholder commitment to adaptively manage the enterprise for its duration
- *Step 2 - Objectives*
  Identify clear, measurable, and agreed-upon management objectives to guide decision making and evaluate management effectiveness over time
- *Step 3 - Management actions*
  Identify a set of potential management actions for decision making
- *Step 4 - Models*
  Identify models that characterize different ideas (hypotheses) about how the system works
- *Step 5 - Monitoring plans*
  Design and implement a monitoring plan to track resource status and other key resource attributes

Iterative phase

- *Step 6 - Decision making*
  Select management actions based on management objectives, resource conditions, and enhanced understanding
- *Step 7 - Follow-up monitoring*
  Use monitoring to track system responses to management actions
- *Step 8 - Assessment*
  Improve understanding of resource dynamics by comparing predicted vs. observed change in resource status
- *Step 9 - Iteration*
  Cycle back to Step 6 and, less frequently, to Step 1

Step 1- Stakeholder involvement

Two key aspects of stakeholder involvement are emphasized here. First, participation by stakeholders is essential if only because stakeholder perceptions of adaptive management as a legitimate process can promote cooperation and reduce the likelihood of conflict. Second, including stakeholders in the process provides opportunities for resource managers to obtain additional information about both the natural system and stakeholder values and priorities before decisions are made. Involving stakeholders builds support for the process and provides a foundation for learning-based resource management.

Key questions to consider when involving stakeholders in an adaptive management project include:

- Has a systematic process been developed that facilitates effective participation by stakeholders?
- Have key stakeholders been identified?
- Have agreed upon lines of communication been established and is their importance to successful adaptive management processes understood?
- Are stakeholders committed to and involved in the adaptive management process including the monitoring and assessment program?
- Is the adaptive management process able to adapt to changes in stakeholder and public viewpoints?

Step 2- Objectives

Objectives in adaptive management play important roles in decision making, evaluation, and learning. These roles are enhanced by the articulation of clear, measureable, and agreed-upon objectives. Because they can change through time as the resource system changes and stakeholder values evolve, it is useful to revisit objectives periodically.

Keeping the following questions in mind will increase the likelihood that decision making will be guided by resource management objectives:

- Have explicit and measurable management objectives been identified and developed?
- Are the management objectives achievable and sustainable?
- Have performance metrics relating to the management objectives been developed?
- Has a system of monitoring and assessment relevant to the management objectives been developed and implemented so that progress in meeting the objectives can be tracked?
- Have tradeoffs among management objectives been considered and are they understood?

Step 3- Management actions

The set of potential management actions determines the range of management flexibility for an adaptive project, and influences learning rates as well as progress in achieving management objectives. Learning is promoted by a wide range of management alternatives, but hampered by alternatives that differ only marginally. As with other components of an adaptive management project, the acceptable range of management options can change through time, as stakeholder perspectives and resource conditions evolve, legal requirements change, and new information becomes available.

Key questions about the set of management alternatives in an adaptive management project include the following:

- Has a range of potential management actions been developed?
- Have the specific tasks to implement the management alternatives been identified?
- Is the range of potential actions appropriate for the timeframe under which changes are likely to occur?
- Can the set of management alternatives be adjusted through time if needed?

Step 4- Models

Models serve as expressions of ecological understanding, as engines for deductive inference, and as articulations of resource response to management and environmental change. They also help bring together scientists, managers, and other stakeholders in a joint assessment of what is known about the system being managed, and facilitate an interdisciplinary approach to understanding through monitoring and assessment. It is important to keep the many roles of models in mind as an adaptive management project is implemented.

The following questions relate to the models used in an adaptive management project:

- Are the hypotheses underlying the strategies for resource management expressed as testable models?
- Have explicit links between management actions and resource dynamics been incorporated into the models?
- Are the ecological/resource processes that drive resource dynamics understood?
- Are the relevant environmental factors incorporated into the models?
- Are the models calibrated with available information?

Step 5- Monitoring plans

The use of objectives to guide decision making depends on linking monitoring and assessment results with the decision making process. Both monitoring and assessment should be designed to ensure that resource parameters are adequately measured and appropriately focused on relevant performance indicators. Effective and useful monitoring is required for the hypothesis testing that leads to the reduction of uncertainty that is key to adaptive management.

Important questions about the monitoring plan for an adaptive management project include the following:

- Will the monitoring plan support the testing of alternative models and measurement of progress toward accomplishing management objectives?
- Is it clear what monitoring data need to be collected to estimate the relevant resource attributes?
- Has the level of accuracy that is needed been identified?
- Are commitments among managers, scientists, and other stakeholders in place to sustain an ongoing monitoring and assessment program?
- Will meaningful and useful data and information be available within timeframes that allow for adaptive decision making?

Step 6- Decision making

An adaptive management strategy identifies actions at each point in time, with strategy implementation at a particular time based on resource status and understanding. The strategy typically evolves through time, as learning accumulates and the resource system responds to management actions.

Key questions about iterative decision making in an adaptive management project include the following:

- Is it clear how decisions will be made?
- Are decisions at each point in time based on the current status and understanding of the resource?
- Are decisions being guided by management objectives?
- Are stakeholders informed and consulted before decisions are made or changed?

Step 7- Follow-up monitoring

The effects of decision making are tracked with post-decision monitoring, and the data collected are used to gauge progress in meeting objectives and improve ecological understanding. Ideally, post-decision monitoring data can be folded into analysis/assessment before the next decision point, so that decision making at that time can take advantage of updated information and understanding.

Key questions about follow-up monitoring in an adaptive management project include the following:

- Are the analysis needs understood?
- Is monitoring conducted on a timely basis?
- Is monitoring targeted to system attributes that are useful for evaluation and learning?
- Are monitoring data collected and managed so that they are available and easy to access?
- Can the monitoring data be used to update the measures of model confidence?

Step 8- Assessment

The information from monitoring is used to evaluate management, improve understanding, and guide decision making. As noted in Chapter 3, these functions are promoted by the estimation of resource parameters and the comparison of these estimates against model-based predictions.

Key questions about analysis and assessment in an adaptive management project include the following:

- Have the expected impacts of alternative management strategies been evaluated?
- Is it clear how results are to be understood and interpreted?
- Have thresholds that indicate a change in management been recognized?
- Have the action(s) to be taken when a threshold is reached been identified?

Step 9- Iteration

The adaptive cycle of decision making, post-decision monitoring, and analysis/assessment (Fig. 3.3) leads to improved understanding as well as improved management. Periodic but less frequent cycling through the components of an adaptive management application (Fig. 3.4) allows for adjustments as stakeholder perspectives, institutional arrangement, and resource conditions evolve.

Key questions about iterative feedback in an adaptive management project include the following:

- Are management actions and decisions reviewed frequently based on monitoring and assessment?
- Have incentives been developed to encourage experimentation and learning?
- Have resource management alternatives been revisited and/or modified over time?
- Has uncertainty related to resource dynamics and the impacts of management actions been reduced through learning over time?
- Are the targets identified in the performance metrics likely to be achieved within the specified timeframe?

Legal considerations

Because of its scope and complexity, the legal framework for an adaptive management project can be confusing, and it is not always obvious to managers and practitioners which legal considerations to focus on. Among other things, this suggests the usefulness of engaging members of the DOI Solicitor's Office early on in an adaptive management project.

Key questions about legal considerations for an adaptive management project include the following:

- Are the applicable resource management laws and regulations understood by managers, scientists, and other stakeholders?
- Have steps been taken to comply with applicable laws and regulations?
- Has a process been developed to focus on compliance throughout the project life?
- Is the process in compliance with specific legal mandates?

4.2 Key Points

- ❖ Adaptive management allows managers to determine systematically whether management activities are succeeding or failing to achieve objectives.
- ❖ An adaptive management project is recognized as successful if (1) stakeholders are involved and committed to the process; (2) progress is made toward achieving management objectives; (3) results from monitoring and assessment are used to adjust management decisions; and (4) implementation is consistent with applicable laws.
- ❖ The implementation of adaptive management can be facilitated by considering a series of questions related to the success criteria and the operational steps.

Rather than relying on anecdotal information about resource status, managers can use monitoring and evaluation adaptively to make smart decisions

In the course of writing this technical guide, contributors and reviewers raised a number of important issues that do not fit naturally into other chapters, but nevertheless merit discussion. Because no document can address all the issues that might arise in adaptive management, DOI bureaus and offices may wish to develop their own planning and implementation guidelines, tailored to specific legal and institutional contexts and focused more directly on relevant authorities.

5.1. Uses of Information in Natural Resource Management

When considering the application of adaptive management, it is important to account for both learning and progress in achieving management objectives, as well as the possible tradeoffs between them. As indicated earlier, learning in adaptive management occurs through the comparison of model-based predictions against information from monitoring. The role played by monitoring, and the information produced from monitoring, is essential in adaptive management.

Several different approaches to resource management can be distinguished, depending on the relative emphases on learning and management objectives (38). Management approaches can range from an exclusive focus on management objectives with no concern for information and learning, to an exclusive focus on learning with little regard for achieving management objectives (60). The most extreme example of the latter is the use of management in a rigorously designed experiment, where the goal is to maximize the precision of contrasts among management treatments.

Management in the absence of systematic monitoring

In this situation, decision making is loosely focused on management objectives, and is based on prior experience, intuition, expert opinion, etc. Monitoring and assessment are not used systematically in decision making, so there is little or no opportunity for learning. This situation occurs more frequently than many believe. For example, managers often feel that their understanding of a resource system is sufficient for them to make smart decisions, and anecdotal information about resource status is all that is needed to inform those decisions.

Management based on resource status

Here the focus of decision making is on achieving management objectives, with little or no recognition of uncertainty in the decision making framework. Monitoring and assessment focus primarily on resource status, rather than the understanding of ecological processes. This approach is sometimes misidentified as adaptive management, presumably because the measures of resource status obtained through monitoring are considered in management actions. A great many multi-year resource applications are of this kind. However, few of these applications specifically focus on learning about the processes that control system dynamics.

Passive adaptive management

In this case uncertainty is recognized in the decision making framework, but the focus is on the achievement of management objectives, with learning as an untargeted byproduct. Ongoing monitoring programs focus on resource status as well as other system attributes that are useful for improved understanding through time, and assessment produces estimates of resource attributes that are used for learning. Because decision making is not focused specifically on learning, the rate of learning is likely to be substantially lower than with a more proactive approach.

Active adaptive management

Decision making involves the active pursuit of learning, either through experimental management that focuses directly on learning, or quasi-experimental management that focuses simultaneously on learning and achievement of management objectives. Both approaches anticipate the effect of management on the rate of learning, and both are included under the rubric of "management by experiment." Monitoring focuses on resource status as well as other system attributes needed to improve understanding through time, and assessment produces estimates of resource attributes that can be used for learning.

It should be emphasized that both active and passive adaptive management utilize management interventions in a learning process. The key distinction between the two approaches is the degree to which decision makers anticipate the influence of management on learning, and the degree to which management is used proactively to accelerate the rate of learning.

Figure 5.1 orders the management approaches described above with respect to their emphases on learning. Several points can be made. First, adaptive approaches to management place a greater emphasis on uncertainty and learning than non-adaptive decision making. Second, non-adaptive management is oriented solely on management objectives, whereas adaptive management considers learning as well. Third, passive adaptive management places a stronger emphasis on learning than non-adaptive management. As a general rule, it makes little sense to manage adaptively to reduce uncertainty, if uncertainty is not at issue in the management problem. When uncertainty does limit effective management, there often is substantial value in managing adaptively (see Section 2.1 for additional discussion on this point).

As a general rule, adaptive management is most useful when the consequences of management are uncertain, but objectives are clear and the potential for management intervention is high.

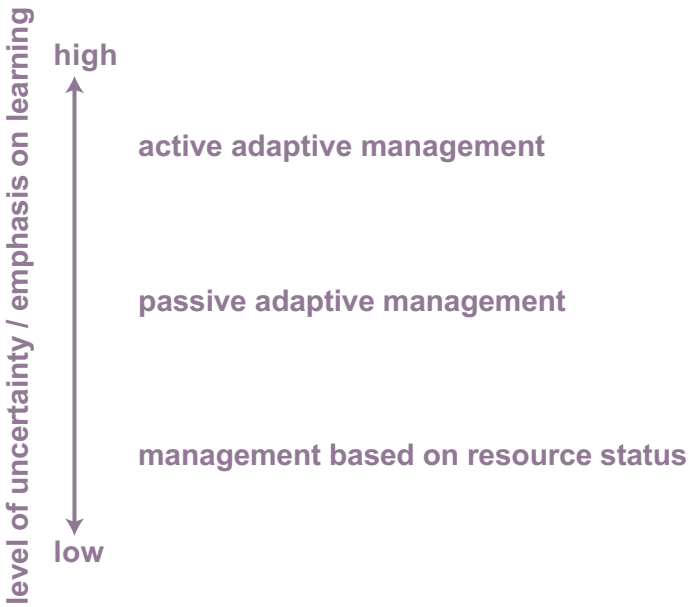


Figure 5.1. Priorities in different management approaches. Not shown is management in the absence of monitoring, which devalues learning and focuses only loosely on management objectives.

5.2. Accounting for Uncertainty in Adaptive Management

An important concern is how to represent and account for uncertainty in applications of adaptive management (61,62). At a minimum, four sources of uncertainty influence the management of natural resource systems.

Environmental variation is the most prevalent source of uncertainty, and is largely uncontrollable and possibly unrecognized. It often has a strong influence on natural resource systems, through such factors as random variability in climate.

Partial observability refers to uncertainty about resource status. An obvious expression of partial observability is the sampling variation that arises in resource monitoring.

Partial controllability expresses the difference between the actions targeted by decision makers and the actions that are actually implemented. This uncertainty typically arises when indirect means (for example, regulations) are used to implement a targeted action (for example, setting a harvest or stocking rate), and it leads to the possible misrepresentation of management interventions and thus to an inadequate accounting of their influence on resource behavior.

Structural or process uncertainty concerns a lack of understanding (or lack of agreement) about the structure of biological and ecological relations that drive resource dynamics.

Environmental variation, partial observability, partial controllability, and structural uncertainty all limit a decision maker's ability to make informed management decisions (Fig. 5.2). Special emphasis is given in adaptive management applications to structural or process uncertainty. However, the other forms uncertainty also can be incorporated in an adaptive management project, depending on their importance. For example, a typical approach to environmental variation is to include environmental conditions in the resource models in an adaptive management project (Fig. 5.2), with probabilities assigned to different values of the relevant environmental variables. In this way model behaviors will reflect environmental variation, as will the projected responses to management actions. Environmental variation therefore ramifies through the decision making process, as projected responses to management guide the selection of management actions.

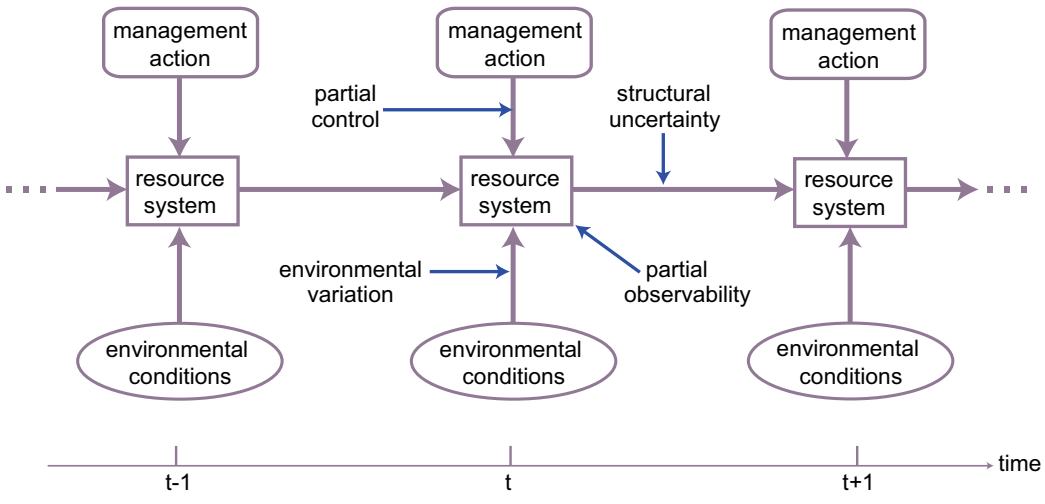


Figure 5.2. Uncertainty sources in natural resource management. Partial control limits the influence of management actions. Environmental variation affects resource system status and dynamics. Partial observability limits the recognition of system status. Structural uncertainty limits the ability to characterize system change.

5.3. The Measurement of Learning

Much has been said about learning in the preceding chapters, but questions remain about how learning actually is achieved and recognized. In Chapter 3, uncertainty was described in terms of different hypotheses about how a resource system responds to management actions, along with models imbedding these hypotheses and their associated measures of confidence. As evidence accumulates through monitoring, confidence grows in the models (and their associated hypotheses) that accurately predict responses to management, and confidence declines for models that are poor predictors. It is through the sequential comparison of predictions against monitoring data that the adequacy of a hypothesis about biological and ecological processes is gradually revealed. A comparison of hypothesis-based predictions against evidence is an essential feature of scientific investigation, and a key reason why adaptive management is described as "science-based."

Questions remain about possible mechanisms for updating the confidence in a particular hypothesis Generically, at each point in time one can use a measure of the difference between the response predicted by a model and the response estimated with monitoring data. A small difference indicates a good fit for the model, and a large difference indicates a poor fit. These differences can be calculated for each model after each post-decision monitoring event, and used to update confidence levels of the models through time. Depending on the desired rigor, an updating protocol can be fairly simple or technically complicated (63).

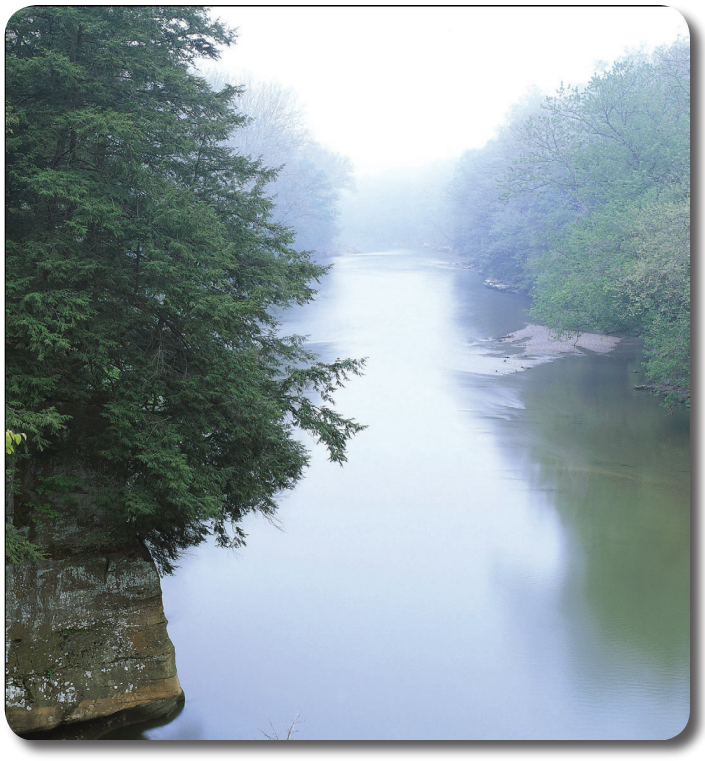
5.4. Learning Organizations

Learning in adaptive management derives from management actions, and is used in turn to inform subsequent actions. But many important issues about how best to facilitate learning are framed in terms of adaptive institutional arrangements, structures, and processes—features that are often lacking in traditional management (64). Despite frequent assertions about the use of adaptive management and the depiction of learning as a key element in applications, there has been limited progress in making adjustments to promote learning institutionally (48).

The notion of technical and process learning bears directly on the concept of learning-based organization, the institutional framework for adaptive management. At the heart of both an adaptive management project and the learning-based organization that supports it is the explicit recognition of uncertainty as a key attribute of natural resource management. Indeed, adaptive management is not feasible unless the relevant management institutions have the capability and willingness to embrace uncertainty (47). Among other things, embracing uncertainty means recognizing different views of a managed system, as well as a direct involvement of stakeholders who have different perspectives, and a commitment to shared decision making that allows uncertainty to be reduced.

At issue here is an organizational structure and context that can promote and facilitate an adaptive approach to resource management. Attributes of a learning organization include the following:

- acknowledgement that the world is uncertain and that failure to predict outcomes accurately is common.
- recognition of the importance of training people in group interactions and collaboration.
- positive reinforcement and rewards for experimentation and learning.
- recognition that surprises and even crises can be opportunities for learning (65).



In fact, many observers think that the major challenges facing adaptive management are fundamentally institutional (8). Institutions are built on major premises and long-held beliefs that are deeply imbedded in educational systems, policies, and norms of professional behavior (66). Yet Senge (4) argues that a learning organization is "… where people continually expand their capacity to create the results they truly desire, where new and expansive patterns of thinking are nurtured, where collective aspiration is set free, and where people are continually learning to see the whole together." There is a natural tension between the tendency of large, long-standing organizations to maintain a strong institutional framework for thinking and decision making, and the need in adaptive management for an open, collaborative approach that recognizes alternative perspectives, embraces uncertainty, and utilizes participative decision making (67).

Structuring a learning-based adaptive organization can be handicapped by a pervasive belief that adaptive management does not constitute a significant departure from the past, but is only a process of adjusting over time (51). One consequence is that little attention is given to the institutional barriers to its implementation, and little effort is expended on the redesign of organizational structures and processes to accommodate an adaptive style of management. At a minimum, it is necessary to rethink the notions of risk and risk aversion, and to promote conditions that encourage, reward, and sustain learning by individuals.

5.5. Realistic Expectations for Adaptive Management

Adaptive management is designed to produce gradual improvements in management through a stage-wise process that promotes incremental learning. However, there is nothing prescriptive in the notion of adaptive management about the length of time required to see substantive improvements in understanding and management. In some cases it may be possible to recognize improvement in only one or a few cycles of the adaptive cycle (Fig. 3.3). In others, learning occurs much less rapidly. Several conditions can influence the rate of learning, including the size and complexity of the resource system, the number and extent of management alternatives, and the sources and magnitudes of uncertainty.

Of interest here is the influence of the management approach itself on rates of learning. As mentioned above, learning can be accelerated by the use of active adaptive management, which utilizes management interventions proactively for the purpose of learning. Learning rates are maximized when interventions are imposed in an experimental context that includes randomization, replication and experimental control. Under these circumstances, contributions to resource objectives are temporarily postponed so that understanding can be attained as quickly as possible (68). Even here, however, environmental variation, partial controllability, partial observability, and the magnitude of structural uncertainty can slow the accumulation of knowledge, and thus impede the improvement of management.

One caveat about adaptation and the rate of learning should be mentioned here. We have described adaptive management in terms of a cycle of decision making, monitoring, and assessment that aims at reducing structural uncertainty (Fig. 3.3). Uncertainty is reduced gradually in adaptive management, through the sequential evaluation of hypotheses and accretion of knowledge about them. However, the accretion of knowledge is clearly undermined if the resource system changes more rapidly than the rate of learning about it. Even if system structure and processes remain relatively stable, the identification of strategies to achieve management objectives is undermined if the objectives change more rapidly than adaptive management can learn how to achieve them. The point here is that for adaptive management to be effective, the need to reassess and possibly change set-up phase components (stakeholders, objectives, alternatives, models, monitoring) should be less frequent than the iterative cycle of technical learning (decision making, monitoring, and assessment) (Fig. 3.4). Otherwise, learning cannot keep pace with changes in the structure of the resource system and changing stakeholder values and perspectives.

smallmouth bass

Key Points

- Active and passive approaches to adaptive management can be distinguished from other management approaches based on their treatment of uncertainty and emphasis on learning.
- Multiple sources of uncertainty can influence resource systems and alter the capacity to manage them.
- Learning is advanced by the sequential comparison of model predictions against monitoring data, whereby confidence in an underlying hypothesis is based on the relative accuracy of model predictions.
- The practice of adaptive management flourishes in a learning organization that is open to surprise, accommodates risk, and encourages and rewards learning.
- Learning in adaptive management proceeds most rapidly when pursuit of resource objectives is temporarily postponed so that management interventions are implemented according to an experimental design.

Concluding Remarks

Adaptive management can be applicable to local resource projects as well as large-scale conservation programs, though the legal constraints on an adaptive approach may differ across scales. But the basic framework presented in this technical guide, involving an iterative process of management, monitoring, and evaluation, applies in either case. The key issues in deciding to use adaptive management are whether there is substantial uncertainty about the impacts on management, and whether the reduction of that uncertainty can be expected to improve management.

For many important problems, adaptive management holds great promise in reducing the uncertainties that limit the effective management of natural resource systems. In many cases, utilizing management itself in an experimental context may be the only feasible way to gain the system understanding needed to improve management. In concept, adaptive management is neither conceptually complex nor operationally intricate. However, it requires refinements of the business models of DOI agencies, to more fully reflect system sustainability and resilience, more explicitly account for uncertainty, and more fully incorporate conservation planning, decision-based monitoring, and evaluation.

A realistic assessment of its challenges suggests that adaptive management is likely to be neither short-term nor inexpensive, and a considerable amount of up-front planning may be required. Stakeholders and implementing organizations must commit to providing the necessary resources for monitoring and assessment over the time required to make progress in achieving project objectives. In particular, an initial investment of time and effort will increase the likelihood of better decision making and resource stewardship in the future. The need for patience and flexibility in adaptive management highlights the importance of carefully considering the potential use of an adaptive approach, and careful planning and evaluation when adaptive management is used.

References

1. Sexton, W.T., A. Malk, R.C. Szaro, and N. Johnson (editors). 1999. Ecological Stewardship: A Common Reference for Ecosystem Management, Volume 3: Values, Social Dimensions, Economic Dimensions, Information Tools. Elsevier Science, Oxford, UK.

2. Haber, S. 1964. Efficiency and Uplift: Scientific Management in the Progressive Era, 1890–1920. University of Chicago Press. Chicago, IL.

3. Bormann, B.T., D.C. Lee, A.R. Kiester, D.E. Busch, J.R. Martin, and R.W. Haynes. 2006a. Adaptive Management and Regional Monitoring. Chapter 10 in: R.W. Haynes, B.T. Bormann, and J.R. Martin (eds.). Northwest Forest Plan—the First Ten Years (1994-2003): Synthesis of Monitoring and Research Results. PNW GTR 651, USDA Forest Service, Pacific Northwest Research Station, Portland, OR.

4. Senge, P.M. 1990. The Fifth Discipline: The Art and Practice of the Learning Organization. Currency Doubleday, New York.

5. Kuhn, T. 1996. The Structure of Scientific Revolutions, 3rd Edition. University of Chicago Press, Chicago, IL.

6. Ashworth, M.J. 1982. Feedback Design of Systems with Significant Uncertainty. Research Studies Press, Chichester, UK.

7. Allenby, B.R. and D.J. Richards. 1994. The Greening of Industrial Ecosystems. National Academy Press, Washington, DC.

8. Stankey, G.H., R.N. Clark, and B.T. Bormann. 2005. Adaptive management of natural resources: theory, concepts, and management institutions. PNW-GTR-654, USDA Forest Service, Pacific Northwest Research Station, Portland, OR.

9. Szaro, R.C. 1996. Biodiversity in Managed Landscapes: Principles, Practice, and Policy. Pages 727-770 in: R.C. Szaro and D.W. Johnston (eds.). Biodiversity in Managed Landscapes. Oxford University Press, New York.

10. Holling, C.S. 1978. Adaptive Environmental Assessment and Management. John Wiley and Sons, New York, NY.

11. Walters, C.J. 1986. Adaptive Management of Renewable Resources. Blackburn Press, Caldwell, NJ.

12. Lee, K.N. 1993. Compass and Gyroscope: Integrating Science and Politics for the Environment. Island Press, Washington, DC.

13. Elliott, G., M. Chase, G. Geupel, and E. Cohen. 2004. Developing and Implementing an Adaptive Conservation Strategy: A Guide for Improving Adaptive Management and Sharing the Learning Among Conservation Practitioners. PRBO Conservation Science, CA.

14. MacDonald, G. B., J. Fraser, and P. Gray (editors). 1999. Adaptive Management Forum: Linking Management and Science to Achieve Ecological Sustainability. Ontario Ministry of Natural Resources, Peterborough, Ontario, Canada.

15. Murray, C. and D.R. Marmorek. 2004. Adaptive management: A science-based approach to managing ecosystems in the face of uncertainty. In: N.W.P. Munro, T.B. Herman, K. Beazley and P. Dearden (eds.). Making Ecosystem-based Management Work: Proceedings of the Fifth International Conference on Science and Management of Protected Areas, Victoria, BC, May, 2003. Science and Management of Protected Areas Association, Wolfville, Nova Scotia. Available online at: http://www.essa.com/downloads/AM_paper_Fifth_International_SAMPAA_Conference.pdf

References

16. Szaro, R.C., C.E. Peterson, and K. von Gadow. 2006. Operational experiments for sustainably managing forests. Allgemeine Forst und Jagdzeitung 177(6/7):98-103.

17. Szaro, R.C., J.A. Sayer, D. Sheil, L. Snook, A. Gillison, G. Applegate, J. Poulsen, and R. Nasi. 1999c. Biodiversity Conservation in Production Forests. Center for International Forestry Research, Jakarta, Indonesia and International Union for Forestry Research Organizations, Vienna, Austria for the World Bank and the Secretariat of the Global Convention for the Conservation of Biological Diversity.

18. Harwood, J. and K. Stokes. 2003. Coping with uncertainty in ecological advice: lessons from fisheries. Trends in Ecology and Evolution 18:617-622.

19. National Research Council. 2004. Adaptive Management for Water Resources Planning, The National Academies Press. Washington, DC.

20. Atkinson, A.J., P.C. Trenham, R.N. Fisher, S.A. Hathaway, B.S. Johnson, S.G. Torres, and Y.C. Moore. 2004. Designing monitoring programs in an adaptive management context for regional multiple species conservation plans. U.S. Geological Survey Technical Report, USGS Western Ecological Research Center, Sacramento, CA.

21. Salafsky, N., R. Margoluis, and K. Redford. 2001. Adaptive Management: A Tool for Conservation Practitioners. Biodiversity Support Program, Washington, DC. Available on www.worldwildlife.org/bsp/.
.
22. Noss, R.F., M.A. O'Connell, and D.D. Murphy. 1997. The Science of Conservation Planning: Habitat Conservation under the Endangered Species Act. Island Press, Washington, DC.

23. Nyberg J.B. 1998. Statistics and the practice of adaptive management. Pages 1-8 in: V. Sit. and B. Taylor (eds.). Statistical Methods for Adaptive Management Studies. Land Management Handbook No. 42, British Columbia Ministry of Forest Research, Victoria, BC.

24. Wilhere, G.F. 2002. Adaptive management in habitat conservation plans. Conservation Biology 16:20-29.

25. USAID. 2002. Biodiversity Conservation Program Design and Management: A Guide for USAID Staff. United States Agency for International Development, Office of Environment and Natural Resources, Bureau of Economic Growth, Agriculture, and Trade, Washington, DC.

26. Bormann, B.T., R.W. Haynes, and J. R. Martin. 2006. Adaptive management of forest ecosystems: some rubber hits the road? Bioscience (in press).

27. Peterson, G.D., G.S. Cumming, and S.R. Carpenter. 2003. Scenario planning: a tool for conservation in an uncertain world. Conservation Biology 17:358-366.

28. Walters, C.J. and C.S. Holling. 1990. Large-scale management experiments and learning by doing. Ecology 71:2060-2068.

29. Gregory R, D. Ohlson, and J. Arvai. 2006. Deconstructing adaptive management: criteria for applications to environmental management. Ecological Applications 16:2411-2425.

30. Boling, E.A. 2005. Environmental management systems and NEPA: a framework for productive harmony. Environmental Law Reporter 35:10022-10031.

References

31. Williams, B.K., J.D. Nichols, and M.J. Conroy. 2002. Analysis and Management of Animal Populations. Academic Press, San Diego, CA.

32. Doremus, H. 2001. Adaptive management, the Endangered Species Act, and the institutional challenges of "new age" environmental protection. Washburn Law Journal 41:50-89.

33. Stankey, G.H. 2003. Adaptive management at the regional scale: breakthrough innovation or mission Impossible? A report on an American Experience. Pages 159-177 in B.P. Wilson and A. Curtis (eds.). Agriculture for the Australian Environment, Proceedings of the 2002 Fenner Conference on the Environment. Johnstone Centre, Charles Stuart University, Albury, Australia.

34. Johnson, F.A., C.T. Moore, W.L. Kendall, J.A. Dubovsky, D.F. Caithamer, J.T. Kelley, Jr., and B.K. Williams. 1997. Uncertainty and the management of mallard harvests. Journal of Wildlife Management 61:202-216.

35. Moore C.T., W.T. Plummer, and M.J. Conroy. 2005. Forest management under uncertainty for multiple bird population objectives. USDA Forest Service Gen. Tech. Rep. PSW-GTR-191:373-380.

36. North American Waterfowl Management Plan, Plan Committee. 2004. North American Waterfowl Management Plan 2004. Strategic Guidance: Strengthening the Biological Foundation. Canadian Wildlife Service, U.S. Fish and Wildlife Service, Secretaria de Medio Ambiente y Recursos Naturales.

37. Williams, B.K., and F.A. Johnson. 1995. Adaptive management and the regulation of waterfowl harvests. Wildlife Society Bulletin 23:430-436.

38. Williams, B.K. 1997. Approaches to the management of waterfowl under uncertainty. Wildlife Society Bulletin 25:714-720.

39. Nichols, J.D. 2000. Evolution of harvest management for North American waterfowl: Selective pressures and preadaptations for adaptive harvest management. Transactions, North American Wildlife and Natural Resources Conference 65:65-77.

40. Rogers K.H. and H. Biggs. 1999. Integrating indicators, end points and value systems in the strategic management of the Kruger National Park. Freshwater Biol. 41: 439–51.

41. Lee, K.N. 1999. Appraising adaptive management. Conservation Ecology 3(2): 3. [online] URL: http://www.consecol.org/Journal/vol3/iss2/art3/

42. Holling, C. S. 1999. Introduction to the special feature: just complex enough for understanding; just simple enough for communication. Conservation Ecology 3(2): 1. [online] URL: http://www.consecol.org/vol3/iss2/art1/

43. Knopp, T.B. and E.S. Caldbeck. 1990. The role of participatory democracy in forest management. Journal of Forestry 88(5):13-18.

44. Lauber, T.B. and B. Knuth. 1997. Fairness in moose management decision making: the citizen's perspective. Wildlife Society Bulletin 25(4):776-787.

45. Ringold, P.R., J. Alegria, R.L. Czaplewski, B.S. Mulder, T. Tolle, and K. Burnett. 1996. Adaptive monitoring design for ecosystem management. Ecological Applications 6(3):745–747.

References

46. Lee, K.N. and J. Lawrence. 1986. Adaptive management: learning from the Columbia River basin fish and wildlife program. Environmental Law 16: 431–460.

47. Gunderson, H.H., C.S. Holling, and S.S. Light (editors). 1995. Barriers and Bridges to the Renewal of Ecosystems and Institutions. Columbia University Press, New York.

48. Stankey, G.H., B.T. Bormann, C. Ryan, B. Shindler, V. Sturtevant, R.N. Clark, and C. Philpot. 2003. Adaptive management and the northwest forest plan: rhetoric and reality. Journal of Forestry 101(1):40-46.

49. Szaro, R.C., P. Angelstam, and D. Sheil. 2005. Information needs for ecosystem forestry. Pages 101-114 in: J.A. Sayer and S. Maginnis (eds.). Ecosystem Approach to Sustainable Forest Management. IUCN/Earthscan, London.

50. Szaro, R.C., J. Berc, S. Cameron, S. Cordle, M. Crosby, L.Martin, D. Norton, R. O'Malley, and G. Ruark. 1998. The ecosystem approach: science and information management issues. Landscape and Urban Planning 40 (1-3): 89-102.

51. Stankey, G.H. and R.N. Clark. 2006. Chapter 7: Adaptive management: facing up to the challenges. Pages 121-161 in: R.W. Haynes, B.T. Bormann, and J.R. Martin (eds.). Northwest Forest Plan—the First Ten Years (1994-2003): Synthesis of Monitoring and Research Results. PNW GTR 651. USDA Forest Service, Pacific Northwest Research Station, Portland, OR.

52. Adamcik, R.S., E.S. Bellantoni, D.C. DeLong, Jr., J.H. Schomaker, D.B. Hamilton, M.K. Lauban, and R.L. Schroeder. 2004. Writing Refuge Management Goals and Objectives: A Handbook. U.S. Fish and Wildlife Service, Washington, DC.

53. Williams, B.K. 1996b. Adaptive optimization of renewable natural resources: solution algorithms and a computer program. Ecological Modelling 93:101-111.

54. Williams, B.K. 2006. Adaptive harvest management: Where we are, how we got here, and what we have learned thus far. Transactions, North American Wildlife and Natural Resources Conference 71:259-274.

55. Szaro, R.C., A. Cooperrider, C.S. Correll, J. Lint, and A. Malk. 1999a. Data collection, management and inventory. Pages 231-239 in: N., Johnson, A. Malk, R.C. Szaro, and W.T. Sexton (eds.). Ecological Stewardship: A Common Reference for Ecosystem Management, Volume 1: Key Findings. Elsevier Science, Oxford, UK.

56. Szaro, R.C., D. Maddox, T. Tolle, and M. McBurney. 1999b. Monitoring and evaluation. Pages 223-230 in Johnson, N., A. Malk, R.C. Szaro and W.T. Sexton (eds.). Ecological Stewardship: A Common Reference for Ecosystem Management, Volume 1: Key Findings. Elsevier Science, Oxford, UK.

57. Nichols, J.D. and B.K. Williams. 2006. Monitoring for conservation. Trends in Ecology and Evolution 21(12):668-673.

58. Williams, B.K. 1989. Review of dynamic optimization methods in renewable natural resource management. Natural Resources Modeling 3:137-216.

59. Williams, B.K. 1996a. Adaptive optimization and the harvest of biological populations. Mathematical Biosciences 136:1-20.

References

60. Bormann, B.T., D.C. Lee, A.R. Kiester, T.A. Spies, R.W. Haynes, G.H. Reeves, and M.G. Raphael. 2006b. Synthesis—interpreting the Northwest Forest Plan as more than the sum of its parts. Chapter 3 in: R.W. Haynes, B.T. Bormann, and J.R. Martin (eds.). Northwest Forest Plan—the First Ten Years (1994-2003): Synthesis of Monitoring and Research Results. PNW GTR 651, USDA Forest Service, Pacific Northwest Research Station, Portland, OR.

61. Bormann, B.T. and A.R. Kiester. 2004. Options Forestry: Acting on Uncertainty. Journal of Forestry 102: 22-27.

62. Moore, C.T. and M.J. Conroy. 2006. Optimal regeneration planning for old-growth forest: addressing scientific uncertainty in endangered species recovery through adaptive management. Forest Science 52(2):155-172.

63. Williams, B.K. 2001. Uncertainty, learning, and optimization in wildlife management. Environmental and Ecological Statistics 8:269-288.

64. Grumbine, R.E. 1997. Reflections on "What is ecosystem management?" Conservation Biology 11(1): 41–47.

65. Michael, D.N. 1995. Barriers and bridges to learning in a turbulent human ecology. Pages 461–488 in: L.H. Gunderson, C.S. Holling, and S.S. Light (eds.). Barriers and Bridges to the Renewal of Ecosystems and Institutions. Columbia University Press, New York.

66. Miller, A. 1999. Environmental Problem Solving: Psychosocial Barriers to Adaptive Change. Springer-Verlag, New York.

67. Gunderson, L. 1999. Stepping back: assessing for understanding in complex regional systems. Pages 27–40 in: K.N. Johnson, F. Swanson, M. Herring, and S. Greene (eds.). Bioregional Assessments: Science at the Crossroads of Management and Policy. Island Press, Washington, DC.

68. Walters, C. and R. Green. 1997. Valuation of experimental management options for ecological systems. Journal of Wildlife Management 61:987-1006.

Key Terms

Estimation

The aggregation of field data into measures of resource attributes. Examples include means, variances, and correlation coefficients computed with sample data. Multiple estimators are always available for any resource attribute, and the choice of which particular estimator to use is based on statistical features such as bias and precision.

Experimentation

The imposition of treatments on subjects or experimental units for the explicit purpose of learning about treatment effects by observing outcomes. Ideally experimentation involves random allocation of treatments to experimental units, replication of treatments, and the use of controls for comparative purposes.

Experimental management

The use of management interventions for the purpose of understanding the effects of management. Interventions are used as experimental treatments, ideally (but infrequently) in the context of randomization, replication, and experimental control.

Hypothesis

A suggested but unconfirmed assertion or explanation of observed patterns. Hypotheses can take many forms, for example, a hypothesized magnitude of a resource attribute or a mathematical relationship between attributes. Hypotheses are tested by comparison against field data.

Management by experiment

An approach to management that recognizes management interventions as experiments, by means of which understanding can be enhanced as management proceeds through time.

Management action

An action affecting a managed system, taken as a result of a management decision. In the context of natural resources, management actions typically influence the status of resources or the processes that control resource dynamics.

Management alternative

A potential management action. In sequential management, a management action is selected at each point in time from an identified set of management alternatives. The set of management alternatives constrains and influences the choice of a management strategy.

Management decision

A decision to take a management action. In adaptive management, decision making typically is driven by management objectives, with active stakeholder involvement. Adaptive decision making takes into account both the current status of resources and the level of understanding about them.

Key Terms

Management option

Used interchangeably with management alternative.

Management strategy

A prescription of management actions pursuant to management objectives. In the context of adaptive management, a management strategy describes time-specific management actions to be taken, conditional on current resource status and the level of understanding about resource dynamics. Management strategies often are expressed in terms of resource thresholds, on either side of which a different action is to be taken.

Model

Any representation, whether verbal, diagrammatic, or mathematical, of an object or phenomenon. Natural resource models typically characterize resource systems in terms of their status and change through time. Models imbed hypotheses about resource structures and functions, and they generate predictions about the effects of management actions.

Objective

A desired outcome or performance measure that expresses stakeholder values and serves to guide natural resource decision making and evaluation of success.

Stakeholders

Individuals and organizations (e.g., managers, scientists, private citizens, nongovernmental organizations) with a vested interest in a shared enterprise. Interests can include an expectation of received benefit, a perceived threat, a prior investment of time and/or resources, or values shared with others associated with the enterprise. Active engagement of stakeholders promotes the successful implementation of adaptive management.

Threshold

The limiting value of a resource attribute that triggers a change in management actions. Management strategies often include thresholds, such that one action is specified for resource values less than the threshold and a different action is specified for larger resource values.

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