A Case Study in Coping with Risk and Uncertainty in Natural Resource Decisionmaking: The Sierra Nevada Forest Plan Amendment

Adaptive Management

> "The strategy I discuss in this book is adaptive management—treating economic uses of nature as experiments, so that we may learn efficiently from experience. Second, we need to grasp far more wisely the relationships among people. One name for such a learning process is politics; another is conflict. We need institutions that can sustain civilization now and in the future. Building them requires conflict, because the fundamental interests of industrial society are under challenge. But conflict must be limited because unbounded strife will destroy the material foundations of those interests, leaving all in poverty. Bounded conflict is politics." (Lee 1993, p. 8)

Definition

The term "adaptive management" first appeared in the natural resources management literature in the mid-1970's (Hollings 1978). The approach borrows heavily from adaptive control process theory, which addresses the question of how to construct decisionmaking devices, or control devices, capable of learning from experience (Bellman 1961). Adaptive control devices have feedback mechanisms that either allow information to accumulate automatically or deliberately probe the environment to gather new information. Because these devices can modify their behavior in response to new information, they are better suited to conditions of uncertainty than nonadaptive control devices. Adaptive management concepts were first applied to natural resource management in the 1970's (Hollings 1978). Adaptive management in natural resources also incorporates informational feedback into the management process to accelerate the rate at which environmental decision makers learn from their experience (McLain and Lee 1996). Walters (1986) argues that scientific understanding of complex natural resource systems with high uncertainty will come from the experience of management as an ongoing, adaptive, and experimental process, rather than through basic research or the development of ecological theory.

Adaptive management borrows from both operations research and management science by relying on the systematic use of the scientific method and mathematical models to help decisionmakers make decisions in the face of complexity, changing conditions, and uncertainty about key relationships among system components (McLain and Lee 1996). It is premised on the idea that managers should structure interventions in ways that permit them to anticipate or take advantage of surprise as a tool for learning, rather than attempting to avoid or react to the inevitable surprises that arise (Timmerman 1986). Adaptive management acknowledges that policies must satisfy social objectives, but must be continually modified and remain flexible for adapting to these surprises (Gunderson 1999). Therefore, it views policies as hypotheses and management actions as experiments, in an experimental sense. In a nutshell, adaptive management is a structured process of "learning by doing," that involves much more than simply better ecological monitoring and response to expected management impacts (Walters 1997). A common form of adaptive management used by the USDA Forest Service involves implementation of plan or project direction with monitoring to determine if the results were as expected. More broadly, though, adaptive management includes a variety of actions, ranging from experimentation in which hypotheses are developed and tested to determine how the system responds and to examine alternative approaches, to traditional scientific inquiry, to less formal, trial-and-error approaches (Stankey et al. 2003).

The most recent forms of adaptive management begin with the synthesis of existing experience and scientific information into dynamic models that attempt to make predictions about the impacts of alternative policies (Walters 1997). According to Walters (1997), the modeling step serves three functions: (1) problem clarification and enhanced communication among scientists, managers, and other stakeholders; (2) policy screening to eliminate options that are most likely incapable of doing much good because of inadequate scale or type of impact, especially those that might lead to irreversibility [irreversibility occurs when the ecosystem cannot escape from particular states no matter what action is taken, such as extinction of a species (Chavas 2000)]; and (3) identification of key knowledge gaps that make the model predictions suspect. By leading to the design of critical management experiments, modeling, in principle, permits the replacement of learning by trial and error (an evolutionary process) with learning by careful tests (a process of directed selection).

The initial focus has been on integrating science into the decisionmaking. However, most of the conflicts and difficulties in reaching satisfactory decisions not only involve scientific uncertainty, but conflicts in values and acceptance of risk and uncertainty among stakeholders. Therefore, more emphasis is being placed on the social side of the process. For example,

> "Scientific adaptive management relies excessively on the use of linear systems models, discounts non-scientific forms of knowledge, and pays inadequate attention to policy processes that promote the development of shared understanding between diverse stakeholders. To be effective, new adaptive management efforts will need to incorporate knowledge from multiple sources, make use of multiple systems models, and support new forms of cooperation among stakeholders." (McLain and Lee 1996, p. 437)

Habron (2003) summarizes adaptive management as a series of linked, iterative steps involving problem identification, collaborative brainstorming, model development, hypothesis testing, planning, experimentation, monitoring, evaluation, and behavioral change (figure 1).

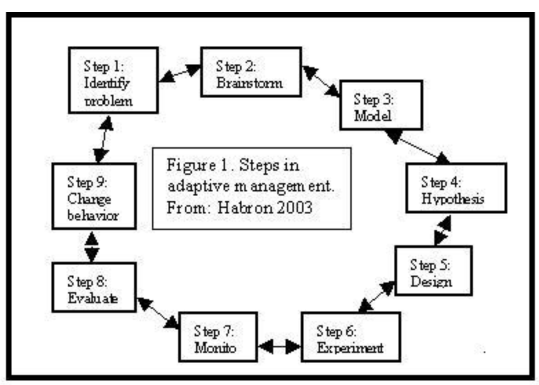

Figure 1. Steps in adaptive management. From: Habron 2003

How adaptive management deals with risk and uncertainty

Central to the concept of adaptive management is the issue of uncertainty (Irvine and Kaplan 2001). Unlike conventional management practices, which may attempt to make precise predictions and presume certainty, adaptive management accepts as given the reality of incomplete knowledge and focuses on opportunities to build learning opportunities into the design and implementation of policies. Therefore, adaptive management emphasizes learning by doing, treating management actions and policies as hypotheses to be tested and then designing them and implementing them to generate critical information about the resources being managed. Irvine and Kaplan (2001) describe three key steps: the assessment phase identifies specific goals for the natural resource being managed, such as desired future condition; the second phase identifies and assesses the significance of gaps in knowledge and generates alternative management actions; the implementation phase treats management actions as experiments; and the final phase utilizes the findings to revise policy as necessary.

In a review and critique of the adaptive management approach used in the Northwest Forest Plan, Stankey and others (Stankey et al. 2003) highlight three critical aspects of adaptive management:

1. Adaptive management treats actions and policies as experiments that yield learning by mimicking the scientific method of specifying hypotheses, highlighting uncertainties, structuring actions to expose hypotheses to field tests, processing and evaluating results, and adjusting subsequent actions and policies in light of those results.
2. Rather than treating uncertainty and risk as a reason for precaution, adaptive management embraces them as opportunities for building understanding that might ultimately reduce their occurrence.
3. Effective adaptive management involves three elements: (a) producing new understanding based on systematic assessment of feedback from management actions; (b) incorporating that knowledge into subsequent actions; and (c) creating situations in which understanding can be communicated.

Management of complex biological and social ecosystems involves risk and uncertainty (Johnson et al. 1999). In most cases, risk and uncertainty result in caution or no action until more information is known. But, acting in a risk-adverse manner can suppress the very experimental policies and actions that would produce the information needed to reduce such risk and uncertainty. It is problematic as to whether such protective approaches are preferable to experimentation as a way to safeguard endangered values (Stankey et al. 2003). And, a consequence of the failure to act adaptively in the presence of uncertainty is that potential learning which might better inform future actions is foregone.

Examples

To evaluate the use, success, and pitfalls of adaptive management, examples from the literature were examined. These examples include setting of air quality standards in Great Britain (Stubbs and Lemon 2001), dealing with the threat of hydropower generation to salmon and steelhead in the Columbia River Basin (Lee 1989; McLain and Lee 1996), regulation of water flows and the threatened Florida Everglades (Gunderson 1999), a review of seven adaptive management cases in riparian and coastal ecosystems (Walters 1997; Rogers 1998), management of scarce ground water supplies in and around Fort Huachuca in Arizona (Gen 2001), use of adaptive management by watershed councils in southwestern Oregon (Habron 2003), an experimental flooding from the Glen Canyon Dam in the Grand Canyon (Meretsky et al. 2000), and the Adaptive Management Areas (AMA's) provided for in the Northwest Forest Plan (Stankey et al. 2003; Stankey and Shindler 1997).

Air quality standards in Great Britain **(Stubbs and Lemon 2001)**

Air quality standards for Europe have been set by international negotiations within the European Union and the United Nations Economic Commission for Europe. In the United Kingdom (UK), proposals for a national air quality strategy focused on local government as the level best able to provide an integrated management response. Local governments, however, were reluctant to take on this task without additional funding. Air quality issues cross boundaries of authority and responsibility and the UK legislation assumed inter- and intra-agency cooperation at scales from local to regional and national, without significant additional financial resources. Beyond organizational complexity were issues of the dynamic complexity of the processes affecting air quality phenomena and the problematic nature of the linkages between air quality and public health.

Stubbs and Lemon (2001) chose to develop and study a process for adaptively implementing the air quality regulations in the Bedfordshire County, UK. The study had two objectives: (1) to identify the network of individuals who had formal responsibility for, or who could make most difference to, Bedfordshire's air quality; and, (2) to facilitate activities designed to share understanding between those individuals and highlight opportunities for coordinated action. They used a reflective and adaptive research process that followed the philosophy of "think of the other." This was manifest in a three-way focus on how actions were being felt by others, how things might be other than they appeared, and how theory and data were informing one another.

The process began by discovering the network. It was clear that the key groups were maintaining diverse, sometimes conflicting, interpretations of the process that generated what were widely accepted as central phenomena or issues relating to air quality. If the language of stakeholders is used in its broadest sense of clusters of shared interest and concerns, then stakeholders were defining issues, but issues were also defining stakeholders. Since the individuals concerned did not have a history of cooperation, Stubbs and Lemon placed initial emphasis on creating a climate that would foster a shared understanding of each other's positions and contributions through creative dialogue, learning from diverse perspectives (Senge 1990).

The process begins with a facilitated stakeholder face-to-face dialogue in which the facilitator takes responsibility for creating and maintaining conditions that encourage assumptions to be exposed and judgments likely to invoke unquestioning, defensive behavior to be postponed. The facilitators foster a spirit of inquiry through such techniques as use of a rule of encouraging "yes, and how…" rather that "yes, but…" to help suspend premature judgment and the defense routines it triggers, so that an idea can be developed more fully. The strength of these techniques is in revealing diverse perceptions of the same issue in order that some level of consensus about the complex nature of that issue may be reached. The process then continues using techniques that facilitate more radical exploration of possibilities for collective action through creative thinking, especially "metaphor and synectics" (Gordon 1961). According to Gordon, synectics is a deliberate attempt to make the familiar strange so that creative suggestions can emerge and that "play with metaphor is one of the most fruitful of the mechanisms which can be used to make the familiar strange" (Gordon 1961 as quoted in Stubbs and Lemon 2001).

> "When used as a tool in facilitated stakeholder dialogue, alongside the 'spirit of inquiry' techniques described earlier, it appears to offer significant potential for building shared understanding of possible futures. It is the combination of the two that we call creative dialogue." (Stubbs and Lemon 2001, p. 325).

The process was conducted through a series of three workshops. The priority for Workshop 1 (divergence) was to establish the spirit of inquiry. Workshop 2 (convergence) used the concept of leverage (Senge 1990) to consider which of the problems highlighted in the first workshop could be influenced by carefully applied but relatively small, local actions. The facilitator asked the whole group to suggest local resources or decisionmaking structures that could be used to achieve actions identified as levers. Participants were then invited to work with their earlier groups to define a small, workable project that would improve air quality in Bedfordshire. Finally, in Workshop 3 (sharing mental models) several individuals felt inspired to share data with a view to recognizing patterns therein and sharing individual appreciations of the processes underlying those patterns. Participants were then invited to suggest how the factors developed in the individual models were connected. The range and interconnectivity of factors was illustrated in composite cognitive map constructed to summarize similarities in individual models of underlying processes shared during the meeting.

> "Critical appreciation of the interests, concerns, and capacities for action of different stakeholder groups, gained through networking and creative dialogue, helped hone a sense of audience for those touched by the issue under investigation. However, that sense of audience both emerged from and drove the processes of networking and creative dialogue. These concepts and the interconnections between them can be represented as constituent parts of a larger process brought into focus by the study's central interest in responses to complex transboundary issues. When the case is viewed in these terms it becomes apparent that the outcome of that larger process is an adaptive response network. In effect, this is a virtual organization of stakeholder representatives with an enhanced capacity for joined-up thinking." (Stubbs and Lemon 2001, pp. 328-329)

***The Columbia River Basin* (Lee 1989; Lee 2001; McLain and Lee 1996)**

Adaptive management was initially adopted in 1984 by the Northwest Power Planning Council, as a way of organizing the activities of the council to protect and enhance Pacific salmon in the Columbia River basin. Those efforts were diverted in 1990 by litigation under the Endangered Species Act, so that the experimental phase of the Columbia basin program did not get very far (Lee 2001; Volkman and McConnaha 1993)

***The Florida Everglades* (Gunderson 1999)**

***Adaptive management in riparian and coastal ecosystems* (Walters 1997; Rogers 1998)**
Walters (1997) argues that adaptive management should begin with an effort to integrate existing interdisciplinary experience and scientific information into dynamic models that attempt to make predictions about the impacts of alternative policies. A necessary second step is to design management experiments to test these models. The modeling step may allow the managers to replace costly learning by trial and error (an evolutionary process) with learning by careful tests (a process of directed selection). However, few efforts in adaptive management planning have proceeded beyond the initial step of model development to field experimentation. Walters

(1997) has participated in 25 planning exercises for adaptive management of riparian and coastal ecosystems but only seven of these have resulted in relatively large-scale management experiments, and only two of those would be considered well-planned in terms of experimental design. In two other cases, he could not identify experimental policies that might be practical to implement. The remainder have either ended with no visible product or are trapped in an endless process of model development and refinement.

Walters (1997) describes four reasons for low success rates in implementing policies of adaptive management based on his experience:

1. Modeling for adaptive management planning has often been supplanted by ongoing modeling exercises, apparently based on the presumption that detailed modeling can substitute for field experimentation to define best management practices. In seven of the cases examined, the initial model development was followed by substantial and continuing investment in baseline information gathering and complex simulation modeling. What seems to drive these continuing investments is the presumption that sound predictions (and, thereby, good baseline policies) can be found by looking more precisely, in more mechanistic detail, at more variables and factors. Walters (1997) is pessimistic that modeling can substitute for field experimentation for seven reasons:
    a. Cross-scale linkages. The most technical issue in developing and using models has been the cross-scale linkage between physical/chemical and ecological processes. The physical models create an enormous computational burden in running the linked, overall model for longer ecological time scales such as years and decades. Decoupling the models and running them independently can reduce computational difficulties but makes it difficult to test sensitivity and to search for better management policies. In the end, not much is learned by "grinding out a few, very detailed management scenarios and comparing them using various quantitative indicators" (Walters 1997, p. 4). Complex models must be tested against results of careful field experiments.
    b. Nonadditivity of parameter and data effects in population dynamics analysis. One might expect that more detailed models are less prone to make bad predictions due to errors in estimating any one model parameter since each parameter relates directly to a smaller part of the overall population structure. It also would seem that when many kinds of data are used to estimate model parameters, the population dynamics assessment should be less sensitive to assumption errors about how to interpret or use each observation. In fact, population dynamics models typically involve sequential products, not sums, of production and survival factors; when any one number in a product is wrong, the whole product is affected proportionally.
    c. Difficult and emergent processes. Modeling for adaptive management planning always reveals substantial gaps in knowledge about key processes and functional relationships, especially when directed at predicting the impact of specific policy options. The specific causal linkages involved in such predictions often concern biophysical relationships that have not been of interest to scientists or have escaped investigation by traditional scientific methods. Such relationships often describe "emergent" effects of events and interactions that accumulate over relatively large space and time scales. Analyses of historical and comparative data are generally part of the model development process but almost never provide the range and resolution

of data needed. Large-scale field experiments aimed at particular processes and relationships are becoming more popular in ecology, but have proven technically very difficult. "An emergent principle of adaptive management is that, for every difficult functional relationship, there is a scientist willing to claim the ability to measure it for you if you will provide enough research money to measure details of how the relationship arises" (Walters 1997, p. 7).

   d. Confounding of factor effects in historical validation data. Modelers may not distinguish between a "valid" model (one that is consistent with, or fits, historical data) and one that makes correct predictions. It is common to find a wide range of alternative models that are equally valid, but make very different predictions about factors whose effects are confounded in the historical record (factors that have varied together over time).

2. Effective experiments in adaptive management often have been seen as expensive and/or ecologically risky, compared to best management practice baseline options. Adaptive management can be expensive, especially if it involves large-scale field experiments. Increased costs begin with the development of the models needed to define clear hypotheses and policy options. This is followed by substantial costs to implement the experimental options. Additional costs are associated with monitoring programs. Finally, manipulative experiments always increase at least some ecological risks. Methodology for objective, economic comparison of experimental management options is not well developed, and there is no general consensus about how to value or weight possible experimental outcomes. There are cases in which experimental management changes of the scale needed to resolve key uncertainties would be unacceptably costly or risky.
   a. Direct costs to riparian interests. Some proposals for experimental manipulation or restriction of water uses would be costly to economic interests. Unfortunately, there is no simple, objective way for economic interests to decide whether the odds of being forced into radical change are high enough to justify switching to a cooperative experimental approach.
   b. Intergenerational trade-offs. Since ecological responses to experimental management regimes generally occur over a wide range of time scales, most management experiments involve a strong element of intergenerational trade-off in value. Treatments initiated today generally have substantial costs to present resource users but the legacy of response information will mainly be useful to the next generation of managers and users.
   c. High monitoring costs. Well-designed management experiments can have high monitoring costs and ecosystem management objectives often result in demand to monitor a far broader set of response variables. Development of affordable monitoring programs for adaptive management may involve substantial, scientifically risky innovation in methods and approaches.
   d. Risk to sensitive species. Management experiments in settings like the Florida Everglades have been considered risky for species that are sensitive, usually those that have very specialized habitats. There is no assurance that experiments designed to restore natural habitat structure will enhance particular habitat types within the overall structure. However, it is an issue of comparative risk. Baseline or default policies are often highly uncertain in the protection that they would provide for

sensitive species. Often the best justification for experimentation is the lack of a clear best course of action.

e. Misunderstandings about experimental design options and opportunities. Many consider modeling and experimentation as distinctive. However, to interpret or measure any response to treatment, the experimenter must engage in modeling, somehow predicting what would have happened had treatment not been applied. In standard research designs, measures on control or reference experimental units are used to model what would have happened. In before-after comparisons on single systems the before behavior is used to predict what would have happened. According to Walters (1997) there is no reason to believe that spatial predictors (spatial controls) are much better than temporal ones, except in rare settings where representative predictions can be "guaranteed" by deliberately selecting a large number of both treatment and reference units at random from a large universe of units. Given that it is often difficult or impossible to practice randomization in ecological experiments, the experimenter may resort to use of the best model possible to predict what would have happened. If modeling is considered an integral part of experimentation, then it is possible to consider a broader range of design options and methods for predicting responses. It also suggests that there is no risk-free experiment: predictions of what would have happened without treatment can be wrong no matter how those predictions are made.

3. There may be strong opposition to experimental approaches by those protecting various self-interests in management bureaucracies. Almost any management proposal or change is threatening to at least some organizational group or interest. Complex management settings seem to especially result in large research investments, both because scientific work offers a possibility of certitude in decision making and because "more research is needed" is a convenient answer in situations where bureaucratic and administrative interests are best served by delaying hard management decisions. According to Walters (1997) at least three organizational factors prevent experimental opportunities from being implemented: belief that pretense of certainty is necessary to maintain agency credibility; promotion of process research approaches by scientists; and inaction as rational choice by bureaucratic decision makers.

4. There are some deep value conflicts within the community of ecological and environmental management interests that prevent policy change.

> "Stakeholder involvement processes have often revealed considerable flexibility and constructive attitudes from 'development' interests (power producers, transportation interests, consumptive water users), but intransigence and bickering among interest groups representing different 'ecological' values. Conflict among ecological interests has been particularly intense where historical development has created 'new' ecological values….There is considerable danger that administrators and politicians will seek to deal with conflicting ecological values by employing compromise restoration policies, based on the presumption that there is a smooth trade-off between hydrologic restoration and species response" (Walters 1997, p. 16).

In response to Walters, Rogers (1998) argues that the problem is divergent operational philosophies and reward systems. Scientists have a propensity to seek problems of intellectual difficulty rather than immediate usefulness while managers are driven by the pragmatic and the needs of their institutional hierarchy. Each group needs to adopt these approaches among their peers, but they must find common process and purpose when working together. Rogers addresses what he sees as three problem areas:

1. Ecology is not serving management well, and adaptive management is not being accepted and applied in practice. A fundamental premise of adaptive management is that management by experiment is a way in which scientists have tried to make science useful. He speculates that the problem may arise because the approach tries to make scientists out of managers and managers out of scientists. It would be better to recognize the divergent operational philosophies and build an effective interface that promotes and supports a lasting science/management partnership. This interface should be built on sound principles of technology transfer, which recognize that the problem has not been solved until the desired end point of management has been met. Too often adaptive management is reactive to crisis management due to the lack of commitment to a clear goal. Solution to the problem must deal with two misconceptions:
    a. That scientific products have intrinsic value and that the best possible product must be developed if it is to influence user choice. In reality, the client determines value and choice is determined by what is good enough to do the job)
    b. That the power of the technology determines its success. In reality, it is often the infrastructure required to support the technology that determines its success.

   Scientists may pursue that ultimate model while managers may fall into a comfort zone of "best use policies" and "passive adaptive use of improved monitoring," rather than adopting a truly experimental approach. The purpose of the scientist/manager partnership should be to develop consensus on institutional purpose, culture, and structure, and to neutralize the adverse consequences of divergent operating philosophies and reward systems (Rogers 1998).
2. Inaction is a most comfortable option for managers. Rogers agrees with this issue as identified by Walters (1997). He believes that the root of the problem is that too few scientists and managers spend enough time in collaborative efforts to unambiguously define the end points or desired conditions of the system being managed. The idea of aiming management at desired end points may seem counter to adaptive management, but experiments can be conducted to determine the best path toward that end point. The value of defining the end point is that the partners have a common goal.
3. Monitoring becomes too expensive for management to implement. By Rogers (1998) definition, a goal is not a goal unless some indicator can be monitored and attainment of the goal audited within the resource constraints of the institution. Pragmatism is essential in designing a set of achievable ecosystem end points and criteria with which to measure their achievement. If consensus can be achieved at one step, then it is possible to enter an iterative, adaptive management cycle in which both science and management can learn and improve the depth and rigor of their contributions together.

***Fort Huachuca* (Gen 2001)**

The application of adaptive management in a military environment presents special problems. Fort Huachuca is located in the upper San Pedro River basin in southeast Arizona. Water is a scarce resource in the basin and defines many of the socio-ecological problems of the area. Surface water in the river is needed to support riparian habitat while groundwater is needed to support human activities in the basin. The groundwater supply appears to be abundant for human demands, but the current draw of groundwater is diminishing surface water in the river, thereby threatening the riparian habitat.

There are two central tensions in the use of adaptive ecosystem management at military installations. The first, is that there appears to be a inherent conflict between the objectives of ecosystem management and the military mission. The second is the inherent conflict between the bureaucratic decision making processes of the military and the open, democratic decision making processes of adaptive ecosystem management. Gen (2001) examined Fort Huaachuca's progress in implementing concepts of adaptive management using three broad criteria: its democratic process in decision making, its ecological focus, and its adherence to 10 guidelines outlined by Department of Defense policy regarding implementation of ecosystem management on military lands.

The military leadership at Fort Huachuca has informed its decision making process in two significant ways. First, they implemented socio-ecological modeling to aid in identifying potential future states of the river basin. Stakeholder participation has been in integral part of the process of identifying alternative desirable states and the values and priorities of the stakeholders. From the inputs of these stakeholders, the study's implementers describe the alternative futures and their implications for current actions. Fort Huachuca has also engaged in significant community involvement, largely through quarterly meetings of the Fort Huachuca Conservation Committee. This is a regular meeting among military officials and area stakeholders to address environmental issues affected by the Fort. While decision making authority remains with the Installation Commander, there is a broad opinion, but not consensus, that the post's personnel are sincere in their consideration of public input and incorporates it in their decisions when possible. However, there is a significant perception by several stakeholders that Fort Huachuca's efforts fall far short of stakeholder requirements (expections?). This partly arises from the requirement that Installation Commanders are obligated to adherence to higher military authority. For example, local decisions about desired futures were overridden when the Base Realignment and Closure Commission required Fort Huachuca to absorb specific Army units from other bases that were being closed. Thus, while local stakeholders in the upper San Pedro River basin were calling for a reduction in water use, Fort Huachuca was obligated to implement any expansions decided by national military policy makers. This has lead some local stakeholders to view the Fort's public involvement efforts as moot and to conclude that litigation is the only effect mode of influence.

Fort Huachuca's commitment of consideration of multiscalar ecological dimensions is evident in its implementation of water conservation measures and a water recharge program within the post. At the watershed level, the Fort actively participates in the Upper San Pedro Partnership and other regional ecosystem management efforts. The Fort must also develop an ecological monitoring program on the land it affects.

Finally, Fort Huachuca has made significant progress implementing the Department of Defense ecosystem management guidelines. However, a major barrier to full implementation is the lack of vertical integration in the Army's policies, resulting in situations where policies affecting ecosystem management are outside local control.

Gen (2001) identified two areas of improvement based on his assessment of Fort Huachuca's implementation of adaptive ecosystem management. First, it must develop a decision making process that integrates its bureaucratic structure into the democratic arena of its stakeholders. As long as any military decision makers are absent from local discussions, the area's stakeholders will have legitimate cause to view the Fort's outreach efforts as little more that a polite gesture, as national military leaders make decisions that override the local interests. Second, Fort Huachuca must develop and specify a decision making process with its stakeholders, that is "deciding how decisions will be made." This addresses the need to delineate how public input will be gathered, assessed, and used in its decisions. Further, this would give the military and local stakeholders clear expectations of how public input can influence military decisions. In the absence of such specification, stakeholders may choose to use more confrontational modes of influence such as litigation and political intervention.

***Glen Canyon Dam* (Meretsky et al. 2000)**

Adaptive management seeks to sustain ecosystems while using the associated natural resources. The goal of endangered species management under the Endangered Species Act is limited to protection and recovery of designated species and the act takes precedence over other policies and regulations guiding ecosystem management. The presence of endangered species can, therefore, limit options for ecosystem management and result in conflicts between the safest course of action for protecting endangered species and the desired course of action for the ecosystems in which the species are found. The Grand Canyon ecosystem has been significantly affected by construction of the Glen Canyon Dam, specifically be reducing or eliminating the natural flood cycles. An adaptive management experiment was used to study the effectiveness of using high-volume controlled releases from the dam to simulate the effects of natural flooding in the downstream environment.

An important conclusion of the Glen Canyon Environmental Studies program was that the Grand Canyon river system had developed in a highly variable environment which was significantly altered by construction of the Glen Canyon Dam. The Environmental Impact Statement on the operations of the dam concluded that traditional methods of management were inadequate to compensate for the magnitude of environmental impacts to the Colorado River ecosystem and an adaptive management approach was recommended. An experimental flood using releases from the dam were planned to mimic floods that occurred annually before the dam was built. At first, no negative impacts were expected and most species were expected to benefit. However, predicted damage to terrestrial habitat of the Kanab ambersnail brought the adaptive management proposal into direct conflict with the endangered species management.

The Kanab ambersnail (KAS) was previously known from only two sites in southern Utah and was believed to have been eliminated from one of those. It was listed as endangered in 1992 on the basis of the small number of known populations. A KAS working group consisting of members of the Arizona Game and Fish Department, the Glen Canyon Environmental Studies, the U.S. Fish and Wildlife Service, and the National Park Service, was organized in reponse to the listing.

Vasey's Paradise, a small patch (>0.25 ha) of riparian vegetation below a limestone spring along the Colorado River below the Glen Canyon Dam, is the only protected location for KAS because it occurs within the Grand Canyon National Park. Photos of the area taken before closure of the dam in 1963 show that spring flooding scoured vegetation back, controlling the lower limit of KAS habitat. After dam closure halted annual flooding, vegetation cover increased by 40 percent down to the lower water level associated with dam operations. After release of the draft EIS on operations of the Glen Canyon dam in 1994, the U.S. Fish and Wildlife Service issued a Biological Opinion that set a permissible level of impact on KAS habitat below which the U.S. Bureau of Reclamation (Bureau) could operate the dam without additional consultation. If flows from the dam resulted in destruction of more than 10 percent of occupied habitat, the Bureau was required to cease operations causing habitat damage until consultation was complete.

The environmental assessment of the experimental flood predicted that as much as 17 percent of the KAS habitat might be destroyed. This set up a potential conflict between the equally desirable goals of trying to return more natural flood cycles to the Colorado River system within the Grand Canyon and the protection of the Kanab ambersnail. The Bureau entered into formal consultation with the U.S. Fish and Wildlife Service to determine whether the experimental flood could proceed. Recognizing the overall benefits of the flood and stressing the need to protect KAS habitat, the Fish and Wildlife Service developed reasonable and prudent measures to mitigate impacts to KAS. The agreement reached required that 90 percent of the snails in the area below the worst-case high water line be relocated above that line and that the Bureau monitor the site to determine the actual level of take. The Bureau also was to monitor for a year after the flood to determine KAS population and habitat recovery.

On-site estimates of KAS population size were substantially higher than counts from the previous fall, probably as a result of an exceptionally mild 1995-1996 winter. Finding a removing active snails required damaging but not destroying much of the vegetation below the worst-case flood line. However, finding and removing dormant snails required removing all vegetation and the associated rootmat in which the snails lay dormant. Therefore, the U.S. Fish and Wildlife reasonable and prudent measures required researchers to destroy 90 percent of the vegetation associated with the worst-case scenario, even though flooding might not rise to worst-case levels. Further, this would prevent the researchers from leaving patches of vegetation to determine the ability of the plants to withstand the force of the flood.

The combination of higher population numbers and potential additional damage to the KAS habitat were made known to the Fish and Wildlife Service biologist charged with writing the mitigation requirements. The following day, the Fish and Wildlife Service issued amended reasonable and prudent measures, directing that 75 percent of snails be relocated from 50 percent of the worst-case inundation zone. Monitoring requirements remained that same. This change gave the Working Group latitude to leave habitat in the error zone above the predicted flood elevation and to leave small amounts of vegetation below the anticipated flood elevation. This allowed a further experiment in which some areas near the anticipated flood elevation were clipped to the level of the root mat to determine if this treatment would improve persistence of roots and soil during the flood and hasten habitat recovery.

The Working Group was successful in meeting the revised measures and the flood waters rose only to the estimated level, sparing vegetation in the error zone. However, as expected, over 95 percent of the primary habitat below the inundation line was lost. Plant species important to KAS showed essentially no ability to persist during floods, and clipping stems provided little protection from scour. The Working Group estimates that it will take several years for all KAS habitat to recover to preflood levels. The spring season following the flood was mild and KAS had an extended breeding season with two reproductive peaks before fall. The KAS population is not considered to be at greater risk as a result of the experimental flood.

The features that contributed to this successful adaptive management experiment included:

1. The establishment of the KAS Working Group two years before the experimental flood. As a result, the team of researchers was experienced with the site, the species, and the research protocols. All agencies with an interest in the KAS population were represented, including the U.S. Fish and Wildlife Service.
2. The agencies associated with the KAS Working Group all agreed that the experimental flood was likely to benefit the Grand Canyon ecosystem. This common understanding and approval improved chances for conservative compromise and allowed the Working Group members to share ideas without concerns about conflicting agency agendas.
3. Although only two populations of KAS were known to exist, the Vasey's Paradise population was relatively large for an endangered species (>10,000 individuals throughout the 1995 growing season). This allowed the Fish and Wildlife Service to allow loss of some individuals without abrogating their responsibilities under the Endangered Species Act.

While the experimental flooding was approved, the endangered species status of KAS still reduced experimental options under adaptive management. Flood levels that would have removed substantially more KAS habitat were not considered, and no area of vegetation at Vasey's Paradise was set aside as a control because the extreme likelihood of loss of all snails in inundated habitat was unacceptable.

The Northwest Forest Plan **(Stankey et al. 2002; Stankey and Shindler 1997)**

The Record of Decision (ROD) for the Northwest Forest Plan (US Department of Agriculture 1994) provided guidance for managing USDA Forest Service and USDI Bureau of Land Management lands within the range of the northern spotted owl. The selected alternative was grounded on the principles of conservation biology, emphasizing risk avoidance to the region's federal lands in the short term through application of the Precautionary Principle. The plan established a system of terrestrial and riparian reserves that, when combined with other protected areas (national parks, wilderness, etc.) covered almost 80 percent of the planning area. In addition, a set of very comprehensive and prescriptive standards and guidelines further restricted management activities and development, even on areas outside of the reserves. Following the advice of the Forest Ecosystem Management Assessment Team (FEMAT), created by President Clinton to address concerns about declining old-growth forests and their associated wildlife, the plan emphasized an adaptive management approach by allocating 10 Adaptive Management Areas (AMA) covering about 1.5 million acres, or 6 percent of the planning area. These areas were established "to encourage the development and testing of technical and social approaches to achieving desired ecological, economic, and other social objectives" and to help agencies "learn how to manage on an ecosystem basic in terms of both technical and social challenges" (US Department of Agriculture 1994). The thought was that adaptive management complemented the precautionary short-term strategy by offering a long-term strategy that would expand knowledge of the complex biophysical system and its interaction with the social and economic systems. This, in turn, would lead to improved management policies.

An evaluation of implementation of the adaptive management portion of the Northwest Forest Plan was undertaken in 1998 by Stankey and others (Stankey et al. 2003). They identified a number of barriers to successful use of the flexibility provided by the AMAs.

1. Leadership and definitional barriers: AMA coordinators and line officers were confused as to where responsibility lay for developing policy direction for adaptive management and the AMAs. Early on, the Forest Service Regional Office decided not to provide direction, guidance, or other instructions for implementing adaptive management, intending to avoid imposing top-down rules. This silence was interpreted as a lack of interest. Further, those charged with implementing adaptive management had differing conceptions and expectations regarding the definition, purpose and objectives of adaptive management and the AMAs.
2. Institutional barriers: AMA coordinators and line officers were given few incentives to undertake adaptive approaches and argued that experimentation and risk-taking are not standards against which they are evaluated. They saw their agencies as risk adverse. A climate existed where the burden of proof had shifted to land managers to provide rigorous evidence that any proposed action would not lead to adverse consequences for threatened and endangered species. This is clearly an anathema to the concept of adaptive management. Further, as budgets declined, funds were diverted away from the AMA's to fund the implementation of the operational aspects of the Northwest Forest Plan. The tendency for agencies to operate according to prescriptive approaches and standardized rules also constrained innovation, even when specific direction providing license to deviate within the AMAs was provided.
3. Statutory and regulatory barriers: Laws such as the Endangered Species Act and the regulatory agencies that enforce such laws provided little latitude to practice adaptive management. Under prevailing interpretations, actions judged to pose a risk to listed species are opposed, even when the efficacy of precautionary approaches is poorly understood (Gunderson 1999). The guarantee of no adverse consequences establishes a difficult, if not impossible, decision criteria to satisfy.
4. Barriers to learning: Despite the clear concept of learning by doing inherent in adaptive management there was no systematic design and documentation to promote learning or to address the question of what it means to learn.

The AMA coordinators and line officers concluded that in such a risk-adverse, litigious environment, an experimental-based type of adaptive management would be difficult to implement. Gunderson (1999) found that when minimizing the possibility of failure dominates the policy and management process, uncertainty is traded for a "spurious certitude" that provides a comforting but illusionary sense of predictability and control.

Lee (2001) in an appraisal of adaptive management states that the Forest Service uses the following definition of adaptive management in implementation of the Northwest Forest Plan:

'"for land managers, researchers and communities [to] work together to explore new methods of doing business"' (Olympic National Forest 1998 as quoted in Lee 2001). He concludes:

> "The Forest Service definition of adaptive management does not emphasize experimentation but rather rational planning coupled with trial and error learning. Here "adaptive" management has become a buzzword, a fashionable label that means less than it seems to promise." (Lee 2001, p. 12).

Lessons learned

Recommendations and conclusions

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