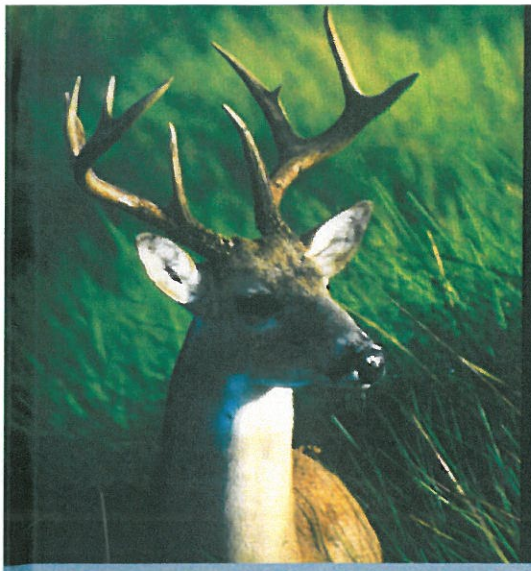

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Management

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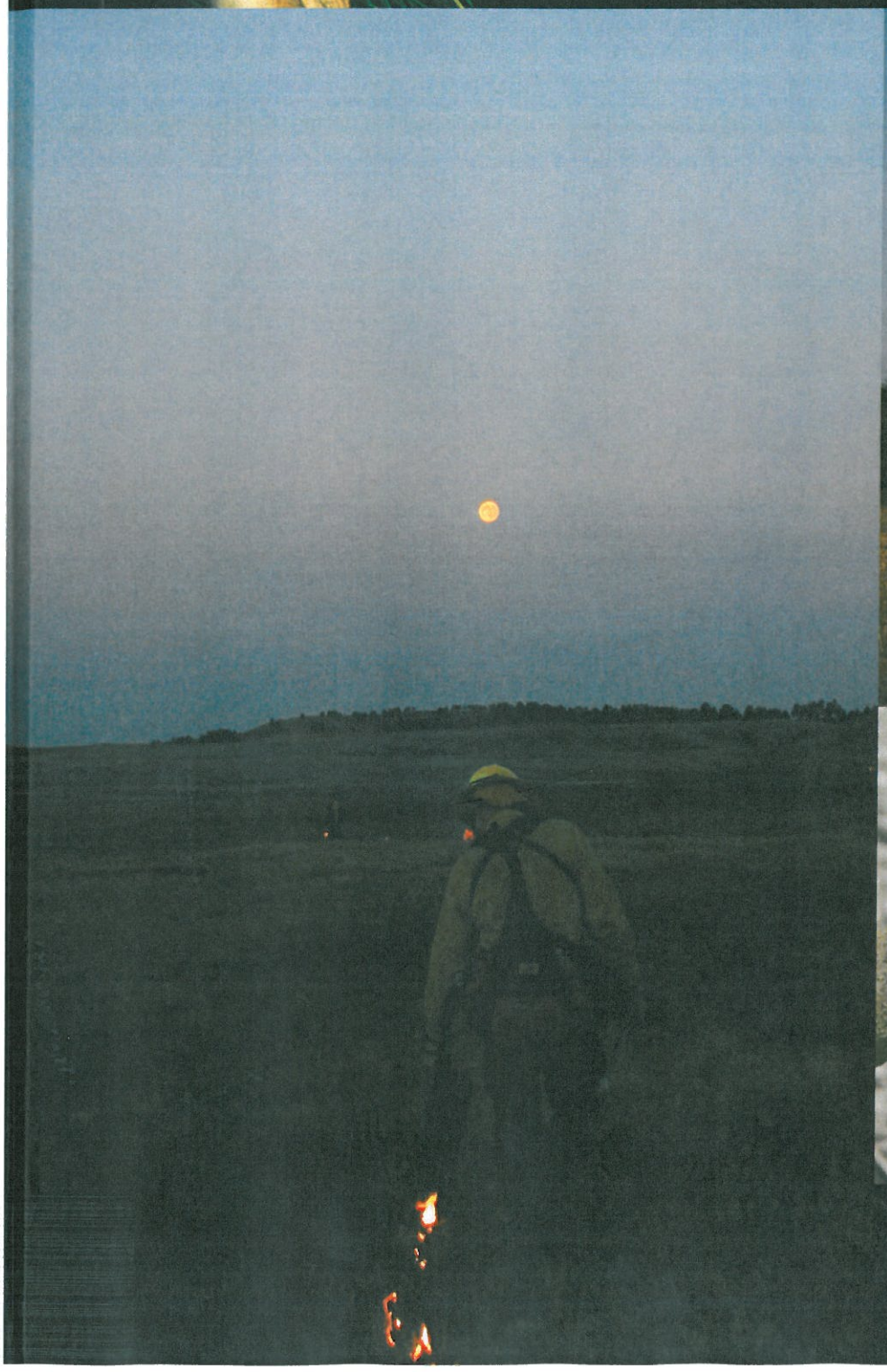

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Adaptive Management in Wildlife Conservation

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INTRODUCTION

ADAPTIVE MANAGEMENT in wildlife conservation emerged from the wildlife profession's search for better solutions to increasingly complex conservation challenges. This search for solutions and better management practices arose from a deeply felt, if poorly defined, sense of vacancy in our conservation delivery mechanisms. Lancia et al. (1996) articulated the philosophical premise for the reason that ecological science and wildlife management should link together within an adaptive management framework. Riley et al. (2003*b*) expanded the concept to integrate social and ecological science, and incorporate stakeholders in the wildlife management enterprise. Today, the term "adaptive management" is used widely in wildlife conservation, although it often is used to describe practices that, at best, merely approximate true adaptive management. The term itself connotes flexibility and responsiveness, traits many people find admirable. The attractiveness of this concept has led wildlife managers, in most cases, to be more adaptable; a few have actually pursued adaptive management.

The **primary principle** underlying adaptive management is the following: decision-makers should learn from their management interventions and apply that knowledge to development of more effective management interventions in the future (Holling 1978, Enck et al. 2006, Williams et al. 2009). Simply stated, this means "learning by doing," but true adaptive management is a rigorous **stepwise process** designed to achieve learning from the management experience. "**Adaptive**" should not be confused with the term **adaptable** in the case of wildlife management. The latter term refers to an ability to change oneself or a management system in adjusting to occurring changes. In ecology, adaptability often is used to describe the ability of ecosystems, or components of ecosystems such as a wildlife population, to cope with unexpected disturbances in the environment. To be adaptable is a desirable trait in managers, but nonetheless means something quite different then managing adaptively. The latter is a rigorous and disciplined process of conscious application; the former often one of reactive technique gradually emergent from experiential learning (Box 25.1).

Each step described in this chapter must be executed for the process to be legitimately called adaptive management. Skipping or inadequately addressing any step compromises the integrity of the process, impairs our ability to learn from management actions (White 2001), and degrades our capacity to effectively apply new insights in a timely and appropriate manner. Thus, adaptive management necessitates a commitment of time and resources above what is required for "**normal**

BOX 25.1. DEPARTMENT OF THE INTERIOR DEFINITION OF ADAPTIVE MANAGEMENT

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.

From Williams et al. (2009).

management" and is not essential for all wildlife management situations. However, executed properly, adaptive management is an investment in the long-term durability and success of a wildlife management enterprise (Lancia et al. 1996).

Wildlife management typically involves making decisions under circumstances where uncertainty may exist about almost every aspect of the management environment. Estimates of an animal population's size or demographic features may lack reliability (Williams et al. 2002, Skalski et al. 2005), or even be unknown. The relative importance of different habitat features to a population's viability may not be well understood (Morrison et al. 1998). The most important positive and negative outcomes of interactions people have with wildlife or their habitat (referred to as **impacts**), and the consequences of these, may not be adequately described, nor the significant stakeholders identified or already engaged (Riley et al. 2002).

Contributing further to overall uncertainty are the dynamic natures of the coupled social–ecological systems managers work with in wildlife management. Change is an inherent part of natural processes and ecosystems. Change also is an inherent trait of human social systems. In addition, anthropogenic forces are influencing change in natural processes in diverse ways and at unprecedented rates; changes that, in turn, influence human emotional and cultural responses. These multiple influences on an organic system coupled with variable rates of change among them make for a management environment with high degrees of uncertainty. It is a complicated business.

Adaptive management has been described as a way to embrace such change and uncertainty (Riley et al. 2003*b*, Williams et al. 2009). Holling (1978) and Walters (1986) established techniques for applying adaptive management principles to environmental assessment, drawing from systems dynamics (Forrester 1968) and industrial operations theory (Ackoff 1970). The promise of adaptive management for addressing complex, uncertain, and dynamic systems then led to its adoption in wildlife management (Johnson et al. 1993, Williams and Johnson 1995, Lancia et al. 1996, Williams 1997, Riley et al. 2003*b*). In many respects, however, adaptive management has been more significant as a concept than a management practice (Lee 1999). Its conceptual power lies in its encouragement of managers to evaluate the effects of their management actions, to learn and adapt, all within a coordinated and iterative process. In fact, it is the circularity of its conceptual dynamic, foraging, and fertilizing within a specific problem landscape, that gives adaptive management its traction in evolving states of knowledge.

THE ADAPTIVE MANAGEMENT PROCESS

Adaptive management taken simply is **an iterative stepwise process** beginning with an analysis of the situation requiring management, then working through several steps: engagement of stakeholders in defining management objectives, model(s) development based on hypotheses about the system to be managed, identification of management alternatives, implementation of management interventions and monitoring of the system's response, making adjustments to the model(s) based on system responses, refining the management alternatives and then implementing refined interventions, and so on (Fig. 25.1). An adaptive management process builds on itself such that continuous learning from management actions and rapid reapplication become integral components of the wildlife manager's job. Capturing the learning and packaging this for reentry into the process emerges as the critical factor, requiring disciplined ongoing analysis of new insights and probabilities.

Situation Analysis

Wildlife management typically occurs within a complex system where ecological, social, political, and economic factors interact. Identification of these factors, their effects on each other, and their relative importance helps to frame the management situation and the likely scope of management decisions. This framing process is termed **situation analysis,** but also may be called context analysis, problem definition, or problem scoping. Whatever it is called, this process is best conducted in 2 phases. Phase I is when the wildlife man-

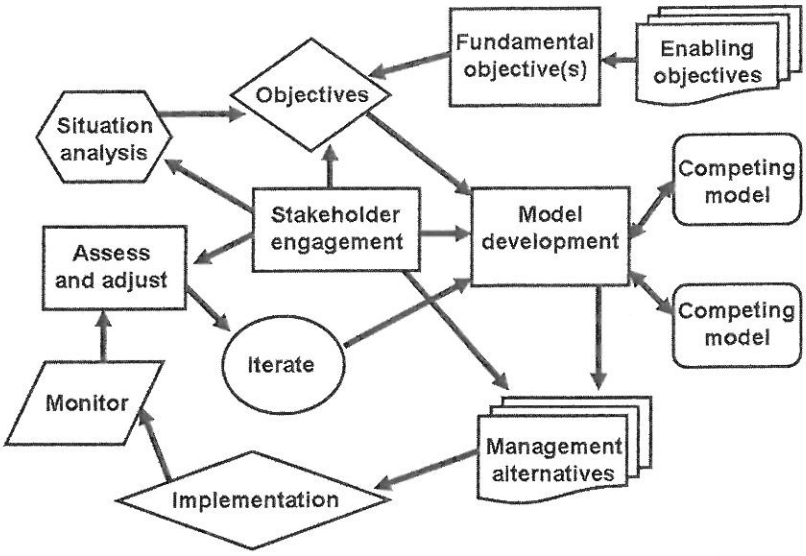


Fig. 25.1. A diagram of the adaptive management process.

ager and team develop an initial assessment of the management challenge and the social–ecological context. This is akin to getting one's house in order. The scope and complexity of the situation will dictate the scale of effort and to what extent the management team will require practitioners from multiple disciplines. It also will inform the range and identity of stakeholders who need to be engaged.

Let us examine a real case study. In insular Newfoundland, Canada, a dramatic decline in woodland caribou (*Rangifer tarandus caribou*) has alarmed the hunting outfitter industry and other citizens, who contend that predation on calves by black bears (*Ursus americanus*), coyotes (*Canis latrans*), and Canada lynx (*Lynx canadensis*) is responsible for the decline (Mahoney and Weir 2009; Fig. 25.2). Others have suggested that land-use impacts (largely induced by extractive resource industries such as oil, gas, mineral, and timber) are the major drivers for the decline, either through direct energetic effects on disturbed animals or indirectly through displacement of animals from preferred foraging and predator-escape terrain. Still others suggest climate change effects on habitat have a significant role to play.

Using an intensive review of existing knowledge, the Province's wildlife managers have scoped out the available intelligence, initiated new inquiries to address knowledge gaps, and are using this understanding to generate a conceptual management system that illustrates the presumed interaction of climatic, ecological, biophysical, socioeconomic, and political factors. Each of these categories is sufficiently

Fig. 25.2. Adaptive management is being applied toward reversing the decline of woodland caribou in insular Newfoundland, Canada. One suspected cause of decline is predation on calves by black bear, coyote, and Canada lynx. *Photo of caribou, black bear, and coyote by Sustainable Development and Strategic Science Branch, Government of Newfoundland and Labrador, Canada; photo of caribou calf mortality by J. F. Organ, U.S. Fish and Wildlife Service; photo of Canada lynx by J. H. Vashon, Maine Department of Inland Fisheries and Wildlife.*

complex to be viewed as a subsystem unto itself (Fig. 25.3). This initial analysis will reveal the key stakeholders, the context within which decisions will be framed, and the limits, constraints, scope, and opportunities for management. In this particular example, the wildlife managers determined they needed to enlist expertise in population dynamics, resource economics, sociology, and landscape ecology as part of the management team now formed. We refer to the product of this initial phase of situation analysis as a manager's model (Decker et al. 2009; Box 25.2).

Phase II of situation analysis involves engagement of stakeholders. A **stakeholder,** in the context of adaptive management, is any person who affects, or is affected by, the wildlife issue or wildlife management approach under consideration (Organ et al. 2006). The latter half of the 20th century saw a shift in how wildlife management agencies perceived the public and vice versa. Historically, **wildlife managers** were the experts who determined what was best for the public as far as wildlife was concerned. This expert authority model derives from the Prussian forestry roots of wildlife management (Gill 1996). Public acceptance of this expert authority approach waned as broader segments of society sought to exert influence over wildlife management programs and policies.

Recent trends have been toward an increase in participatory decision-making (Decker et al. 1996; Jacobson et al. 2010). The purpose of stakeholder engagement in situation analysis is to affirm the management need (i.e., to accurately identify impacts-based management objectives) and apply local knowledge to refine or validate the management system. Of greater importance, potentially, is to foster public trust and ownership in the management process by ensuring transparency and participatory engagement throughout the decision-making process. Stakeholder engagement is an art and discipline unto itself. Depending on the scale of the issue or the risks at stake, enlisting a professional to manage the stakeholder engagement process may be warranted (Fig. 25.4). Stakeholder engagement is most effective when it is attuned to the spatial, temporal, and social scale of the management situation (Chase et al. 1999). Determining the relevant scales and appropriate stakeholders are part of the art of wildlife management (Lee 1993*b*). In our Newfoundland caribou case study, deliberating on the scale of problem and the scale of management response led to a variety of critical questions, such as the following:

- Is the issue unique or limited to specific human and/or biological communities, or will management intervention affect other communities?

Box 25.2. The product of the initial phase of situation analysis is a manager's model

A manager's model is:

- A portrayal of desired conditions, actual conditions, factors that influence conditions, and considerations to be made before taking actions.
- A broad view of what needs to be managed to achieve objectives, with respect to a particular resource.
- Adaptable in that, as one learns more about the management system, the model should be modified.

A manager's model is not a plan, per se. It is a situation analysis.

From Decker et al. (2009:1).

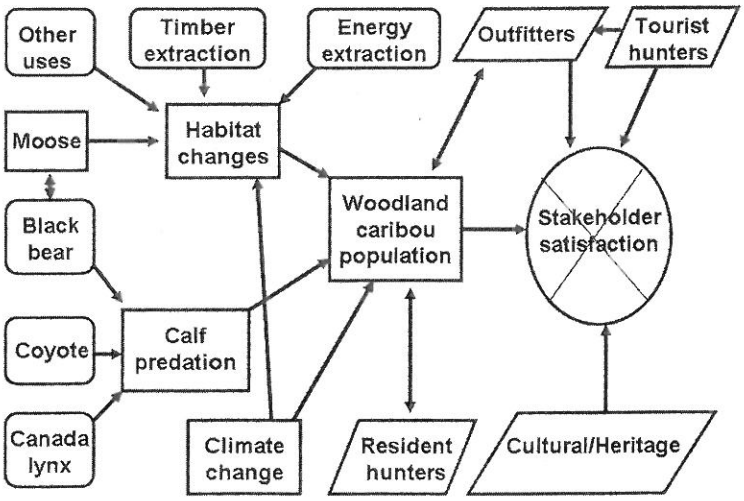


Fig. 25.3. A Conceptual Manager's Model of causes and effects of a decline in woodland caribou in insular Newfoundland, Canada.

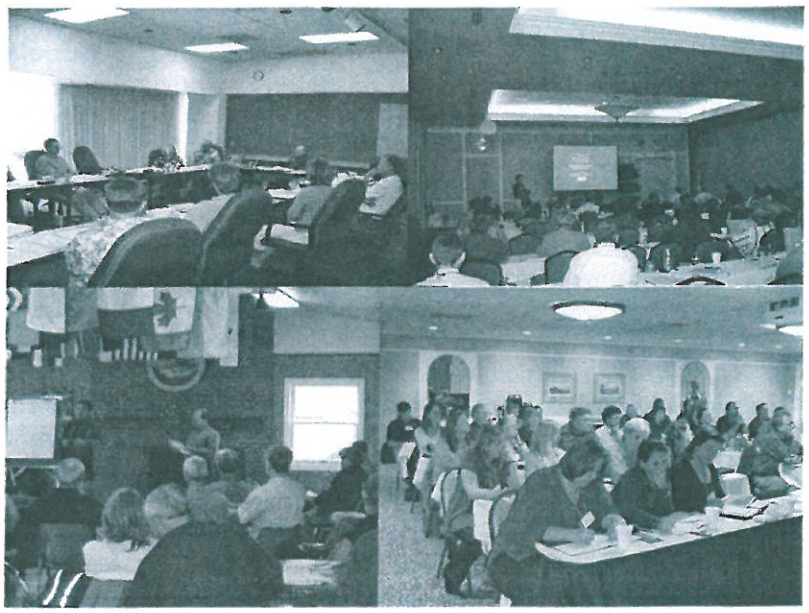


Fig. 25.4. Stakeholder engagement is an important part of the adaptive management process and should be matched to the geographic, temporal, and social scale of the issue. *Photos courtesy of U.S. Fish and Wildlife Service.*

- Is there potential for collateral effects on species other than those that are of concern?
- Will potential effects of management for caribou habitats impact other land uses?
- Will management actions that lead to improvement of caribou hunting inadvertently diminish opportunities for other forms of wildlife enjoyment (i.e., adversely affect other stakeholders)?

These are some of the questions that managers need to address when determining the appropriate stakeholders to engage in situation analysis and management decision-making. Having too broad a suite of stakeholders for the scope of the issue only confounds the process, reducing efficiency and possibly diverting it from the core management issue. Having too narrow a stakeholder base ultimately results in decisions that may not be durable, because affected interests not engaged may believe their concerns were not addressed. Many wildlife management issues involve conflict between different stakeholder interests. Engagement of competing stakeholders may slow the situation analysis process and make objective identification difficult (Wondolleck and Yaffee 2000), but the alternative of dealing with excluded stakeholders (i.e., their political and litigation activities) is even more time-consuming and counterproductive. Conflict resolution may be required early on (Lee 1999) and, depending on the scale and severity of the conflict, may require professional intervention.

In the woodland caribou example, the stakeholder base is broader geographically than is the caribou population itself. Stakeholders were drawn from the hunting outfitter community, the recreational and rural community interest groups, natural resource industries, tourism agencies, conservation organizations, the scientific community, and even nonresident and foreign hunters. This diverse constellation reflects the managers' efforts to consider all angles of this complex situation when identifying the appropriate stakeholders. For example, if reduction of predator populations is a likely management intervention, are there particular stakeholders unique to those species? Should representatives of the extractive industries be included as stakeholders? Although this process of articulating the managers' model initially reveals who the appropriate stakeholders are, others may be identified as the management process proceeds. Indeed, the founder stakeholder group may itself recommend additional members, thus linking stakeholder membership to the evolving and organic nature of the much larger management process.

Effective stakeholder engagement processes are open and transparent. Deliberating as a group avoids managers needing to explain the values of one group to another, which can lead to them being perceived as preferring a particular interest. When eliciting information from stakeholders, expect different perspectives to arise with respect to how the system operates. This can lead ultimately to the development of competing models, an acceptable outcome so long as all steps in the adaptive management process are followed (particularly monitoring the effects of alternative management interventions). Identifying responses of the system to different management actions sheds light on which model(s) best represent it.

Objective Setting

One of the most challenging aspects of wildlife management is establishing objectives that are clearly defined, achievable, and measurable within a specific timeframe. Too often objectives are presented that merely describe an action as op-

posed to an outcome. An objective should describe what you want to achieve, the **desired future conditions** toward which your management intervention is directed. How you intend to get there is a mechanistic descriptor of the process, not the desired change.

Two levels of objectives are appropriate for adaptive management—**fundamental** and **enabling** (Riley et al. 2002). Fundamental objectives correspond to the cumulative outcomes of management that create the desired future condition. Fundamental objectives are defined by stakeholders (e.g., an increase in hunter satisfaction with the waterfowl bag limit by 2015, a reduction of deer–vehicle collisions of 20% in 5 yr, a 20% reduction in bear damage to corn in 2 yr, prevention of the extinction of Kirtland's warbler [*Dendroica kirtlandii*] or an improvement in woodland caribou calf survival sufficient to offset annual adult mortality). Each fundamental objective should have at least one enabling objective linked to it. An enabling objective focuses on a particular management intervention designed to contribute to achieving the fundamental objective (e.g., increase protected waterfowl breeding habitat by 20% in 3 yr, improve visibility and lighting along 300 additional miles of roadway in 2 yr, increase bear harvest by 10% in 3 counties over the next 2 hunting seasons, expand jack pine [*Pinus banksiana*] habitat by 5% in 10 yr, reduce predation on caribou calves in the first 12 weeks of life by 50%).

Creating opportunities for stakeholders to define fundamental objectives is a key role of the wildlife manager, but doing so in some management issues may require independent facilitation. Objectives developed through stakeholder participation are considered more likely to result in sustained support because of greater satisfaction with them and, importantly, commitment to them by the public (Gregory 2000). An important role of the wildlife manager is advising stakeholders of the limits, or management space, as mandated in public trust law (Geist and Organ 2004, Organ et al. 2006). This includes biological capacity of a species or ecological capacity of a system, efficacy of management tools and technology, legal and policy requirements and constraints, etc.

Defining fundamental objectives is best accomplished by focusing stakeholders on identification of impacts. Impacts are significant beneficial and detrimental effects of human–wildlife engagement. These may be identified by managers, scientists, lay people, etc. (Riley et al. 2002). The benefit of focusing on impacts is that it cuts to the core of stakeholders' desired future conditions—the most important effects they perceive and the outcomes they desire. After fundamental objectives are articulated, a suite of enabling objectives for each desired outcome can and should be identified.

Furthermore, the links between fundamental and enabling objectives should be clear and expressly defined. In our woodland caribou case study, this has been much facilitated by ongoing and structured dialogue between managers, stakeholders, and an independent panel of scientists. An objective should either represent the essential reason for management intervention (fundamental) or be necessary to achieve another objective (enabling; Riley et al. 2003*b*). A network of nested objectives is ultimately created that identifies ties between fundamental and enabling objectives. Enabling objectives are initially formed with fundamental objectives in mind, but they are not solidified until models of the management system are created. Even when they are established, enabling objectives may be more prone to alteration than are fundamental objectives. Experience and ongoing review of outcomes may necessitate modification to the managers' enabling approach while leaving intact the fundamental objective.

Model Development

The term "**model**" in the context of adaptive management is intended to mean a "plausible representation of a dynamic natural resource system" (Williams et al. 2009:29). Models can range from informal verbal descriptions to discrete mathematical representations (Fig. 25.5). At least 2 levels of models are valuable, if not essential, in adaptive management. First is the overall management system model, a soft-system model of the coupled social–ecological system that tends to be general and qualitative. The management system model at minimum articulates fundamental objectives, enabling objectives, and the relationship between them. The second-level model is more specific, focusing on known or hypothesized relationships between alternative management actions and enabling objectives they are anticipated to achieve. The first level addresses "why" management is needed. The second level addresses "how" management will be achieved.

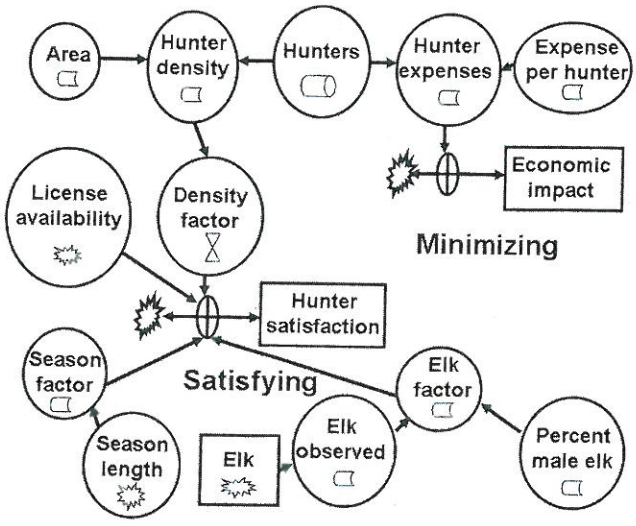


Fig. 25.5. A model of elk (*Cervus canadensis*) hunter satisfaction using mathematical functions to drive flow processes. The figure is a representation of a model created with Stella II® software.

The importance of having both model levels operational in the adaptive management process is they provide (1) better structure to guide and communicate thinking (Walters 1986), (2) increased decision-making capacity (Forrester 1968), and (3) increased rates of learning (Senge and Sterman 1994, Riley et al. 2003*b*). The reduction of a complex state of affairs to more simplified components has a proven track record of problem solving in science, and is of relevance to successful adaptive management approaches. Managers should recognize that adaptive management, while inclusive, does not imply dissociation from science, or any diminished application of it.

Of course, it is unlikely that stakeholders will have (at the outset, especially) a common understanding or vision of the system. However, model development, when conducted as a group exercise, does help participants focus and organize their thoughts and information onto a common template. This exercise reveals biases and assumptions, as well as information available and required. If done well, the process fosters appreciation among the stakeholders for the complexity of the system and the management challenges, as well as for one another's viewpoints. It also exposes where uncertainties exist in the management system. Additionally, models typically illustrate the linkages of ecological and human dimensions in the coupled social–ecological systems in which wildlife management occurs (Riley et al. 2003*b*).

Despite shared knowledge, competing models may still arise as a result of differing beliefs or uncertainty over how the system operates and what its underlying mechanisms are (e.g., compensatory versus additive harvest mortality). Regardless of the ongoing dialogue, some stakeholders will still see habitat issues as driving the woodland caribou decline while others will continue to espouse predator reduction as the only meaningful management response. This does not imply, however, the various stakeholders have not "learned" in the process, or they do not appreciate the complexities involved. Enabling objectives should be assessed in the context of the models to determine their relevance, achievability, and overall acceptability within the larger political and social dynamic. Burnham and Anderson (2002) provide a solid overview of model development and testing.

Identification and Selection of Alternatives

Alternative approaches to accomplishing enabling objectives are developed as a series of management interventions. Stakeholder involvement in identifying alternatives is important because it can reveal any important differences in social acceptability of alternatives. (Some of the most controversial wildlife management issues are about management actions, not about desired outcomes.) Experience also has shown that stakeholders often contribute creative ideas (Gregory 2000). Wildlife managers tend to rely on traditional approaches (Russo and Schoemaker 1989, Riley et al. 2003*b*), but stakeholder engagement fosters consideration of a larger suite of options. It is essential that management interventions are measurable as responses in the context of the system model. In the woodland caribou example, a potential management intervention is to reduce the black bear population (enabling objective) through increased hunter harvest of bears (management action). How to measure its efficacy has been an ongoing dialogue by managers, independent scientists, and public stakeholders.

Clearly, the hunting intervention needs to be implemented and monitored with attention to several questions if it is to contribute to adaptive management purposes. For example: Can the effect of harvest on the black bear population be measured? What is the effect level necessary to detect a change in calf survivorship? How many bears need to be removed to achieve that effect level? Can this level of removal itself be achieved? How do you know with certainty that the reduction in bears was responsible for any change detected in calf survivorship? Clearly, for each management intervention, a **monitoring plan** must be developed to assess whether the enabling objective was accomplished, and if not, why not.

Monitoring

Monitoring is critical to the adaptive management process. White (2001) identified the lack of rigorous evaluation of management interventions as the most common failure in attempts to implement adaptive management. Adaptive management is about learning from management and using that knowledge to improve, which is a good definition of evaluation. Adaptive management treats each intervention as an experiment, and the results of those experiments must be measured, applied to the models, and then used to improve the models, refine management (i.e., enabling objectives and related actions), and ultimately achieve the fundamental objectives. Monitoring provides improved information on the status of species populations, habitats, and satisfaction of stakeholders. In an adaptive management context, field research, surveys, habitat manipulation, and public education efforts are all directed toward contributing information that ultimately leads to improved decision-making.

In the woodland caribou example, the monitoring plan for determining whether an increased harvest of black bears could yield greater calf survival involves several independent yet related efforts (Fig. 25.6). A study of the black bear population was initiated ≥2 years prior to any reduction for purposes of developing baseline estimates of (1) the population size, (2) variation in movements related to the calving grounds and individual behavior associated with calf predation, and (3) the number of bears that would need to be removed to permit detection of a reduction in the population of x% over n years. Harvest of bears will need to be quantified to determine whether the population reduction level was achieved.

Concurrently, caribou calves are being radiomonitored from birth to document predation and mortality rates. In

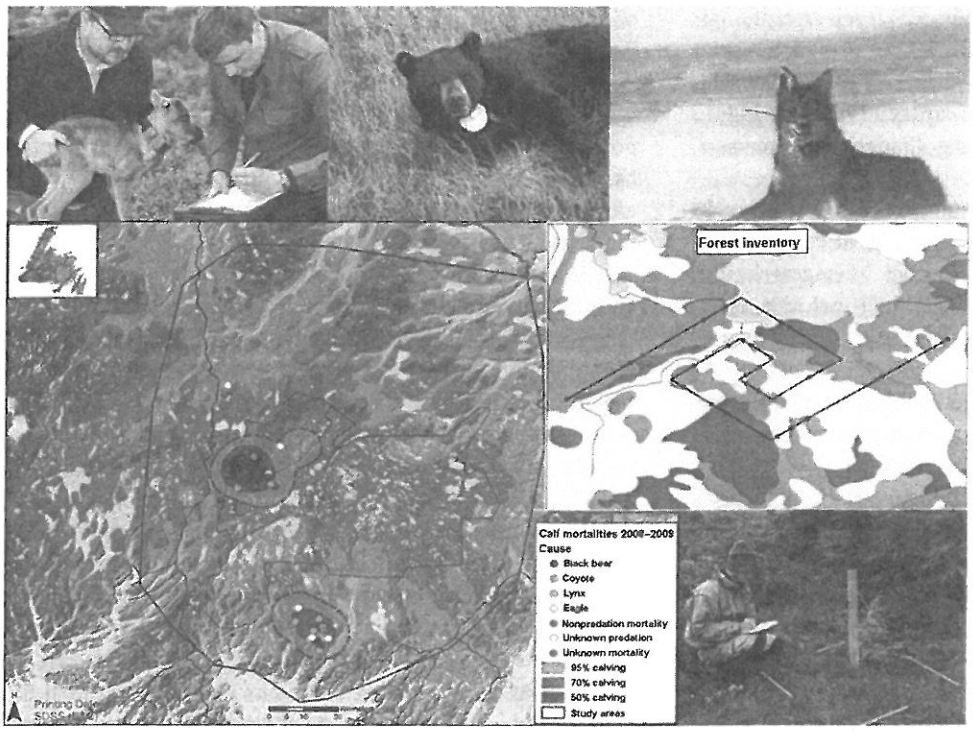


Fig. 25.6. Monitoring is a critical component of the adaptive management process. Adaptive management of woodland caribou in insular Newfoundland, Canada includes monitoring spatial movement and population responses of predators and caribou to management interventions. *Photos by Sustainable Development and Strategic Science Branch, Government of Newfoundland and Labrador, Canada.*

addition, herd composition surveys are being conducted to see if the intervention yields increased calf recruitment. Social science studies are assessing public acceptance of increased bear harvests, and hunter interest in participation and increased effort is being engaged through public workshops and information sessions. Whether the public observes changes in either the numbers of bears or caribou, their overall satisfaction with the management program also can be assessed through this process. Without such monitoring effort, managers would not have the ability to determine whether the interventions were achieving the desired results. Wildlife managers simply cannot afford to expend time and resources on prescribed interventions without acquiring knowledge of the system's response to those efforts.

Implementation

After following the steps of situation analysis, objective setting, model development, identification and selection of alternatives, and establishing monitoring plans, decisions can be made as to which management actions are implemented. Depending on the scale of the management system and magnitude of the issue, the decisions could rest with the managers and their stakeholder advising group or be vested in a policy-making body, such as a commission, administration, or legislature. Regardless of the form of governance in place, the initial recommendations will be formulated within the stakeholder group as facilitated by the wildlife managers.

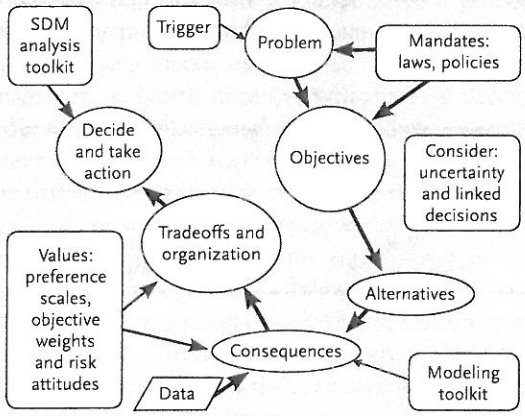
Obviously, the **decision-making process** should incorporate both scientifically derived knowledge and experience-based insights regarding which interventions among the set of potential alternatives should be selected and implemented. The process can be informal and driven by reasoning and consensus, or be highly structured (Box 25.3). In any case, social acceptability of the alternative should be a key selection criterion. Ultimately, however, the long-term sustainability of the wildlife resource must not be compromised. Managers must recognize that, despite the urgency of a prevailing management challenge, certain actions can have implications for wildlife that may be irreversible in their effects. An important part of the stakeholder engagement process is the role of the wildlife manager in advising stakeholders what the limits of management are as defined in law (Organ et al. 2006). Typically, this provides for the long-term sustainability of wildlife.

Assess and Adjust

Within the adaptive management framework, information derived from monitoring the management interventions is used to compare model predictions with actual responses. This process fosters learning, the core purpose of adaptive management, by assessing the effectiveness of the management approach in achieving desired outcomes. Information on the system itself also may be gained, and the system model may need to be adjusted to reflect this new knowledge. Assumptions about system dynamics used to develop the enabling objectives may now be refined or modified, leading to alteration of management prescriptions. Where competing models have been developed, the model that

Box 25.3. A model of structured decision-making

Structured decision-making (SDM) is a term used to describe a process to carefully organize analysis of problems in order to reach decisions focused clearly on achieving fundamental objectives. Based on decision theory and risk analysis, SDM encompasses a simple set of concepts and useful steps, rather than a rigid, inflexible approach. SDM is about making decisions based on clearly articulated fundamental objectives, dealing explicitly with uncertainty, and responding openly to legal mandates and stakeholder preferences or values in decision-making. SDM integrates science and policy. Each decision contains key components—management objectives, decision alternatives, and prediction of outcomes for each alternative. Analysis of each component discretely within a comprehensive framework improves overall decision-making.



An adaptive impact management diagram. *From U.S. Fish and Wildlife Service (2008b).*

most realistically simulates the actual response may be identified as the "best" model to describe the system components and their relationships.

In this sense, the monitoring process and knowledge gained also are used to assess whether the fundamental objectives have been achieved, not just the efficacy of enabling objectives. If the results fall short, adaptations to management interventions (enabling objectives and actions) based on this new knowledge can be developed, and the process can be repeated iteratively. It is important to engage stakeholders continuously in this process. They need to understand the outcomes, see the measures used as credible, and have input into the adjustments for future iterations. It is important to recognize that, in some instances, the results may warrant major alteration of the model or the development of an entirely new one. Such reevaluations and subsequent changes in approach should be viewed as positive outcomes of the process, rather than emphasized as weaknesses in original thinking.

Iteration

The **iterative process** in adaptive management involves a constant cycling back to implementation, involving stakeholders in decision-making about which management interventions to conduct next, in what manner they should be implemented, and what outcomes to expect. Monitoring, assessment, and adjustment, along with economic considerations, determine whether this cycle should continue. Managers normally terminate the process with a final management action informed by assessment of data collected in the previous iteration. This may, due to economic considerations or the unlikely prospect that ecological and social learning is complete, lead to a nonadaptive wildlife management approach (Williams et al. 2009). At that point, management carries on while outcomes inherent to the original fundamental objectives may continue to emerge, facilitated by inertial properties now expressed within the system being managed. This may require some lower intensity supportive measures or, in some cases, just monitoring (the system now being capable of producing desirable outcomes without active intervention).

PASSIVE OR ACTIVE ADAPTIVE MANAGEMENT

Two types of adaptive management are recognized: passive and active. Passive and active adaptive management approaches are distinguished primarily by the degree to which they emphasize the reduction of uncertainty. In practice, this means a different amount of emphasis is placed on learning in the objectives used to guide decision-making (Walters 1986; B. K. Williams, U.S. Geological Survey, personal communication). **Active adaptive management** pursues the reduction of uncertainty (learning) through management interventions, while **passive adaptive management** pursues a particular resource-related objective(s), with learning a useful by-product of decision-making. Passive adaptive management has been criticized at times for not being rigorous enough, but a true passive approach should have adequate rigor and differ from active adaptive management primarily in terms of how explicitly learning is incorporated as an objective. Both passive and active adaptive management incorporate competing hypotheses about how a system works. Passive approaches may (but do not always) base decision-making on only one model deemed most appropri-

ate from among several potential models. Results from management actions are used to update the model. Trial-and-error types of management—in which evaluation of management actions is missing, sporadic, or weak—should not be mistaken for passive adaptive management.

In comparison, active adaptive management uses management actions to elicit a learning response. The objectives used to guide decisions on management actions explicitly incorporate uncertainty and potential for learning. Active adaptive management obviously requires a greater commitment of time, money, intellectual rigor, and other human resources, along with a willingness to take risks with management. The promise of an active approach is that learning will occur more rapidly than in a passive approach. Those benefits must be weighed against the costs and abilities to conduct active adaptive management (Table 25.1).

EXAMPLES OF ADAPTIVE MANAGEMENT APPROACHES

Adaptive Resource Management

Adaptive resource management (ARM) uses the act of managing a system to learn about that system; it is likely the concept that most wildlifers have in mind when they hear the term "adaptive management" (Enck et al. 2006). In ARM, a resource management goal is set; for example, to maximize the harvest of a certain species or group of species or to maintain some amount of habitat in a certain condition within a management unit. A management prescription (a set of harvest regulations or a prescribed burning regime) is then described that is expected to lead to realization of the goal. Thus, managers are required to make explicit predictions of the results of their selected actions (the prescription) based on their existing knowledge of the system as derived through research and modeling. Simply put, ARM requires managers to say aloud, and preferably document on paper, "If we do X then we expect the result to be Y." They are then responsible to implement a monitoring scheme sufficiently robust to detect those expected results. The data collected during the monitoring lead to review of the outcomes relative to the a priori predictions. Finally, the process is repeated, with a new prescription and set of predictions put in place based on the knowledge gained in the previous iteration. Thus, "learning is not simply a by-product, but is formally acknowledged as an integral objective of the management process" (Lancia et al. 1996:439).

Inherent in ARM is the realization that management decisions must be made in the face of uncertainty and that the system changes through the act of management (Williams and Johnson 1995). Thus, ARM provides a framework for managers to reduce that uncertainty through a rigorous approach to the selection and evaluation of management ac-

Table 25.1. Criteria proposed by Gregory et al. (2006) for assessing appropriateness of adaptive management (AM) applied to 4 hypothetical wildlife management cases

Adaptive management criteria	Grassland–bird habitat-management experiments	Suburban deer overabundance	Wolf reintroduction	Land-use plan or climate change
Temporal and spatial scale				
Duration	X[a]	Y[b]	Y	Z[c]
Spatial extent and complexity	X	X	X	Z
External effects	X	Y	Y	Z
Dimensions of uncertainty				
Parameter	X	Y	Y	Y
Structural	X	Y	Y	Z
Stochasticity	X	X	Z	Y
Confidence in assessments	X	Y	Z	Z
Costs, benefits, and risks				
Specifying costs and benefits	X	Y	Y	Y
Magnitude of effects	Y	Y	Y	Y
Multiple objectives	X	Y	Z	Z
Perceived risks of failure	X	Z	Z	Y
Institutional support				
Leadership guidance	X	Y	Y	Y
Flexibility in decision-making	X	Y	Y	Z
Taboo trade-offs	X	Z	Z	X
Capacity of institutions	Y	Y	Y	Y

[a] Not a major barrier to proceeding with an active, experimental, AM approach.

[b] Challenge that must be addressed in order to successfully proceed with an active, experimental, AM approach. Passive approach may be more applicable.

[c] Significant challenge; active, experimental AM infeasible unless resolved. Likewise, passive approach must be resolved in order to be feasible.

tions that will lead to improved understanding of the system in question and ultimately better decision-making in the future (Williams et al. 2002). The actions available to the managers must be sufficiently diverse and intense such that their application to the system would be expected to produce a detectable change in the resource, either consistent with the predicted response such as to increase the confidence in that prediction or inconsistent with the prediction, but consistent with the expectations of an alternate hypothesis about the nature of the system.

Adaptive Harvest Management

In wildlife conservation, adaptive management has been most commonly applied to the process of regulating the harvest of game species, especially waterfowl (Johnson et al. 1993, Williams and Johnson 1995, Williams et al. 1996). **Adaptive harvest management** (AHM) is a special case of ARM because the management prescriptions and assumptions that drive the allocation and regulation of harvest can be expressed quantitatively and the predictions can be measured in the resulting population levels and demographics of the harvested species. Consequently, AHM presents a logical and very clear application of adaptive management theory.

The application of AHM to real world problems requires the specification of models of the population processes of the species in question and clear statements of the assumptions underlying those models. As applied to waterfowl management in North America, Williams et al. (2002) identified 4 key elements that characterize the process: (1) the existence of a suite of regulatory options available to managers that span a range of management (i.e., harvest) intensity, (2) the existence of an objective function by which to evaluate the regulatory options (e.g., harvest over time), (3) competing models of waterfowl population processes that would lead to meaningful predictions of the results of different harvest intensities, and (4) some measures of the reliability of these models that can be used to incorporate uncertainty into the evaluation process.

Specific to the application of AHM to mallard (*Anas platyrhynchos*) populations, Johnson (2001) described 2 competing hypotheses of additive and compensatory mortality in regards to harvest and 2 competing hypotheses regarding the effects of mallard abundance on per capita reproductive rate (i.e., density-dependent reproduction). These hypotheses allowed for predictions of the results of various harvest regulations that could then be used to evaluate their effectiveness in meeting the agreed population goals.

In practice, AHM involves developing an algorithm that is used to determine the appropriate regulatory options in light of the management goals and the likelihoods of the competing models (i.e., hypotheses) to explain population responses to management efforts. Information must be gathered on the population status, realized harvest, harvest rates, hunter effort, and other ecological variables that the managers and researchers believe are necessary to predict the population response to management. Regarding the latter, environmental variables such as previous year's rainfall or current year's number of ponds on the breeding grounds may be useful to understand population-level reproductive rates in waterfowl; alternatively, for white-tailed deer (*Odocoileus virginianus*), especially in northern environments, winter severity may be a key factor explaining population response to a range of management options. Regardless of the species in question, after monitoring and analyzing the relevant variables, model likelihoods require annual updates to drive the regulation setting process anew (Williams et al. 2002).

One of the fortuitous consequences of adopting AHM (or ARM) as a decision-making process is that it requires managers, researchers, and administrators to work together to identify a course of action and the criteria for evaluating those actions relative to an agreed-on set of goals. It requires that all parties acknowledge that decisions are made in the face of uncertainty and that the results of the management actions and their short- and long-term effects on the harvested population cannot be predicted with absolute certainty (Johnson 2001); indeed, if that were not the case, there would be no need for an adaptive decision-making process. Thus, all parties involved in the process have some ownership and cannot deny responsibility or shift blame if a set of predictions is incorrect and the management actions do not meet the goals.

Adaptive Impact Management

Adaptive impact management (AIM) builds off the concept of adaptive resource management (ARM). AIM explicitly incorporates the philosophy of value-based decision-making in wildlife management (Hammond et al. 1999). The main *difference* between AIM and ARM also is the main way in which they *complement* each other (Enck et al. 2006). AIM seeks to define fundamental objectives in terms of stakeholder-defined impacts, which may or may not be related to the status of the resource (Riley et al. 2003*b*). ARM seeks to identify fundamental objectives in terms of the status of the resource, incorporating stakeholder input as to what that status should be.

A focus on impacts and stakeholder involvement leads to management that "really matters" to society (Riley et al. 2003*b*). This improves societal support for the experimental aspects of adaptive management, support that is often lacking. A focus on impacts and stakeholder involvement also improves shared learning among scientists, managers, *and stakeholders.* This attribute of AIM is important to the credibility of wildlife managers and the agencies or organizations for which they work. In our woodland caribou case study this has been manifested in numerous ways, most particularly in how often a majority, though certainly nonunanimous, position is achieved on critical issues by the stakeholder group.

Definition of impacts and associated management objectives requires stakeholder involvement (Shindler and Cheek

1999). The kind of stakeholder involvement, and perhaps even collaboration, depends on the scale of impacts to be addressed, the level of stakeholder interest, and the number of jurisdictions (i.e., other agencies) that are involved. Stakeholder involvement can take several forms, and often must to capture input from all the relevant stakeholders and sustain engagement of key stakeholders. Often wildlife managers, or people they hire and oversee (staff or consultants), guide the flow of interactions with and among stakeholders and the analyses that are required to define objectives.

SUMMARY

Adaptive management is an effective process for wildlife managers to employ to (1) deal with uncertainty in the management system, (2) learn from their management actions, and (3) achieve desired results. Being adaptable or flexible in your management approach is not the same as managing adaptively or conducting adaptive management. Adaptive management requires adhering to a stepwise process and fully executing each step. A critical step is rigorous monitoring and assessment of management interventions. Without this, wildlife managers cannot achieve the essence of adaptive management, which is the explicit goal of learning more about the management system after each management action.

Stakeholder engagement is essential to adaptive management. Stakeholders help define the management system and the issues that are prompting management intervention. Their engagement throughout the adaptive management and decision-making process will foster ownership of the resulting actions and decisions, and will aid greatly in the learning process. Developing both fundamental and enabling objectives will help wildlife managers treat management interventions as experiments, and monitor and evaluate them against desired outcomes.

Different approaches toward adaptive management have been employed in wildlife management. Adaptive resource management is a process where wildlife managers predict a system response (typically an enabling objective) to a management intervention based on a model and then test the observed response against the model. Adaptive harvest management is a special application of ARM applied primarily to waterfowl and other game-harvest management scenarios that uses explicit quantitative models. Adaptive impact management explicitly incorporates the philosophy of value-based decision-making in wildlife management and complements ARM. AIM seeks to define fundamental objectives in terms of stakeholder-defined impacts, whereas ARM focuses on enabling objectives and the best methods for achieving them. In considering the initiation of an adaptive management approach, wildlife managers should carefully evaluate whether it is appropriate for the management challenge at hand. To further understand the concepts presented in this chapter, we recommend the following articles: Lancia et al. (1996), Johnson (2001), Riley et al. (2002), Riley et al. (2003*b*), Enck et al. (2006), Organ et al. (2006), and Williams et al. (2009).