ADAPTIVE MANAGEMENT: STRATEGIES FOR COPING WITH CHANGE AND UNCERTAINTY

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Summary

Adaptive management is widely recommended as a valuable method for managing resources in the face of change and uncertainty. Many people interpret it to mean simply changing policies or practices over time, but this definition misses much of the potential power and rigor of the concept. Adaptive management should instead be recognized as a

systematic process that draws from a diverse set of scientific and social theories and methods.

Adaptive management is best conducted by resource managers working together as a team with stakeholders and scientists. The goals of such teams are to learn how managed systems respond to human interventions, and to improve resource policies and practices in future. One of the key principles behind adaptive management is that many resource management activities are experiments, because their outcomes can not be reliably predicted beforehand. Recognizing this fact, and then using these experiments as learning opportunities, is what distinguishes adaptive management from other management approaches.

Examples of successful adaptive management have been relatively few until recently, but more are now accumulating around the world. It appears that adaptive management will become more common and more effective as techniques improve and society becomes more interested in rigorously evaluating the effectiveness and cost of resource management policies and practices.

1. Introduction

As people struggle to sustain ecosystems while extracting resource goods and services from them, continual change and uncertainty in societal values and environmental conditions arise to complicate their tasks. In the face of such challenges, resource managers often struggle to keep their knowledge and management techniques up to date. They need new knowledge to resolve uncertainties and they need novel management approaches to respond to change, but traditional research and management methods seldom suffice to provide these. Instead today's managers need tools and strategies to integrate disciplines that were previously regarded as distinct and separate, such as systems analysis, social learning, experimental design, decision analysis, and feedback dynamics.

Adaptive management is a process that integrates these and other methods into systematic programs of investigation and resource management. Such programs are designed to enhance understanding, produce resource benefits, and improve policies and practices over time.

Since its genesis in the early 1970s as a new approach to resource management, adaptive management has evolved into a concept recognized and lauded among practitioners and policy makers worldwide. This great growth in familiarity with the term adaptive management has not, however, been accompanied by a concomitant expansion in understanding or application of its methods. Some people have taken it to mean simply changing (adapting) management decisions over time, through trial and error or any other unstructured approach including "policy drift" caused by political or social pressures, changes in personnel, or any of a myriad of other reasons. As a result, it has sometimes been considered to be little more than a buzzword.

Such unstructured changes in management do not, however, incorporate the rigor that was originally a key to the concept in its original, and still most useful, form. The term

adaptive management is best understood as a compound noun with a definition much more specific than simply changing management over time. This article attempts to illustrate the depth and breadth of adaptive management, by explaining the philosophy and methods underpinning it and by illustrating its value for improving stewardship of the environment.

Adaptive management can be defined as a process for improving policies and practices by managing systems (ecological, administrative, and other) so as to both produce desired outputs and learn about the systems' dynamics and responses. Its goal is to inform managers of the probable consequences of decisions they will make in the future, so management programs will be more likely to achieve society's goals and objectives.

Perhaps the element of adaptive management that distinguishes it most clearly from other types of management is that it employs deliberate experimentation with the managed system; or to put it another way, it recognizes that many management policies and activities are actually experiments because their results are not predictable. In adaptive management, experimentation is conducted in ways that are designed to reveal the unknown links between management actions and systems responses or outputs. To accomplish this, adaptive management blends scientific research concepts and operational management protocols. The result is a powerful suite of tools that can assist in resolving many issues that have proven intractable using other approaches.

In a complete application of the full adaptive management process, the sequence would consist of the following:

1. Enlist participants who represent a range of interests and expertise, usually including resource managers, policy makers, scientists, and stakeholders representing various interests.
2. Determine a consensus view of the resource objectives, the scope of the issue in space and time, the potential management actions (policies, practices, or management regimes) that could be carried out, and the variables that would indicate the system's responses to those actions.
3. Develop a model of the system that illustrates the linkages between management actions, system functions and linkages, and outputs (responses).
4. Using the model or other analytical techniques identify knowledge gaps, especially key uncertainties in system relation, forecast outcomes of alternative actions, and state hypotheses regarding the system's responses to projected management actions.
5. Select one or more actions, and design a means of carrying them out that will allow testing of hypotheses and forecasts.
6. Implement the action plan thus designed.
7. Monitor the system's responses to the actions.
8. Using data collected from the monitoring program, test hypotheses and compare the forecast outcomes to actual results; evaluate where the model and previous understanding of the system were faulty.
9. Apply the new knowledge thus gained in improving subsequent forecasts and decisions about the system.

This process has often been summarized as a four- to six-phase cycle as illustrated in

Figure 1. Steps 1 to 4 above would constitute the assessment and planning phase at the top or beginning of the cycle, and steps 5 through 9 would correspond to the subsequent phases. In Figure 1, the linking of the adaptation phase to a new phase of assessment and planning recognizes that management is never perfected, the world continues to change, and further learning about the system often must continue through another adaptive management cycle. Many analytical techniques and tools have been developed for adaptive management or have been brought into its repertoire. These include, among others, adaptive environmental assessment and management workshops, computer simulation models, decision analyses based on Bayesian statistics, monitoring protocols, experimental design guidelines, and power analysis.

Adaptive management can be applied in a relatively straightforward manner in situations where the resource outputs and potential management actions are few or the geographic scale is narrow. Examples include fisheries management in the northeast Pacific and in Australia, and certain forest management applications in Canada. Although institutional and other barriers often complicate matters even in these situations, the ecological and social setting is relatively simple.
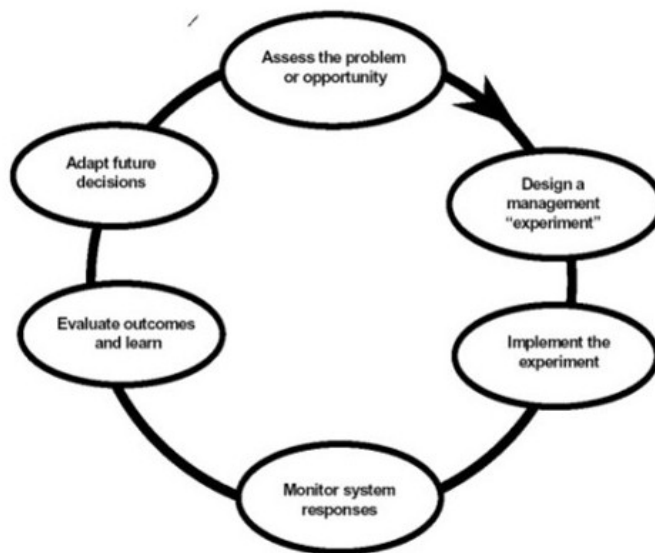
Deming or Shewhart Cycle as shown
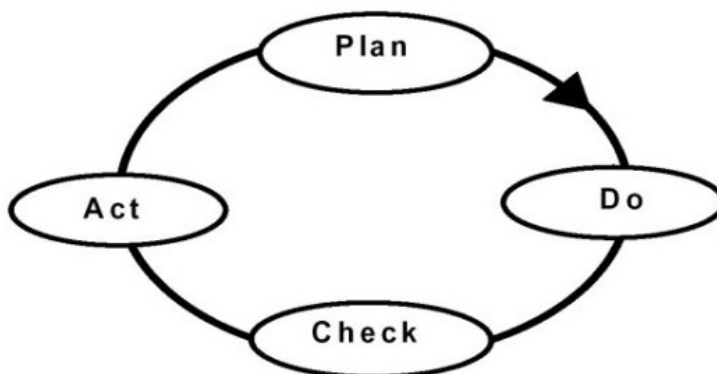
Figures 1a and 1b. The adaptive management process, shown as a cycle leading to further iterations

In other cases, application of adaptive management is far from straightforward. For example, in recent years much emphasis has been placed on the potential value of the adaptive management approach in resolving complex resource problems over large regions, especially in the United States. Examples include forest management in the west coast states and water management in the Florida Everglades, Columbia River, and Colorado River. In all these cases various public and private interests held strong positions on what was appropriate management and held somewhat different values. Because citizens in the United States often have access to the courts to challenge government or industry management plans, they were able to slow or stop implementation of those plans in many cases. In the specific U.S. cases listed above, these factors led to extremely fractious and litigious relations among the various sectors and a general lack of trust.

When adaptive management is touted as a way of resolving these complex issues, great emphasis is usually placed by its proponents on developing collaborative partnerships among citizens, government agencies, and industries. In theory, this should allow regional or local adaptation of policies to suit each area's priorities and ecosystems. Years of effort in the planning and assessment phase may be required, however, before agreement can be reached to proceed with implementation of any resource management policy in such cases. Nevertheless, significant successes in carrying out experimental, operational management to assist in learning about system responses have been achieved in both the Everglades and the Colorado River cases in recent years.

2. Principles and Practice

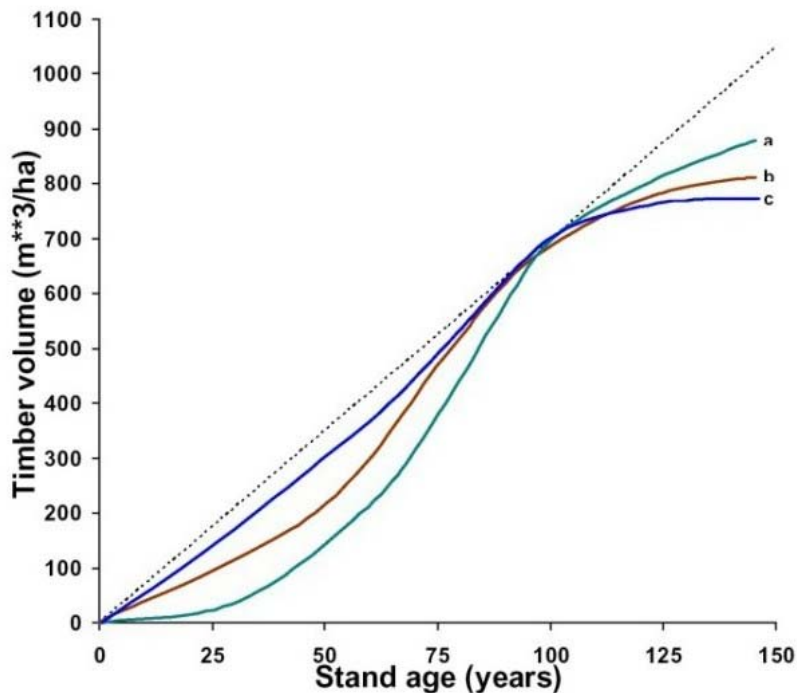### 2.1. Historical Development

Figure 2. The Deming or Shewhart cycle used in business management

The concept of adaptive management was formalized during the mid 1970s through the efforts of an international group of scientists and resource managers led by C.S. Holling and C.J. Walters of the University of British Columbia, Canada. Group members from the International Institute of Applied Systems Analysis in Austria, government agencies in Canada, the USSR, and the United States, and scientific institutes in Argentina and Venezuela, among others, all made key contributions. The philosophy, theory, and methods they developed were explained in the seminal book *Adaptive Environmental Assessment and Management*, published in 1978. Much subsequent analytical work by Walters and others focused on fisheries and wildlife issues, and emphasized the value of quantitative population analyses in concert with experimental harvesting policies. At the same time, adaptive management was used to guide planning of forest management policies in the province of New Brunswick, Canada; and inland water management in Florida, USA. Systems concepts including resilience and dynamic change were important in shaping the nature of those programs.

In the 1990s, emphasis turned toward social and political aspects of adaptive management, with K.N. Lee's work on the U.S. portion of the Columbia River basin exemplifying an increasing emphasis on society's role in resource policies. At the same time, applications of adaptive management expanded throughout the world as it came to be recognized as a key element of modern resource management.

As an amalgam of concepts and methodologies from several disciplines, adaptive management shares common elements with applications as diverse as adaptive control process theory in engineering; operations research in management science; total quality management based on the Deming or Shewhart Cycle (Figure 2); organizational learning in business management; participatory action research in social science; and systems analysis in ecology.

2.2. Key Concepts

Adaptive management was developed in response to failure, that is, the failure of traditional resource management and planning approaches in many situations. These failures took several forms, from long-term declines of salmon stocks in the eastern Pacific Ocean to extensive damage by forest insects in eastern Canada that resisted all control efforts. In many of these situations resource managers seemed to persist in using traditional theories and methods after experience and new theories suggested that radical changes were needed. In response, scientists and policy makers who were frustrated by such failures developed adaptive management around a set of precepts that embodied a new philosophy of resource management. Three of these fundamental precepts of adaptive management are that 1) uncertainty is an unavoidable attribute of management of natural systems, 2) learning is an important goal, and 3) experimentation is a primary tool.

2.2.1. Uncertainty

Uncertainty in resource management arises from several sources, including the stochastic nature of many ecological and climatological processes, our incomplete knowledge of many such processes and the effects of human activities on them, and

changes in society's values and priorities over time. Rather than expecting, then, that any management life regime or managed system will remain stable or in balance, adaptive management recognizes that change and surprise are bound to occur. The challenge for managers is to learn how to "embrace uncertainty" and respond to it appropriately, not to ignore it and hope it will not arise.

2.2.2. Learning as a Goal of Management

If past management approaches have not been successful and the future is uncertain, logic suggests that learning more about the dynamics and responses of a system is a necessary step towards better management. Adaptive management makes learning a priority from the outset, and thus expands the manager's goal set beyond the usual categories of satisfying clients and employers by producing goods, services, and profits.

2.2.3. Experimentation as a Management Tool

Adaptive management recognizes that many human impacts on the environment will continue even in the face of uncertainty and incomplete knowledge. In most areas of the world demand for resources continues to grow, driven by population growth, consumer preferences and needs, and technological innovations. The policies used to guide resource management, and the practices used to implement them, should be viewed as experiments that offer opportunities for learning. These experiments do and will take place continually whether managers recognize them as learning opportunities or not. Adaptive management seeks to capitalize on these opportunities by planning and conducting management so that reliable new knowledge is gained about system interactions and responses. K.N. Lee captured this clearly in stating that "Adaptive management . . . embodies a simple imperative: policies are experiments; *learn from them.*"

In using experimentation for learning, adaptive management shares common elements with scientific research, and this sometimes leads people to question whether there is in fact any difference between the two. Scientists who work in applied fields such as forestry and hydrology seem especially prone to confusion over what makes adaptive management different. Table 1 presents some of the ways in which the two fields differ.

Factor	Experimental research	Adaptive management
Leader	Scientist	Resource manager
Scale of application	Laboratory or small field units such as plots or stream reaches	Operational management units such as whole populations or rivers
Selection of variables studied	Determined by research hypotheses	Determined by management relevance and feasibility
Degree of control of environmental variability	High; to prevent confounding of results	Moderate; to incorporate natural variability in management units
Scope of issues studied	Narrow, but in depth	Broad but shallower
Nature of clients	Other scientists or managers	Public and private clients,

		other managers, scientists

Table 1. A generalized comparison of factors that differentiate adaptive management from experimental research

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Biographical Sketch

J.B. (Brian) Nyberg is a professional biologist and professional forester with the British Columbia Forest Service in Victoria, BC, Canada. He has led the BC Forest Service's adaptive management initiative since 1995, working with forest companies, government professional, scientists and public groups to apply adaptive management principles in forest resource management. He also manages the Forest Service's role in wildlife habitat policy under the BC Forest Practices Code. His other wildlife responsibilities include modelling of habitat supply for wildlife and recovery planning for species at risk. Mr. Nyberg's previous experience includes 16 years in wildlife habitat research as a research ecologist and research manager, and 6 years in forest resource planning. Mr. Nyberg has a Master's degree in Forestry (Forest Wildlife Management) and a Bachelor's degree in Zoology from the University of British Columbia.