Reviews in Fisheries Science, 1(3): 261–283 (1993)

How Adaptive is Adaptive Management? Implementing Adaptive Management in Washington State and British Columbia

Cindy L. Halbert

Fisheries Research Institute (WH-10), University of Washington, Seattle, WA 98195

ABSTRACT: The purpose of this paper is to analyze constraints to the effective implementation of adaptive management from a sociological and institutional perspective. Although formal adoption and institutionalization of adaptive management is critical, it is however insufficient to ensure successful implementation. Successful implementation of adaptive management requires management to take risk-prone actions while providing institutional patience and stability. The experimental nature of adaptive management requires that managers and politicians redefine success so that learning from error becomes an acceptable part of the learning process. In addition, information must be collected and analyzed over time frames that often exceed the typical tenure of politicians. Adaptive management also needs to be predicated on clearly established goals and decision criteria that will allow for accountability and evaluation of how goals are being met. Furthermore, the goals must be compatible with natural processes, existing or achievable technology, and social norms.

One of the fundamental problems to the effective implementation of adaptive management is an agreed-upon definition of that term and how and if it should be implemented. Its application would have far greater success in resolving natural resource management conflicts if it were universally defined as both (1) linking science with management and (2) implementing management itself as an experiment.

KEY WORDS: Adaptive management, experimental management, Timber, Fish, and Wildlife Agreement, natural resource management, dispute resolution.

I. INTRODUCTION

Resource managers are increasingly challenged to balance a wide range of goals and must use innovative management strategies to resolve conflicts inherent in the multiple use of resources. Resolution of such problems is complicated by two kinds of uncertainty: (1) technical (in the dynamics of the resources being managed), and (2) social (in the dynamics of the institutional, economic, and political environment). Management strategies that succeed must transcend both sources of uncertainty.

Adaptive management, a strategy that attempts to address the problems of management under uncertainty, is receiving increasing recognition in the northern U.S. (e.g., see Lee and Lawrence [1986]) and western Canada (e.g., see Walters [1986] and Leaman and Stanley [in press]). Adaptive management is an innovative technique that uses scientific information to help formulate management strategies in

1064-1262/93/$.50

order to "learn" from programs so that subsequent improvements can be made in formulating both successful policy and improved management programs (Holling, 1978; Lee and Lawrence, 1986; Walters, 1986). According to its proponents, adaptive management allows for large-scale natural resource management activities to proceed in the face of uncertainty and potential opposition, facilitates communication among different user groups, and encourages the suspension of conflicts as traditional adversaries jointly develop ways to learn from experience. By allowing large-scale projects to begin in the face of significant uncertainty, long-term costs of resource management can be lowered while raising the probability of success in managing the biological aspects of the resource (Fluharty and Lee, 1988).

Although adaptive management explicitly recognizes the need to link science with management, the literature to date has focused almost exclusively on how to reduce the technical uncertainties of managing natural ecosystems (Holling, 1978; Walters and Hilborn, 1978; Walters, 1986). Very little analysis has been conducted on the sociological and institutional requirements necessary for the effective implementation of adaptive management. The purpose of this paper is to analyze the constraints to the effective implementation of adaptive management from a sociological and institutional perspective. For this analysis, a landmark case is examined, the Timber, Fish, and Wildlife Agreement (TFW, 198") of Washington State, which formally adopted the concept of adaptive management at its inception. Other cases, such as the Salmon Summit negotiations in the Pacific Northwest and an experimental management program for rockfish stocks in British Columbia, are highlighted for comparison purposes.

II. ADAPTIVE MANAGEMENT IN THEORY

The basic concept of adaptive management is to "learn about the potentials of natural populations to sustain harvesting mainly through experience with management itself, rather than through basic research or the development of general ecological theory" (Walters, 1986).

The concept of adaptive management was originally developed by C. S. Holling (1978) and co-workers at the University of British Columbia. It was based on a method called "Adaptive Environmental Assessment and Management" (AEAM). AEAM was originally envisioned as a technique to incrementally influence construction development designs with the use of environmental impact studies. More generally, AEAM is a method by which information from environmental assessment studies can be used to enhance the understanding of biological populations affected by environmental change, thus allowing future management to be done more knowledgeably. This method is based on simple simulation models and databases that are used to predict future environmental conditions of the ecosystem or populations of interest (Walters, 1986).

The original concept of AEAM has been broadened into the concept of adaptive management. In general, adaptive management is the concept of applying "experimentation" to the design and implementation of natural-resource and environmental management policies. An adaptive policy is designed from the outset not only to change or regulate, but also to test clearly formulated hypotheses about the behavior of an ecosystem being changed by human use. Such hypotheses usually take the

form of predictions of the response of one or more species to a certain policy; for example, the response of commercial fisheries to changes in harvest regulations (Walters and Hilborn, 1976, 1978). The necessity to develop quantitatively explicit hypotheses about how the system functions may be both the greatest limitation to its use as well as the greatest benefit (Baskerville, 1985).

Although adaptive management may be utilized in many arenas, it has two distinguishing characteristics. The first essential characteristic of adaptive management is that a direct feedback loop exists between science and management. This allows for management and policy decisions to be modified in light of new scientific information. The second essential characteristic of adaptive management is that management is an experiment. An adaptive approach emphasizes that resource management itself is an important source of experiments on the natural system (Fluharty and Lee, 1988). It is the **combination** of these two characteristics that distinguishes adaptive management from either traditional science or incremental "learning as you go."

III. ADAPTIVE MANAGEMENT VS. TRADITIONAL MANAGEMENT

A. LINKING SCIENCE WITH MANAGEMENT

In traditional management, research is ordinarily separated from actual resource management. Rarely is there an explicit procedure on how the emerging science will be utilized to influence management. Providing a link between science and management generally requires some type of inventory, monitoring, and evaluation program. It is necessary to distinguish between resource inventory and monitoring. Resource inventory is simply compiling population and habitat data, whereas monitoring is the collection of data used to evaluate progress toward meeting objectives, which in turn can be used to adjust management policies. It is the feedback part of monitoring that distinguishes it from inventory (Salwasser et al., 1983). Monitoring can be considered as both an activity (measuring) and a process (evaluation and refinement). As a process, it is the evaluation and use of the data as feedback to improve decision making. "It is in this latter sense that monitoring transcends inventory to become a vital link in the cycle of adaptive management" (Salwasser et al., 1983).

From a conceptual standpoint, resource inventory and monitoring are relatively uncomplicated tasks, although they may be costly and difficult to manage. Evaluation, however, is highly dependent on proper conceptual design. It requires clearly defined objectives so proper measurements that evaluate progress toward meeting the stated objectives can be made. The implicit assumption is that the information gained from experimentation will be used to meet management objectives. Only in this manner can one truly link science with management.

B. MANAGEMENT AS AN EXPERIMENT

One of the pervasive myths of adaptive management is that it can be simply defined as using information as it becomes available to modify decisions. In this light, most

managers imply that they are already operating "adaptively." The notion is one of incrementalism: accumulating knowledge through gradual bits of information and making marginal adjustments as you go (Lindblom, 1959). In this manner, incrementalism is akin to **passive** (as opposed to **active**) adaptive management (Walters and Hilborn, 1978). In **passive** adaptive management, it is assumed that the best information available is correct. Learning is to occur through inadvertent management mistakes and inevitable natural variations (Walters, 1987). Passive adaptive management is likely to be optimal only in systems that have a high degree of natural variation (i.e., they are self-identifying).

In contrast, **active** adaptive management treats all management actions as deliberate experiments in order to sort out system processes. By implementing deliberate experimental management policies, better information is expected for long-term management, particularly in situations where nature does not provide sufficient input disturbances. There is a trade-off in balancing the value of reducing future uncertainties vs. the costs of managing for the status quo without experimentation. The trade-offs will, in part, be due to the revenue generated during the learning period, the costs of observations made during the learning period, and the long-term economic value of learning (Sainsbury, 1991). Whether experimentation is worthwhile will in part be determined by the level of random variation, the discount rate of the future value of the resource in question, and the applicability of results to other management situations (Walters, 1987).

Adaptive management is different from conventional management in that it requires managers not only to utilize updated scientific information as it becomes available, but also it requires that managers directly "test" the policy or management regime that they have decided to implement on the resource itself. It is a deliberate and explicit commitment to "learn" from experience. It is the explicit recognition that all management practices are experiments, that formalizes the learning process, often referred to as experience (Oliver, et al., 1992). Thus, it is the experimental nature of the management regime that facilitates learning.

Although monitoring and evaluation are essential tools in describing the status quo, and can in most cases be used to evaluate how well one has met certain objectives, it does not provide information to measure "why" a particular policy worked (i.e., to determine causality). For this reason, it becomes vital to incorporate an experimental component into the monitoring and management design itself.

Experimentation can be seen as a means of applying the scientific method to resource management. In essence, adaptive management is merely a special case of **experimental management** (Eberhardt and Thomas, 1991). As McAllister and Peterman (1992) noted, "Experimental management promotes a scientific basis for management yet does not require action to be dependent on extensive past studies; instead, actions can be based on limited current data as long as uncertainties are recognized openly and experiments are designed to generate new information to resolve them."

The scientific method relies on two key concepts: controls and treatments. Adaptive management is very different from traditional resource management because "adaptive management really contemplates control and replication as a serious part of the implementation strategy, which traditional resource management does not" (Lee, cited in Halbert, 1991).

Although the concept of using controls and replicates is fundamental to any well-defined scientific investigation that seeks to establish causal relationships, its use in the experimental nature of adaptive management needs to be emphasized. Thus, it becomes necessary to have a clear distinction between resource inventory, monitoring, evaluation, and experimentation.

Experimentation, however, is limited by certain space and time scales. Experimentation is easiest and most defensible for examining local, short-term "tactical management" (field implementation techniques such as alternative fish enhancement technologies, regulation/enforcement schemes). Usually there is a trade-off between the benefits of learning rapidly by introducing large disturbances and a high level of monitoring, and the high costs and risks of doing so (Walters and Hilborn, 1978). Experimentation becomes progressively more difficult, expensive, and ethically questionable when applied to larger scale, longer term (cumulative) strategic options. At some scale, such as global warming, replication and control become impossible. At that level, computer modeling is used as a decision analysis tool, which permits some orderly use of information in comparing larger scale and long-term options.

The use of experimentation and the scientific method are unfamiliar and uncomfortable concepts to those involved in established management regimes that traditionally manage to maintain the status quo. As Taylor (1984) notes, "Clearly, science is easier to pursue in the scientific community than in the political community." However, policymakers' uncertainty about the effectiveness of current practices is a crucially motivating force for experimentation. Policymakers and managers need more than descriptive information; they need to know how well one policy option works compared to another. Experiments provide answers to such questions because the unique contribution of each policy variable can be isolated (Garner and Visher, 1988).

In addition to reducing uncertainty, experimentation also may have other benefits. It may produce unexpected innovative and fruitful results in the people implementing the adaptive program. As one implementer of an adaptive management program noted, "Start experimenting and people begin to think that what they are doing is exciting and interesting. They begin to take a different view of themselves. They begin to think expansively, creatively, originally..." (Minneapolis Police Chief Anthony Bouza quoted in Garner and Visher, 1988).

Some of the key differences between adaptive management and traditional management are summarized in Table 1. Most importantly, unlike traditional management, which is founded on the idea of making small, incremental adjustments as you go, adaptive management allows for the idea that science and management programs may undergo sudden shifts in conceptual design that may necessitate reevaluation of stated objectives. It is the ability to **plan** to incorporate unanticipated changes into objectives and knowledge that distinguishes adaptive management from **crisis management** (Oliver et al., 1992). Thus, "Adaptive learning through management may proceed much more quickly than through conservative management and basic research" (Walters, 1986).

An analysis of the Timber, Fish, and Wildlife Agreement is presented next because it clearly illustrates one of the most fundamental problems to the effective implementation of adaptive management, that is, an agreed-upon definition of that term and how and if it should be implemented.

TABLE 1
Differences between Traditional Management and Adaptive Management

	Traditional management	Adaptive management
Uncertainty	Uncertainty is rarely acknowledged explicitly; it is assumed that the policy is correct and it is not tested	Uncertainty is explicitly recognized and the policy itself is "tested" by treating management as an experiment
Link between science and management	Link absent; vague process for how science will be used to change policy	Direct link; science is used to directly inform policy and management
Management implemented as an experiment	No	Yes
Implementation	Does not use controls and replications in the implementation of its management program	Uses controls and/or treatments in the implementation of its management program
Type of learning	Incremental; manages to maintain status quo, learning from failure unacceptable	Sudden shifts occur, status quo subject to change, learning from failure acceptable

IV. ADAPTIVE MANAGEMENT IN PRACTICE

A. ADAPTIVE MANAGEMENT IN WASHINGTON STATE: THE TIMBER, FISH, AND WILDLIFE AGREEMENT

The historic Timber, Fish, and Wildlife Agreement represents one of the first attempts to negotiate a comprehensive agreement among state agencies, Indian tribes, environmental groups, and timber companies for managing private and state-owned timberlands (NRRC, 1985). This agreement was forged under the auspices of the Northwest Renewable Resources Center (NRRC), an organization that specializes in mediating natural resource disputes (Fraidenburg, 1989). Although several features distinguish the TFW agreement from other resource management agreements (Halbert, 1989), it is innovative in that it formally incorporates the concept of adaptive management through the creation of the Cooperative Monitoring, Evaluation, and Research (CMER) program set up under the agreement (TFW CMER, 1988).

B. FORMAL ADOPTION

In TFW, adaptive management was formally incorporated into the Washington Forest Practices Rules and Regulations (Washington Administrative Code [WAC]

222-12-045). As stated in WAC 222-08-035: "The department [Department of Natural Resources] is directed to report to the board on opportunities to modify these regulations when baseline data, monitoring, evaluation or the use of interdisciplinary teams show that such **adaptive management** will better meet the purposes and policies of the Forest Practices Act" (WSFPB, 1988; emphasis added).

Despite the formal adoption of adaptive management in the WAC regulations, the only specific reference to it in the TFW agreement itself is in the subtitle of a section on annual evaluations and in-depth evaluations. It was agreed by TFW negotiators that having one set of rules for forest management was inappropriate because of site-specific variability. Thus, it was agreed to manage by an "evolutionary process" that will result in different management approaches over time (TFW, 1987).

During the TFW negotiations, negotiators agreed that some issues required additional scientific information in order to make effective management decisions. Thus, the TFW parties deliberately omitted bargaining on those issues during the mediation process (Halbert and Lee, 1990) and created the CMER program. Specifically, CMER was designed "to provide a basis for understanding resource management interactions and the impacts of forest practices on public resources" (TFW, 198"). It was understood that where the impact of timber harvest on public resources can be ascertained, that scientific knowledge should be utilized to manage forest resources as it becomes available.

The importance of being able to defer bargaining on unresolved issues until scientific information becomes available is significant for two reasons: (1) it allowed the negotiations to proceed in other substantive areas and thus come to a successful conclusion and (2) it implicitly endorsed the principle that scientific information can settle disputes, and that research and management should be conducted with that aim (Halbert and Lee, 1990). In sum, successful negotiation depended on future answers to contemporary questions.

The appeal of the adaptive management technique is that it allows management to proceed in the face of sociological and technical uncertainties. Although virtually all decisions about natural resources are made under uncertainty, traditional management regimes do not explicitly acknowledge this uncertainty. TFW has advanced the plausibility of an unlikely idea: that shared uncertainty can be a basis for developing explicit commitments to act differently, once the uncertainty has been reduced by scientific research. This is a significant improvement over trying to resolve environmental management conflicts in an acrimonious and litigious forum; but as the following analysis reveals, the full potential of learning from experience has yet to be realized.

C. *ADAPTIVE MANAGEMENT VS. FLEXIBLE MANAGEMENT*

Because adaptive management incorporates many components of traditional science and management (Holling, 1978; Walters, 1986), it has been subject to misinterpretation. As Kai Lee noted "Adaptive management has proven difficult to understand because it's so easy to understand approximately" (Mayar, 1990). It is a buzz word that is widely used but poorly understood.

The misunderstanding of adaptive management within the TFW negotiations is evident. As one of the original co-chairs of the TFW CMER committee commented,

"Adaptive management is like the joke at the party that every one laughs at but nobody gets" (D. McDonald, personal communication). An outside analyst to the TFW process revealed that, "Radically different opinions are held within CMER as to the meaning and requirements of an adaptive management system and whether CMER should implement such a system and the related planning practices" (Cume, 1989). A key Weyerhaeuser manager noted that they get a "variety of rehashes, of such a gross generalization, it [adaptive management] has no meaning when we try to put a program together" (K. Sullivan, personal communication).

The fact that adaptive management is interpreted in a variety of ways has led to divisiveness concerning **if** adaptive management should be implemented within the TFW framework and, if so, **how**. Some feel that adaptive management requires the development of simple simulation models to conceptualize and understand how the system is working in order to predict future environmental conditions. In fact, some investigators note that the difficulties of implementing active adaptive management may be because it involves relatively sophisticated quantitative methods (McAllister and Peterman, 1992). Others feel that adaptive management needs to be defined differently for diverse user groups, such as managers, regulators, and policy makers. Those groups have different needs and operate on different time frames and at different spatial scales ranging from short-term and localized (managers) to long-term and regional (policymakers).

Managers, to various degrees, are charged with the planning, design, oversight, and implementation of individual actions at specific locations. Thus, they need to know the condition and magnitude of the resource with which they are working. To managers in TFW, adaptive management translates to developing predictive tools that can be used for site-specific management. Although some TFW participants feel they are moving toward site-specific management, most CMER research projects are aimed at providing information that may be used to modify regulations. However, "it isn't clear how you are going to get from regs [regulations] to site-specific management" (K. Sullivan, personal communication).

Regulators are charged with the implementation and enforcement of standards, laws, and regulations. Their overall job is to see that standards are met. They are concerned with individual and cumulative actions. Regulators generally are most interested in the current status of the resource or the likely status after a particular management action. They need resource status information to compare against the standards set by the regulations that they are charged to enforce. In general, they have less interest in the prior or long-term status of the resources (TFW, 1989).

Policymakers are charged with developing standards, laws, and regulations that are implemented by regulators and, in a less direct sense, by managers. Policymakers also may be involved in establishment of the goals and objectives of agencies, tribes, industries, and public groups. Policymakers are usually involved in the setting of policies that affect broad areas such as an entire state. Although their policies are implemented at the local level, they themselves are usually not involved in management of specific actions but rather are interested in the overall effect of their policies (TFW, 1989).

Policy persons have, in general, a major interest in the long-term status of resources and somewhat less interest in the exact current status of those resources. The policies they set are often in place for extended periods and are not always

easily changed. These people are instrumental in guiding the future status of one or many resources.

Much of the emphasis on the use of adaptive management in TFW is regulation oriented. In TFW, adaptive management to decision makers has translated into "performance based regulations." That is, new information generated from the forthcoming CMER studies is expected to modify existing regulations. This view of adaptive management invokes constraints of its own. Public resource managers are often reluctant to advocate rule changes because once regulatory changes are made, they are difficult to reverse or modify. Likewise, industry is often averse to rule changes, particularly if those changes lead to increases in the cost of operation.

The above-mentioned distinctions about the needs of different user groups are generalizations at best. However, the differences in mandate, time, and locational scale have very significant implications on the design and implementation of an adaptive management program that must satisfy the needs of each user group. In sum, discussions within TFW have centered on whether the focus of adaptive management should be on large-scale natural resource system modeling, as originally defined by Holling (1978) and Walters (1986), or whether it should be to delineate adaptive management for each user group.

In this light, one of the interesting outcomes in TFW discussions regarding adaptive management is the redefinition of the term as "flexible management." At a CMER meeting on August 31, 1989, it was pointed out that TFW is not practicing adaptive management as defined by Holling (1978) and Walters (1986). According to meeting minutes (TFW, 1989), "Early in the TFW negotiations the term 'adaptive management' was used to describe the feedback loop of trial and error through which new technical knowledge would be applied to multiple resource management. This generally applied to regulations, i.e., we'll find out if the regulations work and change them if necessary. It was suggested that what we're practicing might better be called 'flexible management'.... If we can focus it toward site specific analysis, assessment/decision making tools, and regulations, then maybe we don't really need adaptive management in its classical sense."

Although flexible management in TFW is never defined in the Agreement, based on the context of its use, it appears to mean a management system that attempts to fit resource use and protection to resource sensitivity according to area. It is the geographical variability of resources that essentially justifies such an approach. Broad regulations invariably fail to capture this variability and ultimately over-protect or under-protect many sites (Currie, 1989). Thus, the need for "flexible management."

The emphasis in TFW is to move toward a management program that is based on site-specific information, rather than to abide by a "one regulation fits all" approach. This is reflected in one of the few substantive changes resulting from the agreement, the incorporation of interdisciplinary team reviews on applications that have been flagged due to potentially sensitive issues (Halbert and Lee, 1990). Illustrations of how this might work include "geographic" management, in which different criteria are used to implement forest practices based on geographic location. Industry appears to favor the use of flexible management over adaptive management. Although "nobody could tell you what flexible management meant when you asked them, **they had some notion that it means that we wouldn't have to do everything by regulations**" (K. Sullivan, personal communication).

It is clear that both the large-scale (ecosystem) and the experimental character of adaptive management require reevaluating and changing current forest land management practices. "Monitoring and evaluation of what has worked and what has not worked is an important part of the adaptive management idea... . There is some concern ... that while all the TFW participants use the term, the timber industry does not yet realize that adaptive management could come to have a more substantial impact on their harvest methods" (Brown, 1989).

Regardless of the substantive outcomes of discussions on if and how adaptive management should be used, it is apparent that simply having adaptive management interpreted in a variety of ways can have serious implications for successful implementation. It also is apparent that formal adoption and institutionalization by incorporation into regulations is insufficient to ensure the effective implementation of adaptive management.

The malleable nature of adaptive management is a double-edged sword. On the one hand, it allows for the concept to be utilized in a wide variety of situations. On the other hand, the fact that it is subject to such an array of interpretations is an effective barrier to successful implementation. Redefining the term as flexible management leads one to question the accountability of such a management regime. In fact, in TFW there is no provision for compliance monitoring, and no provision, as yet, for monitoring the results of a recommendation (P. Haug, personal communication).

The fact that adaptive management is subject to such an array of interpretations may be one of its basic flaws. This author asserts, however, that if adaptive management were universally defined as both linking science with management and implementing management as an experiment, as previously discussed, its application would have far greater success.

D. ADAPTIVE MANAGEMENT IN BRITISH COLUMBIA: AN EXPERIMENTAL MANAGEMENT PROGRAM FOR TWO PACIFIC OCEAN PERCH STOCKS

The case of the TFW agreement demonstrates that misinterpretation of the concept is an effective barrier to its successful implementation. What about those programs in which the concept has been formally adopted and correctly understood? For comparison purposes, a Canadian experience conducted under the Department of Fisheries and Oceans, British Columbia, is highlighted. This example illustrates that even if adaptive management is correctly understood, social and economic constraints may prevent its effective implementation.

An experimental management program was initiated in the 1980s involving two Pacific ocean perch (*Sebastes alutus*) stocks off British Columbia. The program involved a 5-year period of specified overfishing in order to test assumptions about stock dynamics, biomass and productivity estimates, aging methods, and the values of population parameters. The original experimental design required that after the initial period of overharvesting, a period of no harvesting would follow in order to continue testing the assumptions about population dynamics and to allow the stocks to recover. Although there was general acknowledgment by industry and managers that biomass had significantly decreased during the overfishing portion of the

experiment and that the parameter values used to predict stock productivity were correct, there was no agreement on the level of harvest that could be sustained. The logical inconsistency of those two views was not acknowledged (Leaman and Stanley, in press).

Although it was recommended that the experiment stop because industry was not adhering to the second portion of the experimental design (i.e., no harvesting), managers were reluctant to terminate the study. Instead, they returned to a middle level of controlled harvest. As the principal investigator of this study noted, "This represents a classic example of what Walters (1986) refers to as a 'conservative compromise,' an intermediate response which should only be favored if **learning effects are to be ignored**" (Leaman and Stanley, in press: emphasis added).

It was assumed that fishermen would value the learning effects of these experiments because the study directly addressed the industry's contention that the Canadian Department of Fisheries and Oceans underestimated abundance and productivity. Yet, despite declining catch rates throughout the overfishing period, the fishing industry lobbied to keep the area open indefinitely. "Once established, this experimental fishery came to be regarded as an integral, permanent, and necessary part of the groundfish industry... . To reduce or close the...fishery therefore took on much greater significance than the absolute level of landings would infer" (Leaman and Stanley, in press).

This example indicates the troubling aspect that although a management program can make the progressive attempt to officially sanction management experiments with the intent of learning, such experiments can get derailed mid-stream by political pressures that result in severely curtailing the potential to learn. The application of experimental methods can be curtailed by social and economic constraints if the experiment temporarily decreases harvests, or is inconvenient to harvesters by displacing them from traditional fishing grounds (McAllister and Peterman, 1992). Although it has been shown that higher than average yields can be expected in the long run by periodic disturbances and recovery times, such policies may not be optimum in areas where the main objectives are short-term yields and temporally stable and predictable harvests (Walters, 1987). This example illustrates the paramount importance that all of the parties involved realize the payoffs from increased knowledge through experimentation if it is to become an acceptable means of managing natural resources.

V. INCENTIVES AND IMPEDIMENTS TO IMPLEMENTING ADAPTIVE MANAGEMENT

A. FORMAL ADOPTION

In most cases, the formal adoption of adaptive management may be considered a **necessary but insufficient** criterion for implementation. The probability that adaptive management will be implemented (Lee and Lawrence, 1986) is increased if it is formally adopted by management or though regulation. In fact, the lack of formal recognition by management may pose serious barriers to its effective implementation. However, even if the need to apply science is recognized, a clear

and explicit commitment by management may be difficult to obtain, particularly if a restructuring of the management infrastructure is first required. However, it also should be noted that it is possible that important information can be generated in systems that utilize the principles underlying adaptive management even if the approach is not formally used as the management policy for the resource (Sainsbury, 1988, 1991).

Implementing adaptive management requires difficult changes in the way resource management takes place. Fluharty and Lee (1988) outlined four essential elements to implement adaptive management: they are to quote:

1. The possibility of failure must be specifically acknowledged and included in the planning process.
2. Front-end costs for planning, experimental design, and baseline measurement must be incurred, together with a long-term commitment to continue those activities. Institutional patience and stability therefore must be sufficient to measure outcomes.
3. Interventions must be large but should not be applied universally, a characteristic that makes their justification more difficult.
4. Information must be collected and analyzed and reflected in program redesign over time scales that may exceed the terms of office or agency assignments.

The difficulties involved with implementing these types of changes from a political viewpoint are large. None of this is readily achievable, especially in institutional structures where implementation is spread out among several state agencies, Indian tribes, environmental groups, and timber companies. "The rules and processes by which we govern these natural resources must therefore approach the complexity of the ecological interactions themselves. That clearly challenges the capacity of human governance — which is why, as a practical matter, goals set by humans must be provisional, must be revised in light of experience" (Fluharty and Lee, 1988).

B. MANAGING UNDER UNCERTAINTY

One of the central tenets of adaptive management is that it is a technique that allows natural resource management to proceed in the face of uncertainty. **How** to deal with these uncertainties is at the heart of most environmental conflicts. Under an adaptive management regime, management may proceed in the face of uncertainty **because** the uncertainty is expected to be reduced by implementing management itself as an experiment.

The proposed solutions to large environmental issues, such as acid rain and global warming, may be controlled by factors other than ecological uncertainties. For example, Hourcade and Thery (1992) noted that in order to diffuse the crisis perspective on the forest dieback issue in Germany fueled by the media in 1983, European producers had to comply with new regulations to minimize car emissions, despite the lack of scientific knowledge about the real mechanisms involved in forest

dieback. This was due in large part to the fact that the Germans had already developed the catalytic technology for cleaning automobile exhaust gases. Other countries, such as France and Italy, chose different means to respond to the forest dieback issue because their technologies had developed in different directions. However, in all cases, despite the lack of scientific evidence, the presumption was made that there was a direct link between acid rain and forest dieback, and that car emissions were the main culprit (Hourcade and Thery, 1992).

This example illustrates another potential pitfall in managing adaptively. The solutions proposed for an environmental management crisis will depend on the collective expectation of ecological risk, and in the collective interpretation of scientific knowledge. If a crisis situation is perceived by the public, the media, and decision makers, then suboptimal decisions may be made in order to diffuse the crisis. In the example of acid rain in Germany, existing technologies shaped the solutions, rather than a clear understanding of the cause and effect mechanisms of the ecological processes involved. This type of decision making may short circuit the learning process and may, in turn, irreversibly shape the innovation process. Thus, "decision under uncertainty," may be more appropriately termed, "decision under controversy" (Hourcade and Thery, 1992).

This example highlights the fact that many uncertainties have the added burden of having a controversial nature. In addition, the nature of future uncertainties will be determined by actions taken today. In turn, the decisions taken today depend on a certain stability of the existing institutional context (e.g., laws, economic instruments). The existing uncertainty may be used as a means to increase the options available in a negotiation process for resolving environmental conflict. However, it is important that the learning process not be prematurely cut short by a suboptimal decision that may irreversibly shape the innovation process.

C. RISK-PRONE VS. RISK-AVERSE ACTION

One of the reasons why adaptive management may have some fundamental difficulties in becoming effectively implemented into public management programs is because the experimental nature of adaptive management implies the need to take "risk-prone" actions. Public agencies typically manage for some ill-defined equilibrium to maintain the status quo and can generally be characterized as risk-averse. This presents a major dilemma for managers who need to take risk-prone action in order to learn more about the system, when they are enmeshed in a risk-averse setting. In some cases, it may still be optimal to experiment, even when the management objective is explicitly risk-averse, so as to not ignore the longer term importance of learning (Walters and Ludwig, 1987).

As Hilborn et al. (1979) indicated, the drawbacks for managing for an ill-defined equilibrium are that "When a system is at equilibrium it provides no information about system behavior, and if some element of the system changes, an equilibrium management strategy will provide no information about that change." Thus, the argument is that "such systems should be intentionally perturbed away from the equilibrium to provide information about the dynamics of the system" (Hilborn et al., 1979). By intentionally increasing the contrast between key variables, the important processes governing the system may be identified (Sainsbury, 1991).

The arguments for perturbing systems away from their equilibrium point are twofold. One, it is often impossible to determine when the optimum effort (e.g., maximum sustainable yield) has been reached until it has been surpassed. The notion here also is one of providing increased contrast between treatments (McAllister and Peterman, 1992). Second, it is becoming increasingly clear that most systems are not governed by a single equilibrium (or maximum) point and therefore one needs to learn to track changing maxima (Hilborn and Sibert, 1988).

Hilborn et al. (1979) argued that if adaptive management is to reduce uncertainty as rapidly as possible, it may occasionally be necessary to do something that does not appear to be "optimal" because it will provide information about the system. "A somewhat heretical example for fisheries argues that the manager should occasionally 'underfish' and 'overfish' to make sure that productivity estimates of the fish population are correct" (Hilborn et al., 1979; Hilborn and Sibert, 1988).

Despite the fact that the heretical example of overfishing was sanctioned in the Canadian experience precisely in order to test the assumptions of their population estimates, the experimental nature of the adaptive management program was derailed midstream due to political pressures against underfishing.

D. ETHICS OF EXPERIMENTATION

Despite the value of using an experimental approach to management, in some cases, experimentation may be impossible or ethically questionable. The potential benefits for additional knowledge needs to be weighed against the potential adverse effects of taking risk-prone action. Although past efforts in resource management "have been essentially trial-and-error approaches to cope with the unknown and the unexpected...we are now at a time where the intensity and the extensiveness of our trials can generate errors that are potentially larger than society can afford" (Hilborn et al., 1979). We can no longer assume the paradigm "of the infinitely forgiving nature that seems implicitly to have been assumed in the past" (Hilborn et al., 1979).

Deciding when to experiment is challenging at best. At what point should scientists and managers decide that certain actions (experiments) will cause socially unacceptable irreversible harm? How far do we go in the name of science? How much do we let legislative (agency) mandates dictate the nature, extent, and timing of research programs?

If some experiments are deemed too dangerous to allow risk of failure and if failure is reasonable grounds for holding management to account, then the experimental approach of operating adaptively becomes suspect. One can make the reverse argument, however, that certain problems may pose irreversible harm if no policy action is taken immediately. In those cases, there may be no time for experimentation. The point at which the uncertainties are large enough to suggest delaying policy responses is not a scientific question per se, but a value judgment. As Garner and Visher (1988) note, the "purpose of experiments is to inform policy, not to make policy." The actions taken will reflect the risk-prone or risk-averse nature of the decision makers.

Although it is logical that any research design should impose the fewest burdens on participants (and resources) in the experiments, "both practitioners and researchers must recognize that experimentation is not just a study; it is not just a program

evaluation: it is a major process of organizational change. No matter how temporary that change may be, it is still going to be intrusive and major" (Lawrence Sherman, quoted in Garner and Visher, 1988). Ultimately, the impact of the proposed intervention must be weighed against the costs of continuing policies that are ineffective.

The failure of adaptive management to be effectively implemented leads to the question of whether adaptive management is indeed an appropriate technique for managing natural resources. Can the uncertainties in fact be resolved experimentally? Is the learning time short enough that the information will be available before the system changes and the information becomes outdated? Despite admitting the uncertainties, are the natural resource cooperators going to be willing to act on the basis of scientific information or will hidden agendas preclude the effective and honest use of scientific information? Will science merely be used as a tactic to delay action?

VI. SCIENCE AS A DELAY TACTIC: THE CASE OF THE SALMON SUMMIT NEGOTIATIONS

In October of 1990, Salmon Summit negotiations were convened by Oregon Senator Mark Hatfield in the Pacific Northwest as a direct result of petitions filed with the National Marine Fisheries Service (NMFS). The Summit sought to protect four severely diminished Columbia and Snake River salmon stocks under the Endangered Species Act. These negotiations are illustrative of the impediments to adaptive learning in a management regime dominated by multiple user groups with different objectives. The petitions filed are indicative of the failure of the Northwest Power Planning Council to manage equally for fish and power as demanded by the legislative mandate of the Northwest Power Planning Act of 1980. Equally troubling is the aspect that very little learning is apparent despite the formal adoption of the concept of adaptive management in their fish and wildlife program (Lee and Lawrence, 1986). Although the petitions filed with NMFS raise an ax over the heads of both fisheries managers and commercial fishermen (Cone, 1991), it is unclear what the negotiators will be able to do in 3 months that they have not been able to do in the last 3 decades.

A brief reference to adaptive management in a draft version of the document resulting from the Salmon Summit negotiations indicates the two general perspectives present among the negotiators. The first group believes that, given the present state of the resource and the relative uncertainty regarding the impacts of various measures, there should be an immediate commitment to begin implementation of all long- and short-term measures to resolve the problem of declining salmon runs. Should future evaluation indicate that the results of short- and near-term actions are sufficient to meet the target improvements, then it may be possible to discontinue implementation of certain long-term provisions. This was dubbed the "off-ramp approach" (draft Salmon Summit document).

Conversely, the second group believes that short- and near-term measures will be sufficient to achieve the necessary targets for rehabilitating the resource. They suggest that more aggressive, long-term measures are not likely to be required, and

should future evaluation indicate that they are needed, they can be added to the management package at a later date. This was dubbed the "on-ramp approach" (draft Salmon Summit document).

Either one of these management techniques will require agreement on the targets to be achieved and the means by which to determine when and if the target has been reached. Implicitly, the choice is complicated by the projected time-frames for receiving sufficient feedback on the results of actions to enable future choices to be made. The real danger is twofold. On the one hand, institutional impatience may preclude designing effective experiments with appropriate time spans necessary to learn from resources that may take decades to respond to a particular management action. On the other hand, there is a real danger that, as one key negotiator said, it will always be "too soon to tell." As one senator noted, "We've studied more things so many times that it becomes a way of not doing things."

VII. INERTIA VS. INNOVATION: THE CASE OF THE DVORAK SIMPLIFIED KEYBOARD

It is evident that managing natural resources is a very complicated task. Clearly, the uncertainties inherent in natural resource management remain formidable. However, the real question one might ask, is "if one truly knew all the answers (i.e., if the science was able to reduce the uncertainties), would this information in fact be used?" The potential obstacles to acting on purely scientific information is illustrated by the case of the Dvorak Simplified Keyboard as described by Frost and Egri (1991).

Through the use of scientific time and motion studies, Dr. Dvorak developed a new keyboard configuration that would enable typists to work faster and more accurately (50% fewer mistakes) and with 35 to 100% gains in productivity and a 33% reduction in the time it takes to learn the QWERTY keyboard. Despite the fact that the Dvorak Simplifed Keyboard is demonstrably superior to the keyboards now in use (QWERTY), it has failed to be implemented since its introduction in 1932. They conclude from this and other accounts of innovation that it is not safe to assume that the best or superior inventions, innovations will survive on their own merits. "The reasons why a superior technological innovation has not gained acceptance or widespread implementation are often not grounded in rational scientific logic but rather in the political battles of a solitary inventor against vested interest with a **stake in maintaining the status quo**" (Frost and Egri, 1991; emphasis added).

In their extensive review of organizational power and politics, Frost and Egri (1991) noted that Deetz (1985) identified four ways in which humans systematically distort reality for their own benefit. In brief they are to quote:

1. **Naturalization**: Existing forms and privileges are treated by an interest group (for their own benefit) as inviolate and therefore not subject to discussion, debate, or change.
2. **Neutralization**: The particular value base of a set of positions and activities that favors one interest group over another is denied. Such positions are treated as value free, or as the only ones that exist. They become a matter of fact, not of choice.

3. **Legitimization**: Higher order explanatory devices, such as sacrifice, loyalty, one's country, religion, etc., are invoked to justify and sustain the self-interests of an elite in the system. Allusions to such higher levels serve to maintain the compliance of lower power players while cloaking the real motivation and goals of the powerful [e.g., whistleblowers or boat-rockers are established as illegitimate to the decision-making process].

4. **Socialization**: Actions, systems, and processes that serve to direct and shape the behaviors, attitudes, values, and interpretive schemes of some players to the benefit of others... . Those in positions of power have access to a diverse array of normative, reward, and structural mechanisms to guide the individual learning of what they deem to be appropriate (and inappropriate) values, beliefs, and behaviors.

These political strategies are often used as defensive measures to preserve the prevailing distribution of power and, in particular, may be used when a proposed innovation threatens the status quo. Thus, in the face of political games of neutralization, naturalization, legitimization, and socialization, reasoning and rational logic become secondary tools of influence (Frost and Egri, 1991).

It is clear that in both the TFW case and the Canadian case, deliberately setting out to learn from experience threatens to change the existing management structure. Again, this is an uncomfortable position in a management structure in which it is "safe" to manage for the status quo, and where drastically changing the management regime is admitting failure to a previous management regime. The adaptive approach recognizes that learning can only proceed by the identification of error (Baskerville, 1985) yet this open acknowledgment of uncertainty is heretical at best in traditional management political regimes. "Learning is not an easy process, but without learning it is impossible for management to close on a goal... . Adaptive management is not easy because it requires...explicit recognition of error. It is therefore not yet common in resource management" (Baskerville, 1985).

VIII. STATING OBJECTIVES EXPLICITLY AND IMPLICITLY

One of the reasons that learning is not an easy process in traditional resource management regimes is because management rarely proceeds in accordance with simple objectives (Walters, 1986). Often, in cases where the objectives are explicitly stated, they are stated in such a generalized manner that it becomes impossible to measure if one is meeting the objective or not. It is necessary to have specific performance measurements if management is not to be reduced to a trivial academic discussion (Baskerville, 1985).

Along with the need to define clear objectives, there is a need to develop specific decision criteria in order to evaluate different policy options. This is where the feedback loop between technical information and the management process becomes critical. Feedback can be defined as either single- or double-loop learning (Argyris and Schon, 1978). In single-loop learning, existing goals are evaluated, whereas double-loop learning results in changes to existing norms, policies, and objectives.

Development of decision criteria is essential because trade-offs need to be made inasmuch as it is rarely possible to simultaneously maximize multiple objectives. The development of decision criteria can be used not only to measure whether one is meeting objectives, but also whether or not the goals are truly compatible. The compatibility of goals becomes particularly important in management regimes that purport to manage simultaneously for multiple resources. This is exemplified by the TFW agreement whose goals are to simultaneously protect wildlife, fish, water quality, archaeological and cultural resources, and the timber industry. The goals as stated in the TFW agreement are in part as follows:

> **Wildlife**: "to provide the greatest diversity of habitats (particularly riparian, wetlands and old growth), and to assure the greatest diversity of species within those habitats for the survival and reproduction of enough individuals to maintain the native wildlife of Washington forest lands."
>
> **Fish**: "long-term habitat productivity for natural and wild fish, and the protection of hatchery water supplies."
>
> **Water**: "protection of water needs of people, fish and wildlife."
>
> **Archaeological and cultural**: "to develop a process to inventory archaeological cultural spaces in managed forests; and to inventory, evaluate, preserve and protect traditional cultural and archaeological spaces and assure tribal access."
>
> **Timber**: "continued growth and development of the State's forest products industry which has a vital stake in the long-term productivity of both the public and private forest land base" (TFW, 1987: 2–3).

In stating these objectives, there is an implicit assumption that the goals in the agreement are in fact compatible (Halbert, 1989; Halbert and Lee, 1990). Although the purpose here is not to debate that issue, the assumption is problematic and raises serious questions as to the institutional process that this agreement has set up in order to meet those goals.

Although the goals of the TFW agreement are noteworthy and ambitious, they are stated in such a way as to prevent adequate assessment of whether they are being met and if indeed they are compatible with one another. The criteria by which compatibility should be judged have not been developed. What is "greatest diversity of habitat?" How should one define "long-term productivity" and "protection of water needs for people, fish, and wildlife?" What about "continued growth and development of the State's forest products industry?" Are these objectives to be measured and, if so, against what baseline? In this case, the issue that remains to be resolved is how to manage the state's forest in order to maintain the consensus set out in the TFW Agreement.

The only resource for which there exists a clear objective in the TFW agreement is the timber resource because it can be measured in economic terms. The lack of equally measurable economic criteria for the other resources (e.g., wildlife, cultural values) illustrates the challenges of attempting to manage multiple resources in a world that traditionally favors economic priorities to nonmarket or nonconsumptive uses. Furthermore, it is uncertain whether or not adaptive management, which has

previously only been implemented in single resource management regimes (mostly fish), is an effective tool in the management of multiple resource regimes. As one Weyerhaeuser manager (K. Sullivan, personal communication) noted: "I think that adaptive management in TFW for multiple resource management in general is a very uneasy alliance. I believe in fact, that there are formidable obstacles to practicing and implementing adaptive management because of the lack of explicit goals and lack of change in implicit behavior." Without clearly stated objectives, it is impossible to tell exactly how much conflict there really is in managing simultaneously for multiple resources. It is necessary to build objectives that are at least in essence compatible, otherwise, "we're going to end up fighting between, instead of balancing them [objectives]" (K. Sullivan, personal communication).

As implied in the above quote, along with stating explicit objectives, it is necessary to look at **implicit** objectives. "For every one that's said, there's a whole lot that's not said. And that's one of the first things I learned about TFW, nobody said what they really wanted. Really, very few people said what they really wanted" (K. Sullivan, personal communication). Since implicit objectives by definition go unstated, it will always be impossible to tell whether or not they are incompatible with the stated objectives. It is, however, necessary to be aware that implicit objectives have the potential to be at odds with explicit management goals and thus may influence their success. The danger is that if unstated, implicit objectives are incompatible with the stated, explicit objectives, adaptive management may be used as a delay tactic to temporally stop fighting rather than as a tool for the effective management of natural resources.

IX. REDEFINING SUCCESS

Adaptive management in essence requires a redefinition of success because, by definition, it is a management technique that is to be used to evaluate why projects (and/or policies) worked or fell short of expectations. Rather than treating mistakes and failures as useful adaptive experiments, we tend to bury our mistakes rather than learning from them (Walters and Hilborn, 1978). Planning for failure however is a politically hazardous endeavor. As Lee and Lawrence (1986) note "Even to admit uncertainty can be a sign of weakness in the highly combative environment in which fisheries [or forestry] management has been conducted. Correspondingly, those who provide funds want to support projects that succeed — even when measures of success are chosen shortsightedly."

Generally, learning from failure is neither politically nor scientifically acceptable. This is exacerbated by the fact that continuing legislative support often demands that the program demonstrate concrete, short-term results. This poses problems in a regime that requires failure to be an acceptable part of the learning process.

X. SUCCESSFUL ADAPTIVE MANAGEMENT

Trying to find examples in which adaptive management has been implemented successfully in **multiple** resource management regimes has proven elusive. The following example illustrates a case from a different arena in which adaptive

management was successfully implemented in order to demonstrate that the concept of adaptive management can, in fact, be used to learn from management experience.

In the Minneapolis Spouse Assault Experiment (Garner and Visher, 1988), which was conducted between 1981 and 1982, officers responding to a domestic violence call responded in one of three ways: (1) on the spot advice to the suspect, (2) separation of the couple for at least 8 h, or (3) immediate arrest. Responses were assigned randomly to the police officer by the operator. The rate of recidivism after a 6-month follow-up was used to measure which policy was most effective (response 3 had the lowest recidivism rate). The success of that policy experiment illustrates the value of experimentation to reduce uncertainties in a management context. In particular, implementing the management program itself as an experiment, and using the resulting information to modify program procedures in order to meet program objectives, is illustrative of a true adaptive management experience.

XI. CONCLUSION

The effective implementation of adaptive management to manage multiple resource regimes remains elusive. Adaptive management has been subject to a wide array of interpretations that may preclude its effective utilization in natural resource management regimes that are governed by multiple players, various agency mandates, and potentially incompatible objectives. Ultimately, adaptive management may be best suited to problems less complicated than those addressed by either the Timber, Fish, and Wildlife agreement or the Northwest Power Planning Act. Although formal adoption and institutionalization of adaptive management is critical, it is however insufficient to ensure successful implementation.

The inherent nature of adaptive management requires management to take risk-prone action while providing institutional patience and stability. Furthermore, information must be collected and analyzed over time frames that often exceed the typical tenure of politicians. Even when risk-prone action is accepted, other barriers to the successful acceptance of superior innovations may arise, particularly if the innovation threatens the existence of the status quo.

Multiple resource management regimes present unique challenges to the implementation of adaptive management. If adaptive management is to succeed, it must be predicated on clearly established goals and decision criteria that will allow for accountability and evaluation of how goals are being met. This is particularly important in agreements predicated on consensus. Furthermore, the goals must be compatible with natural processes, existing (or achievable) technology, and social norms (Oliver et al., 1992).

Although adaptive management has different requirements depending on the regime in which it is being implemented, the single most important requirement necessary for its effective use is an agreed-upon definition of what the term means and an explicit commitment to implement it as defined. Without an agreed-upon definition and commitment, the resulting understanding will continue to be fragmented and is unlikely to contribute to a comprehensive understanding on a system-wide scale, such as is demanded by adaptive management.

The difficulties of implementing adaptive management from a sociological and institutional perspective are large. In essence, adaptive management requires the

redefinition of success by managers and politicians in which learning from error becomes an acceptable part of the learning process. If we are to move toward successfully resolving natural resource management conflicts, then scientists, managers, and decision makers alike will need to more fully embrace the fundamental concepts of adaptive management, that is, (1) provide effective links between science and management, and (2) implement management recommendations and policies as an experiment. This is necessary if we are to truly "learn" from experience.

ACKNOWLEDGMENTS

This work was supported in part by the Washington Sea Grant Program (NOAA Grant NA89AA-D-SG022), and the United States Forest Service (Mt. Baker-Snoqualmie National Forest and Pacific Northwest Forestry Sciences Laboratories, PNW 90-349). I thank Pete Bisson, Beth Hormess, Murdoch K. McAllister, Randall M. Peterman, and Carl Waters for their helpful comments on the manuscript.

The author would like to extend her gratitude to the numerous TFW participants who engaged in extensive, structured, ethnographic interviews between November 1988 and May 1989.

REFERENCES

Argyris, C. and D. A. Schon. *Organizational Learning: A Theory of Action Perspective*. Reading, MA: Addison-Wesley Press (1978).

Baskerville, B. Adaptive management: wood availability and habitat availability. *For. Chron.*, April (1985).

Brown, J. State-Tribal relations and natural resources. Washington State after the Boldt Decision. Environmental Studies Department, Evergreen State College, Olympia, WA. unpublished (1989).

Cone, J. Squaring off at the Salmon Summit: an interview with Bill Bakke. *Pac. Fishing*, March (1991).

Currie, J. An analysis of program integration and development for the Timber-Fish-Wildlife Report. Cooperative Monitoring, Evaluation and Research Committee (1989).

Deetz, S. Critical-culture research: new sensibilities and old realities. *J. Manage.*, 11(2):121–136 (1985); as cited by Frost, P. J. and C. P. Egri (1991).

Eberhardt, L. L. and J. M. Thomas. Designing environmental field studies. *Ecol. Monogr.*, 61(1):53–73 (1991).

Fluharty, D. and K. N. Lee. Neither wilderness nor factory: learning from natural resource management. *Proc. 1st Annu. Meet. on Puget Sound Res.*, 1:256–265 (1988).

Fraidenburg, M. The new politics of natural resources: negotiating a shift toward privatization of natural resource policymaking in Wasington State. *Northwest Environ. J.*, 5:211–240 (1989).

Frost, P. J. and C. P. Egri. The political process of innovation. In: *Research in Organizational Behavior*. Vol. 13. pp. 229–295 (Cummings, L. L. and B. M. Staw, Eds.). Greenwich, CT: Jai Press, Inc. (1991).

Garner, J. H. and C. A. Visher. Policy experiments come of age. *Natl. Inst. Justice Rep.*, 211: September/October (1988).

Halbert, C. L. Implementing adaptive management: a conversation with Kai N. Lee. *Northwest Environ. J.*, 7:136–150 (1991).

Halbert, C. L. and K. N. Lee. The Timber, Fish and Wildlife Agreement: implementing alternative dispute resolution in Washington State. *Northwest Environ. J.*, 6:139–175 (1990).

Halbert, C. L. The Timber, Fish and Wildlife Agreement: An Analysis in Alternative Dispute Resolution. Masters of Marine Affairs thesis, Institute for Marine Studies (now School of Marine Affairs), University of Washington, Seattle, WA (1989).

Hilborn, R., C. S. Holling, and C. J. Walters. Managing the Unknown: Approaches to Ecological Policy Design. In: *Biological Evaluation of Environmental Impacts*. pp. 103–113. FWS OBS-80/26. Washington, D.C.: Council on Environmental Quality and Fish and Wildlife Service, U.S. Department of the Interior (1979).

Hilborn, R. and J. Sibert. Adaptive management of developing fisheries. *Mar. Policy*, April (1988).

Holling, C. S., Ed. *Adaptive Environmental Assessment and Management*. New York: John Wiley & Son (1978).

Hourcade, J. C., J. M. Salles, and D. Thery. Ecological economics and scientific controversies: lessons from some recent policy making in the EEC. *Ecol. Econ.*, 6:211–233 (1992).

Lee, K. N. and J. Lawrence. Adaptive management: learning from the Columbia River Basin Fish and Wildlife Program. *Environ. Law*, 16:431 (1986).

Leaman, B. M. and R. D. Stanley. Experimental management programs for two rockfish stocks off British Columbia, Canada. In: *Risk Assessment and Biological Reference Points for Fisheries Management*. Can. Spec. Publ. Fish. Aquat. Sci. 20: (in press).

Lindblom, C. E. The science of muddling through. *Public Admin. Rev.*, 19:79–88 (1959).

Mayar, D. Point of view: Kai Lee. *Northwest Energy News*. October, (1990).

McAllister, M. K. and R. M. Peterman. Experimental design in the management of fisheries: a review. *North Am. J. Fish. Manage.*, 12:1–18 (1992).

Northwest Renewable Resources Center (NRRC). Timber/Fish/Wildlife: A Report from the Northwest Renewable Resources Center, 710 Second Avenue, Seattle, WA (1985).

Oliver, C. D., D. R. Berg, D. R. Larsen, and K. L. O'Hara. Integrating management tools, ecological knowledge, and silviculture. In: *Watershed Management*. pp. 361–382 (R. Naiman, Ed.). New York: Springer-Verlag (1992).

Sainsbury, K. J. Application of an experimental approach to management of a tropical multispecies fishery with highly uncertain dynamics. *ICES Mar. Sci. Symp.*, 193:301–320 (1991).

Sainsbury, K. J. The ecological basis of multispecies fisheries and management of a demersal fishery in tropical Australia. In: *Fish Population Dynamics* (2nd ed.). pp. 349–382 (J. A. Gulland, Ed.). New York: John Wiley & Sons (1988).

Salwasser, H., C. K. Hamilton, W. B. Krohn, J. F. Lipscomb, and C. H. Thomas. Monitoring wildlife and fish: mandates and their implications. *Trans. North Am. Wildl. Nat. Resour. Conf.*, 48:297–307 (1983).

Taylor, S. *Making Bureaucracies Think: The Environmental Impact Statement Strategy of Administrative Reform*. Stanford, CA: Stanford University Press (1984).

Timber, Fish and Wildlife (TFW) Final Agreement. February 17, Department of Natural Resources, Olympia, WA (1987).

Timber, Fish and Wildlife (TFW) Cooperative Monitoring, Evaluation and Research Committee (CMER), Timber - Fish - Wildlife Project: Research and Monitoring Program Workplan (1988).

Timber, Fish and Wildlife (TFW) Cooperative Monitoring Evaluation and Research Committee (CMER) Steering Committee Chairs, Co-chairs Meeting Minutes, 8/31 (1989).

Timber, Fish and Wildlife (TFW) Ambient Monitoring Program Workplan (March). Ambient Monitoring Steering Committee (1989).

Walters, C. J. Nonstationarity of production relationships in exploited populations. *Can. J. Fish. Aquat. Sci.*, 44(Suppl. 2):156–165 (1987).

Walters, C. J. *Adaptive Management of Renewable Resources*. New York: Macmillan (1986).

Walters, C. J. and R. Hilborn. Ecological optimization and adaptive management. *Annu. Rev. Ecol. Syst.*, 9:157–88 (1978).

Walters, C. J. and R. Hilborn. Adaptive control of fishing systems. *J. Fish. Res. Board Can.*, 33:145–159 (1976).

Walters, C. J. and D. Ludwig. Adaptive management of harvest rates in the presence of a risk averse utility function. *Nat. Resour. Modeling*, 1:321–337 (1987).

Washington State Forest Practices Board (WSFPB). Washington Forest Practices: Rules and Regulations, WAC 222 (1988).