Chapter 19: Scientific Adaptive Management

19.1 Introduction

The management of natural resources faced a major challenge due to industrialization of our global society because human activities had enough power to overwhelm natural ecosystems. According to Walters (1986), there were two major flaws in resource sciences: “only token consideration [was] given to the socioeconomic dynamics that are never completely controlled by management activities”, and there was no strategic method to deal with the large degree of uncertainty. Scientific adaptive management (SAM) is a “continual learning process that cannot conveniently be separated into functions like “research”, and “ongoing regulatory activities”” (Walters 1986) and blends these into a single process in which management manipulations are designed as experiments that will provide information for better future management. Scientific adaptive management is framed in the decision-making context with an emphasis on addressing and reducing uncertainty through continual management activities that will change as the organization learns more about the functioning of the ecosystem. This process is scientific because it requires rigorous pursuit of new knowledge. It is adaptive because the activities change as the organization learns more. And it is management because it depends on human manipulation of the environment. Scientific adaptive management is the whole process as a strategic approach and is not simply trial and error.

Fisheries management is a good example of the difference between reactive management and adaptive management. There is a major degree of uncertainty in the estimates of the salmon population growth in the Frasier River, BC, Canada. For instance, it is unclear if more salmon leads to more spawning or if it leads to repression due to competition. The adaptive management approach proposed by Walters (1986) would be to allow more salmon to return up-river and then follow what happens to the spawning and production of smolt. The management approach requires a limit on fishing for a period of time, but it could lead to a better understanding of the population biology of salmon and better management of this resource. Even though SAM provides the potential for better management through learning, there were two objections to this approach. First, the salmon fishing industry didn't want to limit fishing and believed that the stock was already being managed well. They would lose confidence if the agency publicly stated that there was so much uncertainty over basic questions of salmon biology. Second, there was an underlying belief that the uncertainty could be resolved with less drastic approaches such as scientific research. This example illustrates that acknowledging uncertainty and developing a strategic plan to use management as a tool to learn more about the natural resource dynamics is central to scientific adaptive management.

The concepts in scientific adaptive management are built on a strong ethical and philosophical foundation.

Leopold –

Norton –

This chapter will define and outline the strategic process of scientific adaptive management. It will then describe the conditions where SAM is needed and where it can contribute. This discussion builds on what you've already learned about the how the dimensions of controllability, uncertainty, and values determine possible modes of engagement (Chapter 14). Then the specific tenets of SAM will be provided and related to several examples from forests, lakes and fishery management. This chapter will also illustrate how SAM deals with uncertainty and the problem of values in science. As you will soon understand, scientific adaptive management requires strong, functional institutions and management. This chapter will build on the information in chapters 16 and 17 on institutions and management. An important aspect of this is how scientific adaptive management compliments and conflicts with the predominant forms of democracy that are both an institution and a belief system in the many levels of government and societies in which environmental management must take place. Finally, this chapter will illustrate how scientific adaptive management is an essential strategy for addressing how societies can learn to be sustainable.

More than any other topic in this book, the discussion of scientific adaptive management must address the role of values in environmental science. On one hand, there is the widely held view that science and scientists should be objective and that scientists should produce objective knowledge to be handed over to policy makers. This was codified in the EPA's risk assessment and risk management programs that were not only done separately but housed in different towers at their headquarters (Norton 2005). A recent modification of this approach has been **** by Pielke (2007) in which he argues that science is best suited to creating policy alternatives, while staying out of the decision-making process. He calls this role for the environmental scientist the "Honest Broker of Policy Alternatives". On the other hand, some proponents argue that those who are most knowledgeable about any particular ecosystem issue should be involved in decision-making and policy. This role is often called an "activist-scientist". Norton explains that in the scientific adaptive management process, all evidence must be presented, assumptions laid out, and values stated. In this mode of full-disclosure, "pre-experiential commitments" i.e. ideological biases are removed. My feeling is that ** since values are a central part of environmental problems, scientists must deal with values and worldviews. This is an exciting and open question that you can address for yourself.

19.2 Conditions when SAM is employed

Scientific adaptive management is one of the major tools that we have to engage with large environmental problems that are large and have long time horizons. Because of the increase in population, energy use, and affluence our impact is large and growing. According to Lee (1993) “The rate of change is outstripping the ability of scientific disciplines and our current capabilities to assess and advise” society on reasonable management strategies using traditional methods. We need to use continual experimentation and organizational learning to address these problems. As Norton states (2005), “We are now living in the age of culture: humans today must learn very rapidly, because our impacts on nature are accelerating at the rapid pace of Lamarkian cultural evolution…long-term survival will be determined not by our ability to transform our environment quickly, but by our ability to quickly react to a more rapidly changing environment.” Both of these authors, Lee and Norton, see adaptive strategies as the only way to rigorously and effectively address the management challenges of dealing with rapid change and uncertainty.

A method for examining the problem narratives along three dimensions of control, uncertainty and values was presented in Chapter 14. As this method demonstrates, the degree of control depends on whether there are methods and resources to affect change in the environment. The second dimension of this method involves the amount of knowledge we have at hand, estimates of knowledge required and what the underlying uncertainty represents. The third dimension is how much of a mismatch there is between individual and community values or whether there is good alignment along different levels of society. In this analysis, scientific adaptive management was deemed to be a good way to engage in problems that have high degree of control (because they can be managed), but high uncertainty and a potential mismatch of values or conflict in preferences across the community. This, and similar analyses, also indicates areas where scientific adaptive management is not appropriate. From our CUV dimensions, problems that have little mechanism for control or, put another way, not enough public support to establish institutions to provide control are candidates for using scenarios to explore possible futures and solutions. Another situation is if the worst-case scenario, i.e. possible outcome from management, is totally unacceptable by society. In this situation, decision rules, such as the precautionary principle, might be invoked in order to avoid that outcome.

The official Department of Interior description of scientific adaptive management provides a typology for problems that should be addressed (Figure 19.1). This is very similar to our CUV treatment minus the value axis. This manual also lists two key conditions that must be met for SAM: 1) a mandate to take action in the face of uncertainty, and 2) the institutional capacity and commitment to take on the problem. There are also six characteristics that contribute to the success of SAM: 1) it must be a real choice with substantial consequences, 2) there must be the opportunity to apply learning in subsequent iterations, 3) clear and measurable objectives have to be created, 4) good information has high value, 5) the uncertainty needs to be represented by sets of conflicting models, and 6) data collection and analysis of monitoring has to lead to reducing uncertainty (i.e. it can't have overwhelming, irreducible uncertainty). If these two conditions and six characteristics are met and well managed, learning organizations can make progress toward solutions of large environmental problems.

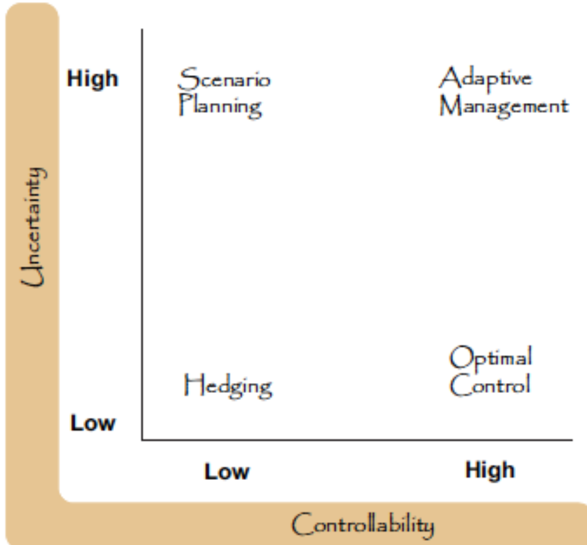

Figure 19.1 Approaches to environmental problems based on controllability and uncertainty. Source is DOI (****).

Adaptive management must be able to deal with fluctuations in the environment at different space and time scales. Healthy ecosystems should be expected to demonstrate a dynamic behavior that "continuously generate and relax tension on a continuum of scales" (Pahl-Wostl 1998). Management schemes can't just exert control to force one level but must strive to manage to the creation of resilience, the ability of the ecosystem to respond to a range of disturbances. A good example of this is how forest fires are managed by promoting many small fires of different sizes and shapes with the goal to reduce the chances of large, mega-fires. Mimicking the natural processes that lead to the forest mosaic takes a dynamic management style rather than a single prescription or simple outcome. The fluid nature of long-term adaptive management allows setting big goals (such as reducing large fires) and using small-scale management activities as both tests of how the system works and as measures of control.

19.3 Tenets of Scientific Adaptive Management

Norton (2005) lays out the three tenets of scientific adaptive management as: 1) experimentalism, 2) multiscalar analysis, and 3) place sensitivity. Experimentalism emphasizes using management as experiments and taking actions that serve both for control but also to learn how the ecosystem works and reduce the uncertainty for future actions. The principle of multiscalar analysis requires managers to use models to understand how the ecosystem works over a range of space and time scales. This tenet is one of the key aspects of using SAM to seek sustainability and will be discussed later in the chapter. The final tenet, place sensitivity, acknowledges that each site of management is a unique spot on Earth with its own history and set of complex processes that have led to the current state. This third tenet stresses the importance of approaching these systems as individual cases and tempering the use of broad simplifying generalizations.

The three tenets support each other philosophically and, in practice, result in the expression of the "land ethic" of Aldo Leopold. Simultaneously relying only on evidence that can be gathered on a particular ecosystem, thinking "like a mountain" over the long term (as Leopold suggests), and approaching each location with respect as a special and complex situation will lead to deeper understanding. These multiple perspectives work together to provide the rich narrative required for generating management hypotheses that do justice to the place. But the discipline of mind required to keep these different perspectives in play and and reach a creative solution are in the context of the pragmatism of SAM, i.e. there will be management action, not just theorizing, and these three tenets and the ethic guide that adaptive management process.

19.4 Examples of scientific adaptive management

Dealing with a dynamic ecosystem: Glen Canyon Dam (Meffe 2002)

- Water releases as experiments
- Tradeoff between power generation and ecosystem health

- Changes in practices during management

Probing population responses: Idaho Elk Management (Meffe 2002)

- Gap in knowledge about population size and growth rate
- Different hunting rates in different areas as experiments

Management of a complex socio-economic system: Columbia River Basin (Lee 1993)

- Many jurisdictions and stakeholders
- Bringing in the values

Counter example: *** trial and error, then reformulation **

- Decide on a solution
- Implement that solution
- Later – figure out it didn't work and go back to the drawing board

19.5 How SAM deals with uncertainty

Scientific adaptive management acknowledges that uncertainty is a major obstacle to management strategies and differentiates between uncertainty and risk. Uncertainty can't be reduced to a simple probability of outcomes. Such is the nature of risk. In cases where risk can be managed using a portfolio of diversified approaches (i.e. hedging) is a more appropriate strategy (see Chapter 17). Scientific adaptive management deals with the three components of uncertainty (Chapter 9): ignorance, surprise and volition in three ways. First, when management actions are used as experiments, this will mainly decrease or delimit the ignorance component, i.e. what we don't know about the system. Second, having a long-term plan for how to handle the results of these experiments and taking a broad, multiple-perspective view lays the groundwork for dealing with surprises, i.e. qualitatively different outcomes than expected. Finally, SAM, in practice, has many features that deal with the unpredictability of the human dimension. A wide range of stakeholders can be brought into management discussions as long as they provide evidence for their viewpoints, agree to a democratic process (discussed later) and specify their values that they are willing to discuss. Scientific adaptive management provides a platform for promoting pluralistic discussions that can lead to organization learning.

The process of SAM often employs devices and technologies that help promote the inclusion of many ideas and values (Meffe et al 2002). The holistic approach includes many people and is essentially pluralistic, actively seeking more input for the whole range of stakeholders and participants. Simulations or scenarios are often used to engage discussion on possible outcomes and get technical and public input on different potential outcomes. For example, simulating the effects of current choices over several decades is a valuable tool for engaging them in the discussion. Furthermore, decision criteria that are formulated in a way that are flexible, preserve future options and graded (i.e. not all-or-nothing) are not only characteristic of SAM but also help to involve public discussion without causing unnecessary strife over an ideological divide. For example the "safe minimum standard" (SMS) decision criteria states that an action should be taken if it has little chance of causing damage and is affordable **check this statement **. SMS is also graded by scale where a small and rapidly reversible action is more likely to meet the standard than an ecosystem scale approach that might take many decades to reverse. The outcome of the SAM process is to promote community and organizational learning that is fast and directed as opposed to tradition (which doesn't change) or trial and error (which is very slow) (Meffe et al. 2002). Thus the process should be attractive and rewarding for those citizens and interest groups that fully participate.

19.6 How scientific adaptive management deals with values

Scientific adaptive management is fundamentally based on value-laden, mission-driven science (rather than curiosity-based). This approach is suited for wicked problems that are inherently complicated by always changing information and values. A specific aspect of SAM (as described by Norton 2005) that addresses human values is the differentiation between considered and held values. Participants need to identify which values they are willing to consider changing in light of evidence and which they are unwilling to change in the face of any evidence. Identifying the assumptions that lead to people's considered values is a useful step in determining what evidence is required to make a change. Scientific adaptive management uses several tools that deal with values including:

- More here
- Scenarios
- Risk and uncertainty
- Consultancy
- Pielke 2007 – honest broker of alternatives

19.7 Control and the importance of institutions

Initial implementation and control of large projects require communities to use existing or new institutions to communicate and make decisions. Scientific adaptive management is most useful in large space and longer time scales. These large projects shift how we think about the world from the concreteness of a particular place to the abstractions involved in large (such as basin scale or forest ecosystem) concepts that deal with the future. Communities use institutions, such as state or local governments, to deal with these abstractions, in particular the uncertainty of the future. Thinking of SAM as a process that attempts to control the future and must be situated in organizations that are able to look to the future. ** Nabokov quote – maybe to strange – "what can be controlled is never completely real; what is real can never be completely controlled." A major risk in all large projects is that the uncertainty and lack of concreteness can lead to large unintended consequences. Pielke (2007) warns that any project that is big enough to be considered as a panacea for all problems is "also big enough, and more likely, to produce unintended consequences of catastrophic dimensions."

Managing large, complicated projects requires strong and high-functioning institutions that use best practices. Control of human nature coupled systems is difficult enough to conceive as a static process, and the goal of managing for dynamic resilience is a challenge to management practice. Mechanistic metaphors and feedback control that depend on cause-and-effect mechanisms have to be discarded in favor of dynamic systems that are always poised at the edge of chaos (Pahl-Wostl 1998). Managing in this zone means that the problem is only partially structured at any time and the management effort must be constantly innovating or improvising (Brown and Eisenhardt 1998). Improvisation and innovation (as we saw in Chapter 15) can be supported by identifying the larger goals while restricting the number of specific operational rules to a minimum. The only way to do this is to have organizations that are designed for the function of learning. These institutions acknowledge uncertainty as a major component of the problem, allocate effort to training people, reward experimentation and possible failure and recognize the importance of surprises as opportunities for learning (DOI ****).

- add in
- Double loop learning
- Setting objectives
- Refer to chapter 17 – optimal management strategies

Constantly improving environmental regulations and policies and dealing with the related politics are addressed using scientific adaptive management. For many of the reasons addressed above, but particularly the uncertainty due to changing human preferences, SAM provides a robust and objective framework within which environmental scientists can interact with politics. Lee (1993) advises "The strategy I urge – to be idealistic about science and pragmatic about politics". Science is designed to find facts and be able to objectively represent gains in knowledge to be reviewed by peers. Politics aims to use power responsibly, i.e. in an accountable manner. Thus both science and politics are beholden to accountability, but to different audiences. The degree of involvement of technical experts and scientists in policy making is an active area of debate, but they are participating whether directly (as an activist) or indirectly (providing arms length advice). Large environmental projects require inherently politically strong and forward-looking institutions that operate effectively. Scientific adaptive management is the set of processes that allows the rigor and objectivity of science to be incorporated into larger governance.

Scientific adaptive management is most often associated with the political institution or democracy. Like our general conception of democracy, SAM is a process that attempts to bring in many points of view, encourages the participation of many and works toward a fair and just outcome. Norton specifically proposes that all participants in a scientific adaptive management process be committed to the democratic process (Norton 2005). A potential major challenge to good environmental management is the requirement for policy to be based on cause-and-effect mechanisms, i.e. if pollution causes fish kills, then we will pass regulations to reduce pollution. Democratic processes may help deal with uncertainty in some situations by bringing more ideas to the table and providing a framework in which the participants trust that the outcome will be fair and just. This framework of trust is also crucial for allow time to work through periods of ambiguity and contradiction. However, democratic processes can also stall that same flow by serving as a mechanism for pure interest group pluralism, i.e. only interest groups not the public get to provide new options (Pielke 2007). It is important to consider where democracy and SAM reinforce each other positively, are in conflict and reinforce each other negatively (Table 19.1). In this treatment we are considering the liberal form of democracy in which the majority rules but also protects the freedoms of the minority.

Table 19.1 Alignment of the institutions of scientific adaptive management and liberal democracy.

Positive reinforcement	• Democracy generates many options
In conflict	• Democracy can't impinge on the rights of individuals, but it is often the definition of these rights (water, land use, etc) that is the center of the debate for environmental issues • Large scale environmental issues require infrastructure (i.e. agency/bureaucracy) which has been called the "double state". • Democratic public debate has difficulty dealing with issues that don't have a clear "cause-and-effect" relationship. Sophisticated and expensive SAM can address this
Negative reinforcement	• Both have trouble when there aren't clear objectives • Differences in values that persist after problem definition • Wicked problems in which the problem morphs as more information is gained

Aggressive efforts to manage environmental problems at the level of pragmatic stewardship proposed by Leopold (****) can lead to overall better governance. Most complex and wicked problems that a community addresses require institutions that can manage balancing individual vs. community values and planning for an uncertain future. If the community agrees on solving an environmental problem because they see that doing so is valuable to all individuals, the same institutional framework can be used for governance of other community issues. The claim is that good environmental stewardship can lead to better governance.

- Putnam – trust, commerce, democracy
- Cooperative win/win as described even in non-democratic societies Mersini 2002
- Portland example – Steve Johnson – watershed agreement

As was presented in Chapter 15, innovations such as scientific adaptive management processes require concomitant institutions to implement and control innovations. For example, if we export innovative environmental methods to developing countries, these will go hand-in-hand with stronger and more competent forms of governance. This has been the experience of the US Peace Corps and other environmental NGOs, and democratic community processes should be considered a benefit of our environmental actions.

19.8 Sustainability

As described above, scientific adaptive management is a process that can be implemented by effective and forward-looking governance institutions. This combination of evidence-based environmental decisions and democratic processes are exactly what we need in the discussion of sustainability. Too much of the sustainability push is to determine which particular outcomes we need. Although specific goals (such as 350 ppm CO_2, zero population growth, or target Gini coefficients) are useful for rallying popular support, they don't describe how we will get to those targets or the forms of cooperative governance that will be required. Norton (2005) is very clear in his call for using SAM to address the science and values of sustainability. Currently, the dominant paradigm is the so-called "grand simplification", which states that since we don't know which forms of capital (human, built, financial or natural) future generations will value most, the best we can do is to pass on to the future a world with maximized total capital. This "weak sustainability" argument assumes that all forms of capital are exchangeable and that more capital is always better. Scientific adaptive management of the future accumulation of capital would require that the values of all of these forms be explicitly identified and that any assumptions about these different forms be tested objectively on the basis of evidence (not ideology). The SAM approach to the future, although it may seem incongruent with sustainability, would require many small experiments and continual adaptation to match the proper scale and speed necessary to maintain the parts of our world that we value (Thiele 2011). The argument for small scale experiments was laid out *** years ago by Schumacher **1975**) in “Small is Beautiful”; “There is wisdom in smallness if only on account of smallness and patchiness of human knowledge, which relies on experiment far more than on understanding.” And more recently under the banner of localization that describes the two paths necessary to approach sustainability, “One path is on-the-ground practices. . .The second path builds in part on these many small experiments and their accumulating knowledge” (de Young and Princen, 2012). The authors continue to describe how this will form a base for political action at the local, community level: "People need to be engaged in a process, the details of which cannot be worked out by others, certainly not by decision makers far removed from people's everyday existence." Thus, even though the main thrust of the discussion in this chapter on scientific adaptive management has been on how it can be used in large environmental projects, individual citizens can be involved in the ongoing pursuit of a sustainable society by participating in small experiments guided by the principles of scientific adaptive management.

19.9 Summary

Scientific adaptive management is a process that uses environmental management actions as experiments that simultaneously help solve the problem and reduce the uncertainty of on-going management. This process is not simple trial-and-error but requires an over-arching scheme for dealing with the results of current experiments, unexpected quality changes in the system (i.e.

surprises) and shifts in public opinion. SAM is particularly useful for large environmental projects in which there are mechanisms to effectively control management approaches, but the uncertainty is high and there is no clear alignment between the benefits to individuals and the larger community. Several typical examples of SAM are management of fisheries, forest fire suppression through mosaic of small burns, and dynamic management of water releases in Glenn Canyon. Scientific adaptive management directly addresses human values, uncertainty and control through institutional governance. Even though SAM is usually associated with large environmental projects, the pragmatism and ethical framework is applicable for citizen engagement in sustainability through "massively parallel" small scale and local experiments.

