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Adaptive Management of Rangeland Systems

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Chapter 11
Adaptive Management of Rangeland Systems

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Abstract Adaptive management is an approach to natural resource management that uses structured learning to reduce uncertainties for the improvement of management over time. The origins of adaptive management are linked to ideas of resilience theory and complex systems. Rangeland management is particularly well suited for the application of adaptive management, having sufficient controllability and reducible uncertainties. Adaptive management applies the tools of structured decision making and requires monitoring, evaluation, and adjustment of management. Adaptive governance, involving sharing of power and knowledge among relevant stakeholders, is often required to address conflict situations. Natural resource laws and regulations can present a barrier to adaptive management when requirements for legal certainty are met with environmental uncertainty. However, adaptive management is possible, as illustrated by two cases presented in this chapter. Despite challenges and limitations, when applied appropriately adaptive management leads to improved management through structured learning, and rangeland management is an area in which adaptive management shows promise and should be further explored.

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11.1 Introduction

Adaptive management (AM) is an approach to management that emphasizes structured learning through decision making for situations where knowledge is incomplete and managers must act despite uncertainty regarding management outcomes (Walters 1986). Adaptive management produces iterative decisions based on information resulting from management, and builds knowledge and improves management over time (Allen and Garmestani 2015). Natural resource management contains numerous uncertainties and ecosystem managers can make better decisions in the future if they can learn, and these ideas underlying AM hold intuitive appeal and should be common sense. Indeed, C.S. Holling, the describer of AM, recognized, "Adaptive management is not really much more than common sense. But common sense is not always in common use" (Holling 1978).

Although AM may be "common sense," there continues to be confusion regarding what actually constitutes AM. This misunderstanding is largely based upon the belief that AM is what management has always been—trial-and-error attempts to improve management. However, unlike a trial-and-error approach, AM has explicit structure, including a careful description of objectives, hypotheses of problem causation, alternative management approaches, predicted consequences of implementing management alternatives, procedures for collection and analysis of monitoring data, and a mechanism for updating management as learning occurs.

From its inception until the 1960s, fish, wildlife, and range management in many nations focused primarily on the management of game and commercially important species, including domestic livestock. Game management included such activities as the control of predators, the establishment of hunting and fishing regulations, and the direct manipulation and creation of habitat considered suitable for target species. This focus has gradually broadened and during the last two decades a convergence of the formerly discrete fields of fish and wildlife biology, ecology, rangeland ecology, and conservation biology has occurred, reflecting a shift in dominant stakeholder groups from consumptive to nonconsumptive users (van Heezik and Seddon 2005). Range management has started to embrace a broader view of management that includes non-game species, and management no longer is exclusively focused on providing harvestable resources, but increasingly deals with conservation of threatened species, invasive species control, and the regulation of populations that are perceived as overabundant. Globally, fish, wildlife, and range management has followed similar patterns in different countries over the last few decades as international boundaries have become more open and communication and travel easier and faster. However, attitudes toward "management" and "conservation" still bear the stamp of historical contingency and reflect the norms of the cultures and governments of the countries within which managers reside.

A relatively recent trend in fish and wildlife biology is a more explicit focus on biodiversity conservation, monitoring, and the protection of endangered species and their critical habitat (Baxter et al. 1999). During the 1980s and 1990s, there was an increase in awareness of the social issues and uncertainties surrounding fish, wildlife, and range management (Cutler 1982). Increasingly, managers have implicitly or explicitly recognized that managing natural resources includes managing people, an area where adaptive management can provide a useful approach.

Adaptive management has been attempted in a variety of settings, including in river and watershed management (Habron 2003; Allan et al. 2008; Smith 2011), park management (Agrawal 2000; Varley and Boyce 2006; Moore et al. 2011), and wildlife harvest management (Williams and Johnson 1995; Johnson 2011), with varying success. Varied success is in part because AM is not a panacea for the navigation of "wicked problems" (Rittel and Webber 1973; Ludwig 2001) and does not produce easy answers. Adaptive management is only appropriate for a subset of natural resource management problems in which both uncertainty and controllability are high (Fig. 11.1) (Peterson et al. 2003). It is a poor fit for solving problems of high complexity, high external influences, long temporal extent, high structural uncertainty, and where there is low confidence in assessments—climate change for example (Gregory et al. 2006). Although even in these situations, concepts of AM are useful because they emphasize the need for clear objectives, flexibility, and learning.

Rangeland management in particular shows promise for application of AM (Bashari et al. 2009; Boyd and Svejcar 2009), having a tradition of modeling system dynamics (e.g., state-and-transition models) (Westoby et al. 1989; Anderies et al.

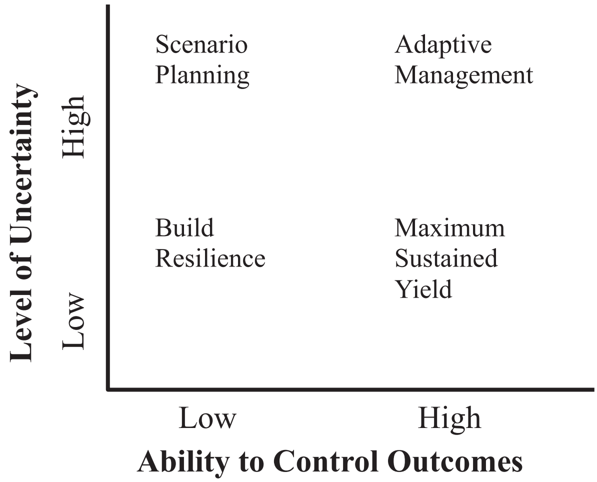

Fig. 11.1 Adaptive management and scenarios are complementary approaches to understanding complex systems. Adaptive management functions best when both uncertainty and controllability are high, which means the potential for learning is high, and the system can be manipulated (adapted from Peterson et al. 2003)

2002), identifiable spatial management units (e.g., pastures), clear management objectives (e.g., maintain forage production), and reducible uncertainties related to management impacts. In this chapter we discuss the techniques and challenges of AM and apply them to rangeland systems with two case examples.

11.2 Development of Adaptive Management

Adaptive management was founded in decision approaches of other fields (Williams 2011a), including business (Senge 1990), experimental science (Popper 1968), systems theory (Ashworth 1982), and industrial ecology (Allenby and Richards 1994). Adaptive management philosophies in natural resource management may be traced back to Beverton and Holt (1957) in fisheries management, although the term AM was not used (reviewed in Williams (2011a)). Adaptive management did not come into common usage until C.S. Holling, building upon his own work on resilience theory (Holling 1973), edited the volume *Adaptive Environmental Assessment and Management* in 1978. The concept of resilience, predicated upon the occurrence of more than one ecological state for complex systems such as ecosystems, had several ramifications. First, it meant that managers should be careful not to exceed thresholds that might change the state of the system being managed, and that the location of those thresholds is largely unknown. Second, for ecological systems in a desired state, management should focus on maintaining that regime, and enhancing its resilience, and management should not inadvertently erode the resilience of the system being managed. Adaptive management was developed as a method to continue management while probing the dynamics and resilience of systems using "management experiments" to enhance learning and reduce uncertainty (Chap. 6, this volume).

Carl Walters (1986) built upon Holling's foundational contribution (1973) and further developed AM ideas, especially in regard to modeling. Whereas Holling's original emphasis was in bridging the gap between science and practice, Walters emphasized treating management activities as experiments designed to reduce uncertainty. Both scientists sought an approach that allowed resource management to continue while explicitly acknowledging and reducing uncertainties. Walters (1986) described the process of AM as beginning "with the central tenet that management involves a continual learning process that cannot conveniently be separated into functions like research and ongoing regulatory activities, and probably never converges to a state of blissful equilibrium involving full knowledge and optimum productivity." Walters characterized AM as the process of defining and bounding the management problem, representing what is known through models, and identifying: (1) assumptions and predictions, (2) sources of uncertainty, (3) alternate hypotheses, and (4) policies that allow continued resource management while enhancing learning.

Adaptive management has been referenced either implicitly (Beverton and Holt 1957) or explicitly (Holling 1978; Walters and Hilborn 1978) for more than 50 years, but despite a relatively long theoretical history, AM has been difficult to implement in natural resource management. The limited implementation of AM stems from four fundamental problems: (1) a lack of clarity in definition and approach, with multiple interpretations of AM falling upon a continuum of complexity and design from simple "learning by doing" to more complex processes with planning and design linked with evaluation and monitoring (Holling 1978; Wilhere 2002; Aldridge et al. 2004); (2) a limited number of successful examples (Lee 1993, 1999; McLain and Lee 1996; Moir and Block 2001; Walters 2007); (3) management, policy, and funding that favor reactive approaches (Ascher 2001; Schreiber et al. 2004); and (4) laws, policy, and management plans built upon equilibrium-based conceptions of nature (Garmestani and Allen 2014). These challenges have slowed the development of AM and resulted in incomplete and inappropriate implementation of AM.

Despite implementation issues, momentum and interest in the subject continues to grow. An indication of the growing movement toward taking a more proactive approach to natural resource management is the publication by the United States Department of Interior of an AM technical guide (Williams et al. 2009) and applications guide (Williams and Brown 2012), and the policies developed around these manuals to:

"Incorporate adaptive management principles, as appropriate, into policies, plans, guidance, agreements, and other instruments for the management of resources under the Department's jurisdiction."—Department of Interior Manual (522 DM 1)

11.3 Process of Adaptive Management

Deciding on the objectives and management options is critical to any management approach. This is challenging for natural resource management because social–ecological systems are complex, including multiple objectives and stakeholders, overlapping jurisdictions, and short- and long-term effects, and they are characterized by multiple sources of uncertainty, both social and ecological (Chap. 8, this volume). Decision makers are presented with challenging decisions—predicted consequences of proposed alternatives, value-based judgments about priorities, preferences, and risk tolerances—often under enormous pressure (economic, environmental, social, and political) and with limited resources. This can result in management paralysis, or continuation of the status quo, as managers and policymakers become overwhelmed by the decision-making process and lose track of the desired social–ecological conditions they are charged with achieving. Resource management can be arduous and controversial, particularly with diverse stakeholders. Fortunately, there are methods to overcome these pitfalls and maximize the potential for success.

Structured decision making is one method of overcoming management paralysis and mediating stakeholder conflicts. Borrowed from the sociological fields, structured decision making is an approach to identify and evaluate alternative resource management options by engaging stakeholders, experts, and decision makers in the decision process and addressing the complexity and uncertainty inherent in resource

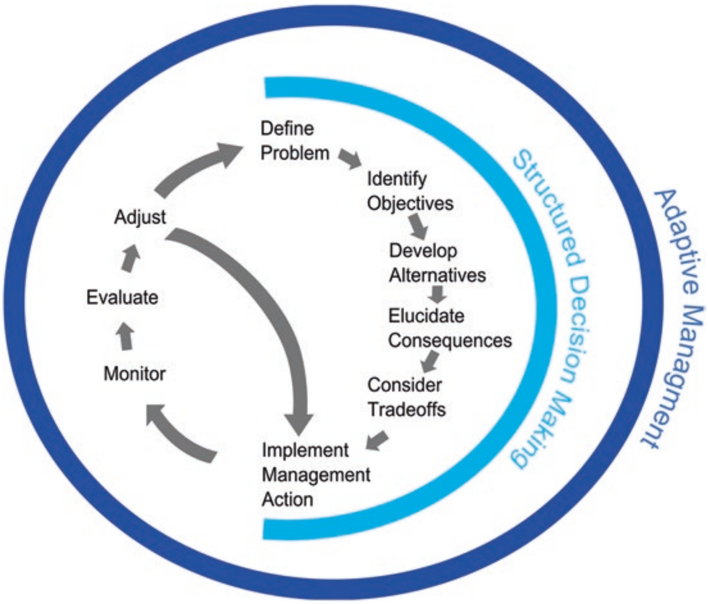

Fig. 11.2 The minimum steps necessary to implement a structured decision-making process; more complex integration of individual steps may be necessary if future steps clarify the process or if the decision is iterative over time

management in a proactive and transparent manner. Structured decision making uses a set of steps to evaluate a problem and integrates planning, analysis, and management into a transparent process focused on achieving the fundamental objectives (Fig. 11.2). Central to the success of the structured decision-making process are clearly articulated objectives, explicit acknowledgement of uncertainty, and transparent incorporation of stakeholder interests into the decision process. The conceptual simplicity inherent in structured decision making makes the process useful for a variety of decisions.

In addition to structured decision making, AM requires the potential for learning through monitoring, evaluation, and adjustment of decisions based on what is learned. Combining the essential steps of structured decision making—monitoring, evaluation, and adjustment—creates the cycle of AM. Therefore, AM can be seen as a special case of structured decision making (Walters 1986; Williams et al. 2002).

11.3.1 Steps of Structured Decision Making

11.3.1.1 Define the Problem

The first step in a structured decision-making process is a clear and concise description of the problem and the motivation underlying the need to address the problem. Although identifying the problem may seem self-evident, failure to clearly define the problem to stakeholders and subsequent agreement by stakeholders as to the nature of the problem are often cited as the primary reason management and policy actions fail. To facilitate this process, decision makers need to ask:

(a) What decision(s) have to be made?
(b) What is the scope of the decision?
(c) Will the decision be iterated over time?
(d) What are the constraints within which the decision will be made?
(e) What stakeholders should be involved in the decision process and what are their respective roles?

11.3.1.2 Identify Objectives

The centerpiece of the structured decision-making process is a set of clearly elucidated objectives. They define the "why do we care" about the decision by describing stakeholder values. Objectives also facilitate the search for alternatives and become the metric for comparing and evaluating management outcomes. Ideally, objectives are stated with the desired direction of change and in quantitative terms that relate to parameters that can be measured and evaluated. Objectives are meant to focus efforts on the importance of the decision in a consistent and transparent manner that exposes key trade-offs and uncertainties so decision makers can generate creative and proactive alternatives. Objectives should be complete, controllable, concise, measurable, and understandable (McDaniels 2000). To achieve this requires working closely with stakeholders to identify what is important about the decision. The outcome of such efforts may produce a variety of objectives that will need to be simplified.

Objectives can be separated into fundamental objectives (the ultimate goals) and means objectives (ways of achieving the ends) to ensure that management actions really affect the defined problem. For example, "maximize forage" may be an important objective for the management of a ranch, but if the property is being managed for multiple objectives including wildlife, forage is primarily important because it increases the diversity of wildlife supported. "Maximize forage" is thus a means objective for reaching the fundamental objective of "maximizing wildlife populations." Clearly there are other means objectives that would also facilitate this fundamental objective (e.g., minimize mortality, maximize forage diversity). The benefit of distinguishing the two types of objectives is that the identification of means objectives can help lead to alternative management actions, while the identification of fundamental objectives gives a basis for evaluating and comparing alternatives. The status of fundamental or means is not an innate quality of an objective, but rather is context dependent. Consequently, what was a means objective for one decision may be a fundamental objective for another.

After developing a careful list of objectives, it can be useful to develop a hierarchy, or means-ends diagram, to group similar objectives and clarify the links and relationships between means and fundamental objectives. An objectives hierarchy can help clarify the context of each fundamental objective by identifying all the important elements that are affected by the decision process and demonstrate to stakeholders the importance of all objectives even those that are not “fundamental objectives.”

11.3.1.3 Develop Alternatives

Management success is only as likely as the creativity and diversity of management alternatives. Unfortunately management paralysis and status quo too often limit managers to few options and thereby impede management success. The process of identifying management alternatives, like the process of identifying objectives, starts with brainstorming. Identifying alternative management actions is a process that should be addressed iteratively, as knowledge of best practices and the creativity to develop novel ideas should not be expected to develop instantaneously. It is important to have a group with a set of interdisciplinary skills that represent the larger decision to ensure that the needs of stakeholders are not overlooked. This is not to say that the stakeholders involved in identifying alternative management actions are the same as the larger stakeholder group, usually they are not. This is primarily due to the technical knowledge necessary to present plausible alternatives. Still there are opportunities where the benefit of being naive may present novel actions that might not otherwise be considered.

The brainstorming process should begin by identifying alternatives for individual objectives, but should also be looking for opportunities when one action may fulfill the needs of multiple objectives. Identifying alternatives also means acknowledging those actions that must be done (e.g., policy) as well as constraints and potential trade-offs between objectives and management actions. It is important that the “brainstorming” process focus on developing management actions that are (1) designed to address the outlined objectives, (2) built on the best known practices, (3) comprehensive enough to include the technical understanding for implementation, (4) expose trade-offs between the decision process by having mutually exclusive strategies, and (5) achieve the maximum benefit for the stakeholders involved.

Once an extensive list of alternatives has been identified, it can be useful to group them into strategies based on general similarities in what they aim to achieve. Sometimes these represent the needs of specific stakeholder groups or specific conditions that could be achieved. For example, management actions on a rangeland may be grouped into those addressing the needs of cattle, wildlife, or diversity; alternatively, they may be grouped based on their ability to restore the landscape to 50, 75, or 95 % of historical heterogeneity. Both methods have merit; the first method makes it clear to the stakeholders what objectives are being met and where trade-offs must occur, and the second minimizes the inherent interests of any particular group to make the process less contentious.

11.3.1.4 Exploring Consequences

The list of alternative management actions is only effective if it creates an opportunity to evaluate and compare actions in light of the objectives before implementation. It is important to realize that the process of identifying management consequences is not a value judgment, but an assessment of the likely outcomes of the action(s). Using the best knowledge available, this process is an exercise focused on predicting the likely outcomes of each alternative and the likelihood that each achieves the desired objective. Depending upon knowledge of the system this process can be highly quantitative where extensive data are modeled and probabilities assigned, or as is often the case, it can depend heavily on expert opinion or comparisons to similar systems. In both cases, there is a degree of uncertainty associated with predicted outcomes as well as the parameters included in the modeling process. Decisions are almost always made in the face of uncertainty because system function is rarely precisely understood and the effect of management actions is never certain. Uncertainty can make differentiating among alternatives difficult. It is important that uncertainty be confronted throughout the decision process and that the uncertainties are identified and the possible impacts on the system and the ability to achieve stated objectives documented. These uncertainties may be reduced through the addition of monitoring, evaluation, and adjustment steps as part of an AM cycle (discussed in detail shortly).

Once the modeling process has predicted the likely outcomes of each management action, the next step is to develop a consequence table. The purpose of a consequence table is to produce a summary of the anticipated consequences of each potential management action on each of the objectives in a table or matrix. A consequence table can take a variety of forms, from a simple rating system (e.g., consumer report five-star rating) to a complex table with specific probabilities of outcomes and subsequent likelihoods of achieving each objective. Independent of the complexity of the underlying models that populate the matrix, the purpose of the consequence table is to ease and facilitate direct comparison of each management actions' ability to achieve each objective.

11.3.1.5 Consider Trade-Offs

Ideally the structured decision-making process would lead to a clear management alternative that achieves the objectives of all interested parties; unfortunately, this is rarely the case. Generally, the process of developing a consequence table will make clear which options are the least likely to be effective, but if there are multiple stakeholders and multiple objectives most decisions will require a trade-off between the ability of the remaining options to achieve each objective. The process of identifying where these trade-offs arise is analytical, but the decision process itself is highly value laden and dependent upon stakeholders. In most complex decisions, this will involve stakeholders choosing between less-than-perfect alternatives. There are a variety of methods to facilitate highly value laden decisions by weighting options based on the values of the stakeholders and then comparing alternatives to find the "best" compromise solutions. However, trade-offs are real and it is unlikely that all parties will be totally satisfied with the eventual outcome. Indeed, the benefit of the structured decision-making process is that even if there is disagreement, the process makes the disagreement transparent and enables stakeholders to re-evaluate using new knowledge and perspectives.

11.3.1.6 Implement Management Action

The final step in the structured decision-making process is implementation. Although this may always seem to be the desired outcome of a decision process, social and political pressures to reach "perfection" often impede implementation and leave decisions in a continuous state of inaction. To ensure success, managers, policymakers, and stakeholders must collaborate to move through the decision process in a timely manner to ensure action can be taken. Failure to take action is a decision, whether it is made passively or actively.

11.3.2 Monitoring, Evaluation, and Adjustment

The steps of structured decision making are a useful way to begin the planning and management process by allowing for transparent decisions, but structured decision making alone is not sufficient for AM. In order for a project to be truly AM, there must be (1) potential for learning through monitoring and evaluation of results and (2) adjustment of decisions following learning. As such, monitoring and evaluation are key components. Ongoing monitoring can be resource demanding and seen as an unnecessary expense; budgets often do not incorporate funds and personnel to support monitoring. Even when monitoring does occur, it is only as useful as its use in evaluation. Monitoring must be conducted rigorously, following a structured protocol, and designed such that learning about system dynamics and the impact of management can occur. The learning from evaluation must be used to adjust future management.

Monitoring, evaluation, and adjustment are key steps of AM and create an ongoing cycle of managing and learning. The cycle of managing and learning can be divided into two phases, a setup and an iterative phase (Williams 2011a). The setup phase is made up of the structured decision-making steps, while the iterative phase is a cycle from decision making to monitoring to evaluation and back again. Learning occurs during the iterative phase, but re-evaluation of the structured decision-making process should also happen periodically to examine how the context has changed.

11.4 Types of Adaptive Management

There are two prevailing schools of thought emerging from different traditions of AM, the resilience-experimentalist school and the decision-theoretic school (McFadden et al. 2011). The resilience-experimentalist school emphasizes inclusion of stakeholders throughout the process, active learning about ecosystem resilience through experimentation, acknowledgement of cross-scale linkages, and potential for surprises in complex systems. Adaptive management involving a large degree of stakeholder collaboration has also been called collaborative AM or adaptive co-management. The decision-theoretic school includes stakeholders to properly identify the problem, objectives, and alternatives. Relatively simple decision-focused models are then developed following principles of decision theory to identify the appropriate management action.

The resilience-experimentalist school recognizes a need for bridging organizations to address cross-scale linkages found in nested, complex social–ecological systems. Bridging organizations connect stakeholders and policymakers at different levels (Olsson et al. 2007). To do so successfully, bridging organizations must formulate strategies, coordinate joint action, address uncertainty, and link diverse stakeholders in a world of increasing complexity. Brown (1993) investigated bridging organizations from across the world, and a variety of applications—regional economic policy in the USA; small-scale irrigation projects in Indonesia; and agricultural productivity in Zimbabwe—found that bridging organizations are independent of stakeholders in a social–ecological system, which allows them to negotiate with stakeholders and advocate multiple positions. This unique role in the management of social–ecological systems affords bridging organizations the capacity to catalyze the formation of policies that are flexible and reflective of the realities of ecosystems and institutions (Brown 1993). In addition, bridging organizations have the capacity to reduce transaction costs and provide a mechanism to enforce adherence to desired policies, despite their lack of regulatory authority (Hahn et al. 2006).

Examples of bridging organizations include (1) assessment teams, which are made up of actors across sectors in a social–ecological system; (2) nongovernmental organizations, which create an arena for trust-building, learning, conflict resolution, and adaptive co-management; and (3) the scientific community, which acts as a watchdog as well as a facilitator for AM.

The decision-theoretical school applies the tools of decision science to select optimal management choices under conditions of uncertainty. A distinction is made between passive and active AM. In either case learning occurs, but in passive management the emphasis is on achievement of the management objective with learning a by-product, and in active AM, reducing uncertainty is an objective and management actions are selected based on the potential for learning (Williams 2011a, b).

11.5 Adaptive Management in Rangelands

In this section, we outline the implementation of AM in two case examples that reference both the decision-theoretical and resilience-experimentalist approach. The first example is the US Fish and Wildlife Service (USFWS) Adaptive Harvest Management

Plan (AHM), which is often heralded as the most successful case of AM and it provides an example of passive AM following the decision-theoretical school. The second case is directly tied to the management of rangelands and describes AM in prescribed burn associations (PBAs), a private citizen-led management effort in rangelands that follows the resilience-experimentalist AM approach.

11.5.1 USFWS Adaptive Harvest Management

Adaptive harvest management (AHM) is one of the most successful efforts to apply the principles of AM and demonstrate how to successfully manage natural resources through improving our understanding of natural systems through management actions. The AM processes of AHM have greatly improved our understanding of the harvest potential of waterfowl populations, the ability of managers to regulate harvest, and the importance of monitoring and assessment programs to support the decision-making process.

Why has AHM succeeded while so many other attempts to implement AM have stalled? First, AHM developed a clear and concise objective: maximize long-term waterfowl harvest while ensuring long-term viability of waterfowl populations. The development and agreement by stakeholders to a concise set of fundamental objectives is paramount to ensuring the success of any AM program. Failure to agree upon fundamental objectives will ensure management will fail. The second key to AHM success was the simultaneous support for management, research, and monitoring. Waterfowl research and management in North America are nearly unequaled by any other natural resources management program in terms of history, scope, and investment (Hawkins et al. 1984). The combination of well-supported management, research, and monitoring programs has resulted in a reduction in the uncertainty of how waterfowl populations respond to management and enabled managers and policymakers to meet stated objectives. Unfortunately, attempts to implement AM often fail to address all of these requirements. In particular, resources for monitoring and research are often undervalued with the outcome being a series of management actions with no capacity for understanding the implications of those actions.

The final key to the success of AHM has been the ability to implement management and policy decisions based on the best information available. One reason for this is that the model predictions have dictated liberal harvest as the supported management action, meaning tough trade-offs have not needed to be made between hunter satisfaction and sustaining waterfowl populations. In many attempts to implement AM, the regulatory body charged with implementation of management recommendations is unable, or worse unwilling, to implement actions proposed by the outcome of the AM process; the body in charge of regulatory control is too often a stakeholder in the process of AM with an agenda independent of regulating the resource alone. In contrast to AHM, which is regulated by the USFWS with support from various stakeholders with parallel interests, several regulatory agencies often control resources for a given program, each an independent stakeholder with an independent agenda. Such a situation can make implementation of management recommendations challenging, especially if it contradicts long-standing dogma. Consider for example the management of Glen Canyon Dam and the waters of the Colorado River. Heralded by Congress as an AM success story, the Colorado River Adaptive Management Program has fallen short of success despite years of work, and the ecological status of the Colorado River and the conflict inherent to the development of an AM program continue to worsen (Susskind et al. 2010). The regulatory agency that controls the flow of water throughout the Colorado River Basin, the Bureau of Reclamation, is also one of the major stakeholders in the AM process with an agenda (water storage) that conflicts with several other stakeholders and regulatory agencies that manage people and wildlife along the Colorado River (e.g., California Department of Water Resources, Mexican National Water Commission, USFWS). From these examples one might conclude that AM is difficult to implement for management of resources where various stakeholders and regulators are at odds. Actually, implementation of AM is appropriate in both examples. The Colorado River Adaptive Management Program example highlights the importance of collaboration, the benefits of a single regulatory body, and the need to agree upon a priori objectives that guide long-term management decisions despite short-term political, societal, economic, or even environmental impacts.

11.5.2 Adaptive Management in PBAs

Prescribed burn associations (PBAs; also referred to as prescribed burn cooperatives) have risen to the forefront of prescribed fire management in central North America private lands (Twidwell et al. 2013a) and provide an example of the implementation of the resilience-experimentalist AM approach in rangelands. Prescribed fire associations are neighbor-help-neighbor partnerships where members pool knowledge, training, and resources to implement prescribed fires for rangeland management (Taylor 2005). These associations have emerged as a bottom-up response to broad-scale encroachment of *Juniperus* species and its negative impact on multiple grassland services important to rangeland managers (Twidwell et al. 2013a). We outline how PBAs are now operating under the resilience-experimentalist AM framework; however, it is interesting to note that AM was not explicitly considered during the early formulation of PBAs. Instead, the use of AM has emerged as a need to provide solutions to a biome-level threat to rangeland resources. As burn associations have matured over the past 20 years, so has their ability to integrate the full scope of AM principles outlined previously.

At the heart of PBAs exists a tight coupling among stakeholders, scientists, and agency personnel engaged in bridging organizations and shaping decision making. University scientists and outreach professionals host workshops regularly, providing training, scientific outreach, and an open forum that targets adaptive learning outcomes among participants. State and federal natural resource agencies recognize the joint mission among agencies and landowners, and as a result have started funding prescribed burns associations to help local groups buy equipment and conduct prescribed burns. The management objectives of PBAs have triggered applied research experiments conducted through a resilience lens, resulting in the identification of fire thresholds across alternative states that fire practitioners can target and learn from (Twidwell et al. 2013b). Such management-research linkages have contributed to the increasing use of high intensity fires in areas that have undergone a shift to an alternative state dominated by non-resprouting *Juniperus* trees, while providing a cautionary learning experience for land managers in other regions also susceptible to this type of transformation (Twidwell et al. 2013a).

The implementation of AM among PBAs reveals how the resilience-experimentalist approach can lead to more flexible policies and legislation. Over the last century, controlling and limiting variability in fire behavior has been a central priority of natural resource management across the globe. Yet, more flexible policies are consistently called for in fire management to more closely mimic variation in natural fire regimes to manage species dependent upon such variability (Hutto 2008; Conway and Kirkpatrick 2007; van Wilgen 2013; Odion et al. 2014). In local areas, some PBAs, through AM, have successfully shifted regulatory constraints governing the use of prescribed fire in the private sector. Special legal exemptions have been granted to a small proportion of PBAs to provide flexibility to conduct fires during periods of government-mandated outdoor burning bans for restoration purposes (Twidwell et al. 2013a). While this has allowed some associations to conduct prescribed fires in conditions capable of overcoming woody plant mortality objectives, members recognize that legislation can shift to their disadvantage (Toledo et al. 2013). As a response, burn associations are moving beyond local affiliations of landowners and developing a formal hierarchical structure with existing alliances in the state (e.g., Prescribed Burn Alliance of Texas; http://pbatexas.org) and region (e.g., Alliance of Prescribed Burn Associations). Ongoing discussions are addressing the creation of a national alliance.

Clear recommendations have now been developed for cross-organizational and cross-scale monitoring and evaluation of PBA management actions. Such recommendations were provided, in part, to maintain engagement among stakeholders, university personnel, and agency professionals throughout both phases of AM—structured decision making, and monitoring and evaluation—with the intent of learning and informing future decisions (Table 11.1).

11.6 Adaptive Governance

Administrative agencies typically change incrementally (Lindblom 1959), and as such changes in policy are small because there is not enough information to make large overhauls of organization policy. Standard operating procedures often contribute to organizational inertia, as they slow the bureaucratic process (Allison 1969). Further, the lack of organizations matched to the appropriate scale is a significant barrier for sound environmental management (Dietz et al. 2003). Within this

Table 11.1 Example of how the two-phase process of adaptive management is being implemented to foster learning and adjust decision making of prescribed burn cooperatives dealing with *Juniperus* encroachment (adapted from Twidwell et al. 2013a)

Phase I. Structured decision making	Example of formalizing AM in PBAs
1. Define the problem	Juniper encroachment, loss of grasslands, and the services they provide
2. Identify objectives	Use fire to prevent juniper encroachment, reduce juniper abundance, and restore grassland services
3. Identify management alternatives	Use mechanical and chemical treatments to supplement fire activities; alter grazing practices to increase fuel loading and fire intensity
4. Explore consequences	Develop a consequence table summarizing potential consequences of each management action and likelihood of achieving objectives
5. Identify and evaluate trade-offs	Assess successional trajectory of vegetation following fire, potential to trigger invasion of exotic plant or animal species, negative responses from neighbors or urban residents impacted by smoke
6. Implement management action(s)	Conduct prescribed burns in conditions capable of meeting management objectives
Phase II. Monitoring and evaluation	
7. Monitoring and evaluation	Track fire effects on juniper and changes in juniper abundance, the reestablishment of grassland vegetation, potential livestock stocking rates, and biodiversity and conservation values. Recognize long-term monitoring is needed for accurate evaluation of management actions in many rangelands (Herrick et al. 2006)
8. Adjustment	Adjust management actions and targeted burning conditions based on monitoring programs; assess need to adjust structured decision-making steps

context, adaptive governance can help overcome this scale mismatch via collaboration of a diverse set of stakeholders at multiple scales (Hughes et al. 2005). Adaptive governance is a form of governance that incorporates formal organizations, informal groups and networks, and individuals at multiple scales for purposes of collaborative environmental management (Folke et al. 2005). Bridging organizations, enabling legislation, and government policies can also contribute to the success of an adaptive governance framework; governance creates a vision and management actualizes the vision (Folke et al. 2005).

Adaptive governance works via sharing of management power and responsibilities and promotes a collaborative, participatory process. It is dependent upon adaptive co-management, and adaptive co-management in turn is dependent upon social networks for success. Social networks have the capacity to allow for development of new ideas, to facilitate communication between entities, and create the flexibility necessary for the interplay of the fluid (ecological systems) and the rigid (organizations) to be successful for environmental management (Folke et al. 2005). Leadership has been well established as a critical factor in facilitating good environmental management. Leaders develop and facilitate a vision for environmental management, incorporating local knowledge and information from social networks (Folke et al. 2005).

Studies of adaptive co-management in Sweden and Canada have concluded that this form of management of ecological systems was most effective when there was: leadership with vision for the system of interest; legislation that created the environment for AM; funds for AM; monitoring of the ecological system; information flow (i.e., cross-scale linkages); combination of a variety of sources of knowledge; and venue for collaboration (Olsson et al. 2004). These factors are critical to manage for resilience in social–ecological systems, as they help to protect the system from the failure of management decisions under uncertainty (i.e., imperfect information). Adaptive governance is facilitated by informal networks and leadership, which creates the capacity for development of novel ideas for environmental management (Folke et al. 2005). These informal networks have the capacity to generate political, financial, and legal support for novel environmental management (Folke et al. 2005). Further, adaptive governance is dependent upon polycentric institutions that are redundant (e.g., scale-specific) and are quasi-autonomous (Olsson et al. 2006). A comparison of five case studies from around the world concluded that in order for a social–ecological system to transition to adaptive governance, it must undergo a preparation and a transformation phase, linked by a window of opportunity (Olsson et al. 2006).

11.7 Adaptive Management and Law

One of the most significant barriers for managing social–ecological systems is that aspects of society, especially the certainty of law and institutional rigidity, are not in concert with ecological realities, including multiregimes and nonlinear systems and responses (Garmestani et al. 2013; Garmestani and Allen 2014). The certainty of law and institutional rigidity often limit experimentation that is necessary for AM (Garmestani et al. 2009). This is critical, and some scholars contend that environmental governance can only succeed if rules evolve with the system of interest (Dietz et al. 2003).

Ecosystem management has been applied within the outdated framework of the Endangered Species Act (ESA), but would be better suited for an AM framework (Ruhl 2004). In its current form, the ESA does not have the flexibility in its regulatory language to effectively implement adaptive responses to changing environmental conditions (Boyd et al. 2014). The fundamental constraint to AM is the current state of administrative law (Ruhl 1998). As the law now stands, the procedural rules require a vast amount of work before an agency promulgates a rule or issues a permit (Ruhl 2008). This "pre-decision" activity allows for public input and prepares agencies for judicial review. Ruhl (2008) contends that "agencies will find that interest groups and courts relentlessly will erode adaptive agency behavior, using all the tools conventional administrative law puts at their disposal." Having to operate in an atmosphere where each policy is evaluated on the "front-end," in anticipation of public and legal scrutiny, has squelched agencies' appetite for AM.

US administrative law is a two-step process, in which the first allows for public comment on draft documents and alternative options (Ruhl and Fischman 2010). The second step is final agency action, which creates "certainty" to the process and makes the decision subject to judicial review. This process is based on the assumption that agencies have the capacity to predict the consequences of a "final agency action" (Ruhl and Fischman 2010). This establishes a fundamental conflict between linear legal processes (i.e., administrative law) based on "stationarity" and environmental management frameworks (i.e., AM) based on the realization of dynamic systems characterized by nonstationarity (Ruhl and Fischman 2010).

Only in rare cases, such as AHM and PBAs, has AM been successful within the current regulatory framework. In effect, administrative agencies in the United States largely do not conduct AM as it was originally conceived (Ruhl and Fischman 2010). Rather, agencies conduct AM "lite," a form of partially flexible management, because the courts have provided some leeway to AM projects provided they have requirements that are legally enforceable (Ruhl and Fischman 2010). The primary problem with AM "lite" is that it does not measure up to the standards of AM theory, nor does it hold up under the scrutiny of substantive and procedural law.

11.8 Future Perspectives

Considerable confusion exists regarding what constitutes adaptive management. The methods and theory behind AM have been described (here, and citations herein), as have the barriers to successful implementation (Allen and Gunderson 2011). However, implementation remains frequently problematic, with trial-and-error approaches described as adaptive management, and frequent application of adaptive management to intractable large-scale management problems that are inappropriate for adaptive management, largely because controllability is not present. A simple process of structured decision making can be applied in such situations. However, many of the challenges found in range management are appropriate for adaptive management, because grazing unit replication is possible and most management interventions applied are controlled by managers or landowners. Integration of adaptive management and range management should increase the rate of learning, necessary in a rapidly changing world.

In order for AM to move past AM "lite" and realize its true potential for rangeland management, administrative law will likely need to be reformed. Administrative law would then proceed on two trajectories: (1) a fixed-rule track that would apply unless an agency can justify otherwise; and (2) an AM track, where a new set of administrative law standards specific to AM would hold precedence, in order to actualize AM as a tool for rangeland management (Karkkainen 2005). A recent law review article heeded this call for an AM track and provided a model law for administrative procedures and AM (Craig and Ruhl 2014). In particular, the model law highlights the categories of agency decision making that are amenable to AM (see Craig and Ruhl 2014).

11.9 Summary

The conceptual underpinnings for AM are simple; there will always be inherent uncertainty and unpredictability in the dynamics and behavior of complex ecological systems, yet management decisions must still be made. The strength of AM is in the recognition and confrontation of such uncertainty. Rather than ignore uncertainty, or use it to preclude management actions, AM can foster resilience and flexibility to cope with an uncertain future, and develop management approaches that acknowledge inevitable changes and surprises. Since its initial introduction, AM has been hailed as a solution to endless trial-and-error approaches to complex management challenges. However, it does not produce easy answers, and it is appropriate in only a subset of management problems.

Clearly AM has great potential when applied appropriately. A prime example in rangeland management is PBAs, now established throughout the Great Plains. Rangelands in general are appropriate for application of AM because of the ability to model system dynamics (state-and-transition models), identifiable management units across large areas, clear management objectives (e.g., maintain native grasses), and reducible uncertainties related to management impacts. Adaptive management may be the best way forward for improving how we approach rangeland management, but will require more than most current applications of the strategy. In particular, in order to account for coupled human and natural systems, AM will require (at a minimum) legal reform (Craig and Ruhl 2014), integration with adaptive governance (Folke et al. 2005), and accounting for scale and cross-scale interactions (Garmestani et al. 2013). If these steps are taken, perhaps then AM will fulfill its promise for rangeland management.

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