Chapter 24

Adaptive Management and Ecological Restoration

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Most people involved in resource management have heard of adaptive management (AM), and many claim to practice it, but few seem to really understand it. Many have a general notion that it involves adapting policies and procedures based on results, but it is a misperception that AM simply comprises "adapting as you go" based on trial and error. In this chapter we intend to shed some light on this tremendously powerful tool and to illustrate its enormous benefits for ecosystem restoration.

Beyond the Myth: More Than Just Adapting

Ecosystems are complex and dynamic. Our understanding of how they work and how they respond to natural and anthropogenic disturbances is limited. Unexpected events are inevitable. This makes ecosystem management and restoration challenging: What conditions, structures, and functions should we restore? How do we achieve these goals? Restoration goals are based on values, and AM cannot help resolve conflicts over values. However, it can aid in answering the second question and in implementing restoration in the face of change, surprises, and uncertainty.

AM is a rigorous approach for learning through deliberately designing and applying management actions as experiments. First developed in the 1970s (Holling 1978), it has since been applied to a wide range of resource and ecosystem management problems (ESSA 1982; MacDonald et al. 1997; Bouris 1998). AM is a problem-solving environmental management approach, not a recipe. It involves synthesizing existing knowledge, exploring alternative actions, making explicit predictions of their outcomes, selecting one or more actions to implement, monitoring to determine

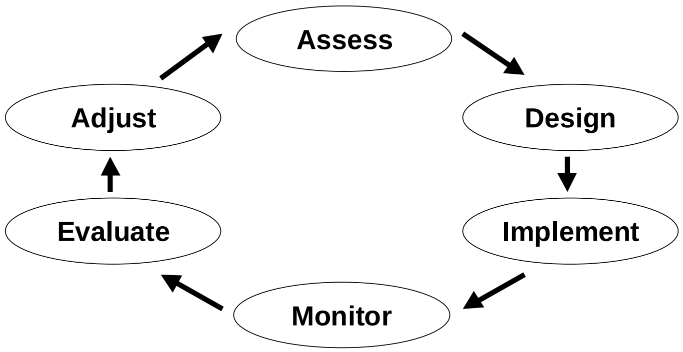

FIGURE 24.1. The adaptive management framework. Figure 1 from Nyberg 1999, copyright Queen's Printer for Ontario, 1999. Reprinted with permission.

whether outcomes match those predicted, and using these results to adjust future plans (Walters 1986; Taylor et al. 1997; Figure 24. 1). In reality, these conceptual steps may not occur in this neat order (e.g., baseline monitoring may continue while initial evaluations and adjustments are made), but breaking the approach into discrete sequential steps increases the level of rigor in management discussions. Of cardinal importance is the circular nature of the AM approach – evaluation and adjustment ("closing the loop") are integral parts of a systematically designed learning process.

Step 1: Assess

The first step involves clearly defining and bounding the problem. Within the context of ecosystem restoration, this includes identifying

- restoration objectives, identified from input from all stakeholders, carefully focusing on fundamentals, or what you want, rather than means, or how to get it (Gregory and Keeney 1994)
- possible suites of actions that could be taken to achieve objectives
- indicators or performance measures that could be monitored to determine whether the actions are indeed achieving desired objectives
- relevant spatial limits and resolution of the actions and indicators
- relevant temporal horizon and resolution of the actions and indicators
- key uncertainties, or what is not known about how the actions will affect the indicators

- hypotheses regarding the uncertainties (predictions about how the indicators may be affected by various actions), sometimes explored through tools such as computer models
- what to do under each possible set of outcomes

Useful tools in this process include stakeholder workshops, computer simulation models, conceptual models, hypotheses of effect, and decision analysis.

Step 2: Design

The second step involves designing a restoration plan that details what specific actions will be taken to move concurrently toward achieving restoration objectives and testing hypotheses regarding the key uncertainties identified in step 1. The plan needs to rethink the actions defined in step 1 in light of both uncertainties and alternative hypotheses; that is, there are now both restoration objectives and learning objectives. It is important to freely explore alternative designs and actions, given the inevitable trade-offs between statistical power, cost, feasibility, and ability to meet restoration objectives while avoiding unacceptable risks. Testing hypotheses involves creating contrasts in time and/or space. Ultimately this should be in the form of detailed prescriptions that specify what is to be done at each site, and when. This plan should contain sufficient detail for a contractor or field worker to properly carry out all prescribed activities. There are numerous experimental design issues (e.g., creating sufficient contrasts, including sufficient replicates, avoiding confounding, including controls) and tools available to assist with this (Walters 1986; Sit and Taylor 1998; Chapter 23). This step also includes the preparation of a detailed monitoring plan, specifying sampling design, scale, variables, and methods. Sampling design should be sufficient to detect effects that are environmentally important, given the natural variation in indicators over time and space.

Step 3: Implement

The third step comprises implementation of the restoration plan. It is critically important that implementers understand the logic of the experimental design. All aspects of the plan must be adhered to, including prescribed locations and timing of restoration actions. Deviations from the plan may occur for unavoidable operational reasons – a common occurrence in forest restoration. If so, these deviations and their rationale must be clearly documented.

Step 4: Monitor

There are three aspects to monitoring (for more detail, see Chapter 23):

- Monitoring implementation to ensure that activities were undertaken as prescribed
- Monitoring indicators to learn whether the activities worked, or achieved the original objectives
- Monitoring indicators to test alternative hypotheses for key uncertainties (e.g., Does method A do a better job of restoring structural diversity within a shorter timeframe than method B? How do the costs of the two methods compare?)

Step 5: Evaluate

Analyze monitoring data to learn what happened, and compare the results with the hypotheses and predictions documented in Step 1. Which hypotheses can be rejected? Which are strongly supported? Which hypotheses are neither strongly supported nor rejected? Which activities moved the system toward restoration objectives, and which did not? This step focuses on discovering whether predicted outcomes were accurate and on learning which activities best achieve desired objectives.

Step 6: Adjust

Alter restoration policy, plans, practices, and/or prescriptions as warranted based on what was learned. This sounds obvious and simple, but often it does not occur in traditional resource management; we do not tend to formally recognize uncertainties and then explicitly design management actions to reduce these uncertainties. Thus, the products of steps 1 and 2 have a big influence on the ability to learn and make adjustments in step 6.

Passive and Active Management

Adaptive management experiments can be categorized into two types: “passive” and “active” (Walters and Holling 1990). In passive AM, alternatives are assessed in step 1, and the management action deemed best is designed and implemented in steps 2 and 3. Monitoring and evaluation (steps 4 and 5) then lead to appropriate adjustments (step 6). In active AM, managers explicitly recognize in step 1 that they don't know which activities are best, and then select several alternative activities to design and implement in steps 2 and 3. Monitoring and evaluation of each alternative help in deciding which was more effective in meeting objectives, and adjustments to the next round of management decisions can be made based on those lessons.

Passive AM may be initially less expensive and require fewer people, because only one alternative management technique or strategy is implemented. However, if managers are incorrect in their assumptions, it can take longer to learn which activities are indeed most effective. The absence of a formal comparison of alternatives may mask weaknesses in the approach assumed to be best. As a result, it may prove necessary to go through several iterations of passive AM experiments. Passive AM is also more likely to confound natural environmental change and management effects, hampering managers' ability to draw confident conclusions.

Active AM may require a larger initial investment of time, labor, and funds, but since several alternatives are tested (usually including a no-action control), learning happens faster and fewer iterations may be needed to find the best alternative. The application of numerous thinning prescriptions in Fort Valley as part of the Flagstaff urban-wildland interface restoration project is a promising step in this direction (Chapter 1).

Step 3 does not always require active application of management experiments. This step can sometimes be achieved by taking advantage of uncontrolled events (Schwarz 1998), such as monitoring results of a naturally occurring large wildfire while also monitoring an appropriate control site. Past events and preexisting data can also illuminate longer-term processes through retrospective studies (Smith 1998a). For example, Remple et al. (1997) used sixteen years of survey data and three Landsat satellite scenes spanning two decades to evaluate hypotheses about the relationship between moose (*Alces alces*) populations, habitat, and timber management guidelines in Ontario.

Paradigm Shift: Focus on Learning

It should be clear by now that the primary goal of adaptive management is to learn. Uncertainty about management or restoration objectives can lead to either charging ahead blindly or wallowing in indecision, either of which can have serious social, economic, and ecological implications. AM instead allows resource managers to take action in a manner that explicitly seeks to reduce uncertainty. It is of particular relevance in a field as new as ecological restoration. Under-taking this learning successfully requires an understanding of the AM approach, a willingness to recognize and admit uncertainties, an ability to focus on "need-to-know" uncertainties, the knowledge and resources necessary to implement sound experimental design, and an effort to faithfully document and share the process and findings.

The AM approach compels resource managers to say "I don't know which actions best achieve my management objectives, so 1 am going to proceed in a manner to help me learn just that." This requires a real paradigm shift in ecosystem management, a willingness to come out and clearly admit what we don't know. This takes courage. It can be very risky for individuals, as most agencies do not reward staff for clarifying and focusing on uncertainties. It can also be risky for agencies, which may risk losing funding and support if they advertise what it is they don't know. It can be unsettling to learn of such uncertainties, but they are inevitable and should not be feared if action is being taken to reduce uncertainties and to learn.

Implicit in this is the need to articulate restoration goals and objectives (Walters 1986), which requires clear strategic thinking and should involve consideration of ecological, social, and economic values. What are the fundamental objectives of the restoration plan? When do we want to achieve these objectives? Science by itself does not provide these answers (Chapter 5). Key uncertainties can be clarified only after these goals and objectives have been identified and linked to potential actions.

Resolving Key Uncertainties

AM seeks to resolve key uncertainties (Taylor et al. 1997), which requires distinguishing "need-to-know" from "nice-to-know" questions. A "need-to-know" uncertainty is one that prevents a decision from being made with confidence on particular management actions. For example, it would be useful to know historic levels of all native animal species in southwestern ponderosa pine forests, and this might assist stakeholders in formulating restoration objectives. However, this knowledge would likely not significantly affect decisions about restoration prescriptions. In contrast, a lack of knowledge about how the timing, severity, and intensity of burning affects threatened, endangered, sensitive, or exotic species does affect our ability to make confident decisions about restoration treatments.

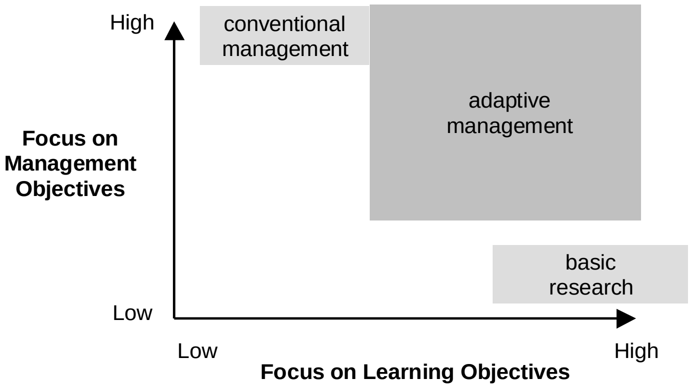

FIGURE 24.2. Adaptive management within the context of conventional management and research. Reprinted by permission of ESSA Technologies Ltd.

Adaptive Management and Conventional Management

AM also differs from conventional management by focusing more on learning. One of the challenges of AM is to find the right balance between management and learning objectives (Figure 24.2), which may require compromises. For example, undertaking a range of thinning treatments to maximize learning will almost certainly result in some areas not achieving management objectives as well as others. The trick is to know when and where this risk is and is not acceptable; a restoration treatment far from human structures, for example, might be more suited to broad experimentation than a fire-prone forest at the edge of town. AM practitioners must walk the sometimes fine line between maximizing learning and minimizing risk.

Hitting the System Hard

Learning tends to happen more quickly when there is sufficient contrast in experiments to be able to distinguish effects from different treatments and from background noise. One effective way to do this, particularly when space or funding to undertake a large number of treatments and replicates are lacking, is to "hit the system hard" by employing contrasting treatments. An audacious example concerns the effects of forestry roads on lake trout (*Salvelinus namaycush*) in central Canada (Gunn and Sein 2000). Lake trout were considered highly sensitive to forestry-related disturbances; current guidelines require buffer strips around lakes with trout populations. The relative effects of high harvest levels and forestry induced sedimentation of spawning sites, though, were unknown. As an experiment, the Ontario Ministry of Natural Resources covered spawning substrate with plastic sheeting on two lakes to see what would happen to trout abundance, population size structure, and spawning activity. Researchers began cautiously at first, covering only 15 percent of the known spawning sites, then 35 percent, 50 percent, and finally 100 percent. They predicted that this would cause a decline in juvenile abundance as a result of habitat loss, and an increase in mean fish size. On a third lake, researchers merely built an access road within 330 feet (100 meters) of a remote lake (with no signs or other advertising), and monitored both angling effort and the trout population.

They learned that, contrary to common belief, lake trout proved to be highly adaptable to spawning habitat disturbances, repeatedly selecting new sites when previous spawning sites were covered. Monitoring showed no decline in juvenile abundance and no increase in average fish size. In contrast, exploitation effects on the third lake were dramatic. Anglers discovered the road and harvested trout at an unsustainable level; within three months the population dropped by 72 percent. This is an excellent example of several AM principles: hitting the system hard (repeatedly covering all known spawning areas for several years in a row), taking a creative approach (using plastic tarps to render previous spawning habitat unavailable), and testing hypotheses (challenging the conventional wisdom that trout are highly sensitive to spawning disturbance).

Sound Experimental Design

It may not always be possible or acceptable to hit the system hard, but AM experiments should always follow sound experimental design principles. Controls are essential for discerning treatment effects, as illustrated in the following story attributed to Dr. E. Peacock Jr. (Lee 1993).

"One day when 1 was a junior medical student, a very important Boston surgeon visited the school and delivered a great treatise on a large number of patients who had undergone successful operations for vascular re-constructions. At the end of the lecture, a young student at the back of the room timidly asked, 'Do you have any controls?' Well, the great surgeon drew himself up to his full height, hit the desk, and said, 'Do you mean did I not operate on half of the patients?' The hall grew very quiet then. The voice at the back of the room very hesitantly replied, 'Yes, that's what I had in mind.' Then the visitor's fist really came down as he thundered, 'Of course not. That would have doomed half of them to their death.' God, it was quiet then, and one could scarcely hear the small voice ask, 'Which half?'"

Replication in time or space is necessary for reliability of conclusions, as is ensuring that appropriate response variables are being measured. The simplest means of detecting impacts is a before-after-control-impact paired survey (Schwarz 1998), but there are many others to chose from. Of utmost importance is ensuring that the design chosen and the indicators measured will suffice to answer key questions or uncertainties.

Documentation

The learning process requires faithful and thorough documentation of goals and objectives; key uncertainties; alternate hypotheses for these uncertainties; an action plan describing what will be done on the ground; a monitoring plan describing what indicators will be measured (when, how, and for how long); predictions of what will happen to these indicators; any deviations from the action plan during implementation; monitoring results; evaluation results; and any changes or adjustments that are made based on the results. Recording all this is important in fueling the feedback loop, which is necessary for making adjustments based on what happened and what was learned. It is also important for institutional memory, as it is very likely that staff will change during the course of any long-term restoration project.

Lessons Learned: Advice from Those Who Have Been There

Adaptive management has formally been used in land and wildlife management in a variety of settings in North America: in forests of the U.S. Pacific Northwest (Stankey and Shindler 1997; Bormann 1999; Gray 2000) and British Columbia (Nyberg 1999), in restoration of Wisconsin pine and oak barrens (Power and Haney 1998), and in the management of Glen Canyon Dam on the Colorado River (Walters et al. 2000). The successes and failures of these efforts have provided many lessons to those who would apply AM to ponderosa pine forest restoration in the Southwest.

Lessons for Managers

What lessons can be offered to ecosystem managers from the successes and failures of past adaptive management efforts?

- Embrace uncertainty and take risks. Managers often fear taking risks or acknowledging that current management is problematic. To allay these fears, build support for AM initiatives by committing to use them as an opportunity to learn. Look for small victories and early successes. It may be best to start with problems and pilot projects that can provide new data and insights within one to two years to demonstrate an approach and its value, then tackle larger-scale issues that may take decades to resolve.
- AM is an innovative alternative to ever-tightening regulation. It can be used to rigorously assess the necessity and sufficiency of standards and guidelines, and to foster creative solutions to local problems.
- Comparisons of multiple pathways speed learning. This requires accepting that more than one management pathway can likely achieve management goals and then comparing different pathways by rearranging practices across the landscape.
- AM must be institutionalized to be successful. Add learning objectives to environmental decision documents. Educate and train resource managers at multiple levels in the organizational hierarchy about AM concepts and processes. Take advantage of the energy, drive, and imagination of innovators at the field level, while supporting them from above. Lead rather than command, and pull staff along by enthusiasm and example. Demonstrate how to do it, for various issues and at various scales; not all AM needs to be large-scale and long-term. And be patient – build understanding and use of AM into the organization slowly, on generational time scales.
- Managers may feel they are too busy trying to fulfill current duties to learn a new approach. To get around this, seek out and work with enthusiasts who will accept challenges if they understand the resulting benefits.
- The roles of both management and science in AM must be clear. Some managers make the false assumption that only scientists do AM. In fact managers are best positioned to learn by doing, and

should take the lead; they can rely on other experts for technical assistance with experimental design, data analysis, and so on. Management should be separate from science, but there must be good communication between the two.

- Some managers are under the false assumption that they have been doing AM for years. This leads to a “watering down” of AM, which in reality is a rigorous, systematic process, not a trendy, fuzzy concept.
- If there is a lack of funds for new initiatives, begin with a high-profile “crisis” issue of major concern, or an issue that can be investigated inexpensively and deliver a short-term payoff. Develop good “business case” examples of how improved management practices can save money.
- Do not limit the time horizon up front. Assume that AM will be undertaken for as long as it takes to achieve goals.

Who Should Be Involved?

Past projects involving adaptive management also offer lessons in participation.

- Citizen involvement is essential. Society no longer accepts expert-based learning and decision-making (Chapter 5), and new roles for citizens are needed to relate management to societal values, infuse fresh ideas, and challenge existing institutions. New citizen-manager-scientist partnerships are needed.
- Involve all stakeholders in developing shared goals and objectives. Ideally, the majority of stakeholder groups should understand the ecosystem, be willing to share their opinions, and be involved in deciding future conditions and management actions. A good collaborative process is fundamental.
- Even when stakeholders have agreed on ecosystem goals, they may differ on how best to achieve them. AM experiments are a good way to test alternative management actions that arise from different hypotheses and are supported by different stakeholder groups. If necessary, employ conflict resolution to have stakeholders admit uncertainties, and focus constructively on reducing them. Creative solutions are often possible.

Data Collection and Analysis

Finally, past efforts can teach an array of technical lessons.

- Choosing proper indicators is critical. Monitoring data should allow managers to demonstrate progress toward goals and to test hypotheses. Linking monitoring to hypothesis testing is the best way to make use of limited resources. Consider how quickly an indicator will respond to treatment, and the likelihood of catching undesirable changes before they become irreversible. Include indicators of long-term trends.
- It is generally more effective to monitor a few indicators well across a number of treatments and reference sites than to intensively monitor many ecosystem components in only a few locations.
- Look for efficiencies in monitoring. Reuse ground-truthed plots for permanent monitoring to reduce variance and improve chances of detecting change. If collecting data on a variety of taxa, locate sampling plots around a single plot origin point where possible, as this will save time and energy in documenting and traveling to plot locations, especially if field technicians vary from season to season. It also provides a clear, concise framework for explaining the program to others.
- Decide how data are to be analyzed before finalizing sampling methods. Statistical methods for both initial inventory and monitoring should be developed in concert with sampling design.
- Adopt an approach for ensuring quality, credibility, and objectivity for the science within AM experiments.