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Adaptive Management of Natural Resources: Theory, Concepts, and Management Institutions

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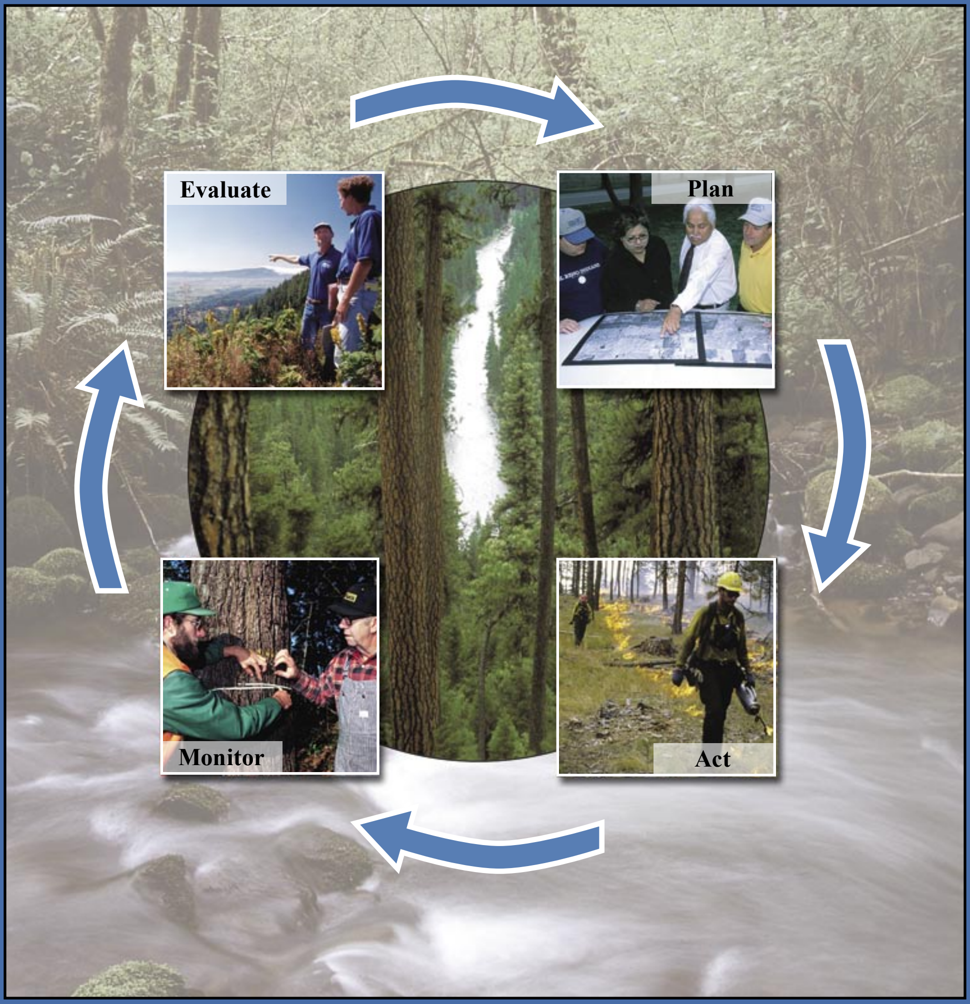

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Abstract

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This report reviews the extensive and growing literature on the concept and application of adaptive management. Adaptive management is a central element of the Northwest Forest Plan and there is a need for an informed understanding of the key theories, concepts, and frameworks upon which it is founded. Literature from a diverse range of fields including social learning, risk and uncertainty, and institutional analysis was reviewed, particularly as it related to application in an adaptive management context. The review identifies opportunities as well as barriers that adaptive management faces. It concludes by describing steps that must be taken to implement adaptive management.

Keywords: Adaptive management, social learning, public policy, research design, risk and uncertainty, natural resource management.

Contents

Introduction

A common feature of contemporary natural resource management issues is the underlying uncertainty regarding both cause (What causal factors account for the problem?) and effect (What will happen if a particular management strategy is employed?). These uncertainties are, in part, a product of the growing emphasis on long-term, multiscale, and integrative aspects of resource management. These involve multiple disciplinary perspectives, multiple jurisdictions and associated management objectives, and a growing concern with cause and effect over large spatial scales and long timeframes.

In the face of such issues, traditional approaches to scientific inquiry increasingly have been found inadequate, particularly with regard to the ability to predict consequences and effects. As many have argued (e.g., Herrick and Sarewitz 2000, Kuhn 1970), the central strategy of mainstream science has been to break phenomena into distinct components (disciplines), remove those components from their larger context, and identify mechanisms or processes to frame specific research questions. Although this paradigm has served science and society well (and will continue to do so), its capacity to contribute effectively to addressing many contemporary environmental problems is problematic.

These limits generally are acknowledged. Calls for ecosystem-based, integrative resource management explicitly or implicitly are grounded in the need for innovative institutional structures and processes (Cortner et al. 1996). Such approaches acknowledge the critical role of ongoing monitoring and evaluation as the basis from which learning would inform subsequent action. The iterative relation between learning and action is a hallmark of social learning planning models (Friedmann 1987).

The concept of adaptive management has gained attention as a means of linking learning with policy and implementation. Although the idea of learning from experience and modifying subsequent behavior in light of that experience has long been reported in the literature, the specific idea of adaptive management as a strategy for natural resource management can be traced to the seminal work of Holling (1978), Walters (1986), and Lee (1993). These scholars have framed and articulated the idea of an approach that treats on-the-ground actions and policies as hypotheses from which learning derives, which, in turn, provides the basis for changes in subsequent actions and policies.

This contemporary concept of adaptive management has been applied across a range of resource sectors (agriculture, water resource management, fisheries, etc.) as well as a variety of sociopolitical contexts (Australia, Canada, Europe, Southeast Asia, South Africa, United States). The potential of adaptive management makes it an attractive strategy in situations where high levels of uncertainty prevail. It was this quality that led to adaptive management becoming a central component of the Forest Ecosystem Management Assessment Team (FEMAT) report (1993) and the subsequent Northwest Forest Plan (hereafter, the Plan) (USDA USDI 1994).

Implementation of the Plan began in 1994. The Plan's goal was to initiate an ecosystem-based management approach across 24 million acres (9.7 million hectares) of federal land in a three-state region in which sharp conflicts over objectives and values existed. These conflicts were exacerbated by high levels of uncertainty. Most existing science had been undertaken at the site or stand level, and its applicability at the watershed and regional level was not well understood. Moreover, the precarious status of endangered species and the diminishing extent of old-growth forests in the region combined to create a situation in which there was great concern—among citizens, managers, policymakers, and scientists—that it was important to be cautious in not aggravating the problem (fig. 1). As a consequence, the Plan placed a heavy emphasis on reserves; about 80 percent of the planning region is in an administrative or statutory reserve. The reserve allocations were augmented by a set of restrictive standards and guidelines (S&Gs) that set performance standards for on-the-ground activities.

A key question regarding the Plan's implementation concerns the extent to which adaptive management has achieved its intended objectives.

The Plan also acknowledged that improving understanding within and among the complex biophysical, social-economic-political systems in the region would require an increased emphasis on new knowledge. As a result, it called for adoption of an adaptive management strategy to gain new understanding. It proposed a four-phase adaptive management cycle (fig. 2). In the first phase, plans are framed, based on existing knowledge, organizational goals, current technology, and existing inventories. In phase two, on-the-ground actions are initiated. Phase three involves monitoring results of those actions and, in phase four, results are evaluated. The cycle could then reinitiate, driven by emerging knowledge and experience. Results could validate existing practices and policies or reveal the need for alterations in the allocations, S&Gs, or both.

To facilitate the adaptive strategy, about 6 percent of the area was allocated to 10 adaptive management areas (AMAs) distributed across the three-state region to represent the diversity of biophysical and socioeconomic conditions (fig. 3). The AMAs provided areas where there would be latitude to experiment with management practices, where the S&Gs could be tested and validated, and where innovative relations between land managers and citizens would be encouraged.

The Plan has been in place for more than a decade. A key question regarding implementation concerns the extent to which adaptive management has achieved its

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Figure 1—In the Northwest Forest Plan, the diminishing extent of old-growth forests in the region has raised concerns whether these forests can be sustained and restored.

intended objectives; has it provided a framework within which key uncertainties contained in the Plan have been critically examined, tested, and, as appropriate, modified? A companion report[1] of this literature review describes this evaluation.

The use of an adaptive management strategy for forest management has been given additional importance by the revised planning rule that guides implementation

[1] Stankey, G.H.; Bormann, B.T.; Ryan, C.; Shindler, B.; Sturtevant, V.; Clark, R.N.; Philpot, C., eds. Learning to manage a complex ecosystem: adaptive management and the Northwest Forest Plan. Draft manuscript on file with G.H. Stankey.

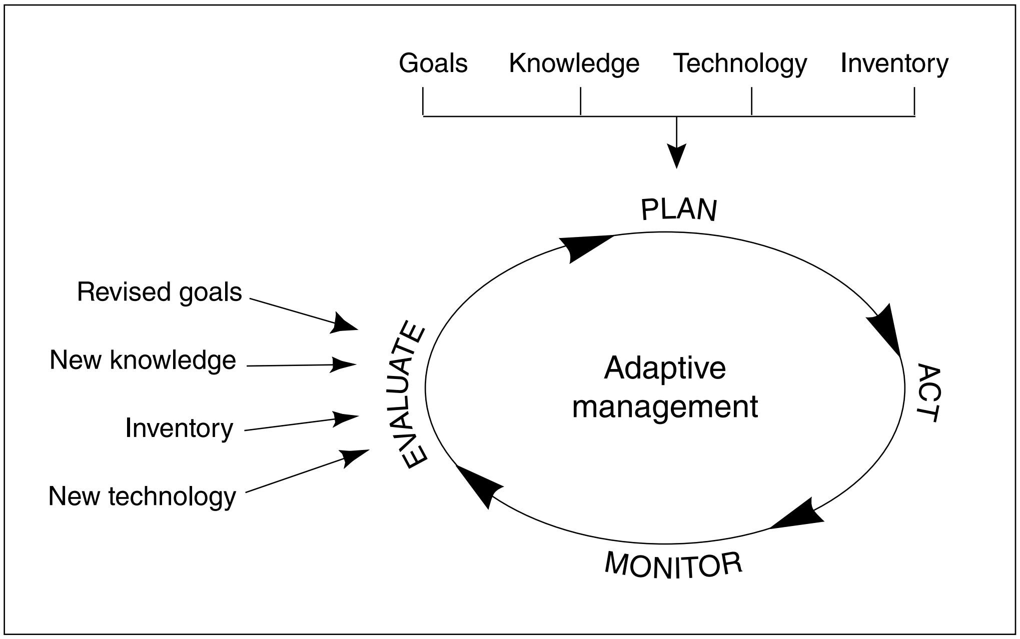

Figure 2—The adaptive management cycle (USDA USDI 1994: E–14).

of the National Forest Management Act (NFMA). The new rule replaces the former chapter dealing with "regional planning," replacing it with "The Adaptive Planning Process" (see Forest Service Handbook 1909_12 chapter 20) and outlining the procedures responsible planning officials are to follow in implementing the new approach.

As suggested above, the adaptive management concept has been pursued in diverse fields, from agriculture, fisheries, and forestry in the natural resource arena to business and education. It incorporates diverse academic perspectives including learning theory, public policy, and experimental science. In some cases, relevant concepts and experiences derive from literature or policy experiments where the explicit notion of adaptive management is either absent or only of tangential interest. In this review, we have attempted to blend the results of substantive and technical analyses and discussions of the key conceptual components of an adaptive approach, with results from various implementation efforts.

The Concept of Adaptive Management

Haber (1964) traced the origins of adaptive management to the ideas of scientific management that took root in the early 1900s. The idea is linked to disciplines outside natural resource management; for example, adaptive management, or closely-related notions, are found in business (total quality management, continuous improvement, and learning organizations [Senge 1990]), experimental science

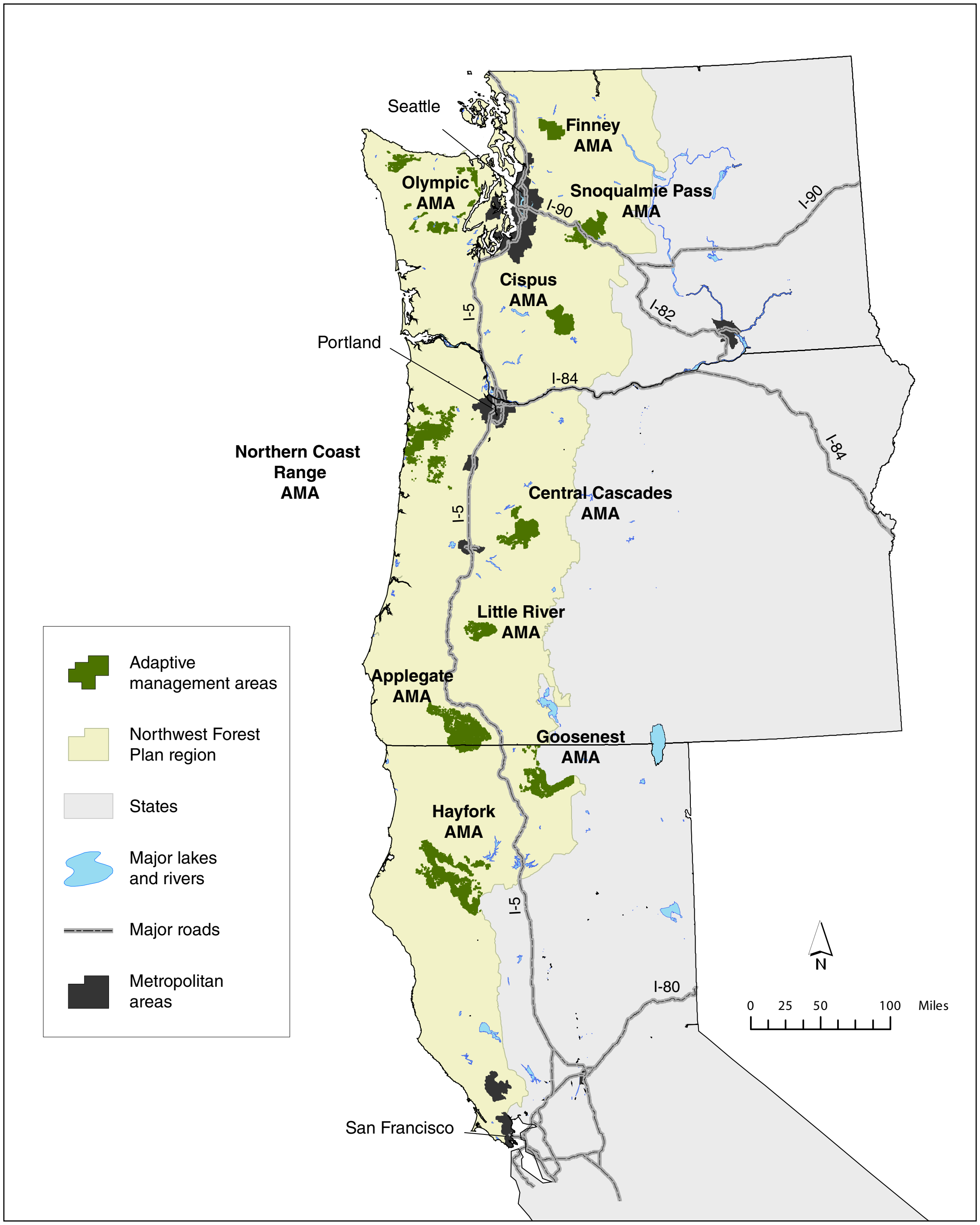

Figure 3—The 10 adaptive management areas in the Northwest Forest Plan provide a diverse range of biophysical, political, and socioeconomic conditions.

(hypothesis testing [Kuhn 1970]), systems theory (feedback control [Ashworth 1982]), industrial ecology (Allenby and Richards 1994), and social learning (Korten and Klauss 1984).

The concept has drawn particular attention in natural resource management (Bormann et al. 1999). In 1978, with publication of Holling's *Adaptive Environmental Assessment and Management*, its potential as a framework for dealing with complex environmental management problems began to be recognized. The subsequent publication of *Adaptive Management of Renewable Resources* (Walters 1986), *Compass and Gyroscope: Integrating Science and Politics for the Environment* (Lee 1993), and *Barriers and Bridges to the Renewal of Ecosystems and Institutions* (Gunderson et al. 1995a) added increasing sophistication and elaboration to the concept and its potential. Key elements of adaptive management were explored in these texts; the importance of design and experimentation, the crucial role of learning from policy experiments, the iterative link between knowledge and action, the integration and legitimacy of knowledge from various sources, and the need for responsive institutions. A growing professional literature, reflecting a diverse body of interest and experience in application of adaptive management, has now developed. For example, in a literature search of the Cambridge Scientific Abstracts and SciSearch for 1997–98, Johnson (1999) found 65 papers that used adaptive management in their title, abstract, or keywords, covering issues from wildlife management, wetland and coastal restoration, and public involvement.

Holling (1995: 8) hypothesized that expanding interest in adaptive management has been driven by three interlocking elements:

> The very success in managing a target variable for sustained production of food or fiber apparently leads inevitably to an ultimate pathology of **less resilient and more vulnerable ecosystems, more rigid and unresponsive management agencies, and more dependent societies.** This seems to define the conditions for gridlock and irretrievable resource collapse [emphasis added].

In confronting these conditions, societies have sought strategies to forestall collapse. McLain and Lee (1996) reported that ethnographic evidence indicates humans long have relied on ad hoc hypothesis testing as a means of learning from surprise and increasing the stock of knowledge on which future decisions to use environmental resources are made. For example, Falanruw (1984) described how the Yap of Micronesia for generations sustained a high population despite resource scarcity by practicing adaptive techniques. Such techniques resulted in the production of termite-resistant wood and the creation and maintenance of coastal mangrove depressions and seagrass meadows to support fishing. The Yap altered their environment by using adaptive management processes; they undertook actions, observed and recorded results through story and songs, and codified practices through rituals and taboos. In short, at one level, the Yap experience embraces the modern concept of adaptive management: "policies are experiments: learn from them" (Lee 1993: 9).

Despite examples of the potential of an adaptive approach, contemporary examples of successful implementation are meager. In many ways, this seems paradoxical. On the one hand, adaptive management offers a compelling framework; i.e., learn from what you do and change practices accordingly. Yet, the literature and experience reveal a consistent conclusion; while adaptive management might be full of promise, generally it has fallen short on delivery. This dilemma is widely recognized (Halbert 1993, McLain and Lee 1996, Roe 1996, Stankey and Shindler 1997, Walters 1997), leading Lee (1999: 1) to conclude "adaptive management has been more influential, so far, as an idea than as a practical means of gaining insight into the behavior of ecosystems utilized and inhabited by humans."

Adaptive management learning derives from deliberate formal processes of inquiry.

In part, the root of the difficulties might lie in the general level of familiarity with the notion of adaptation. As the Yap experience demonstrates, humans have long demonstrated the capacity to adapt to new information and contexts. Environmental stimuli provide feedback that inform us and modify subsequent behavior. Over time, individuals, groups, societies, and cultures learn to respond to changes; i.e, they adapt (or conversely, they don't and eventually inherit the consequences). There are a host of adaptive mechanisms, some more conscious and explicit than others. In sum, however, most people have personal experiences with "learning by doing" and as a behavior, it therefore seems obvious, even unexceptional.

Adaptive management, as discussed in the contemporary literature, stands in contrast to these conventional conceptions. Although it shares the general premise of learning by doing, it adds an explicit, deliberate, and formal dimension to framing questions and problems, undertaking experimentation and testing, critically processing the results, and reassessing the policy context that originally triggered investigation in light of the newly acquired knowledge. Thus, adaptive management in this context involves more than traditional incrementalism; learning derives from purposeful experimentation that, in turn, derives from deliberate, formal processes of inquiry, not unlike scientific study. In this sense, assertions that resource agencies have long been adaptive are less than persuasive.

Carl Walters, a contemporary proponent of experimental adaptive management, offered a pessimistic appraisal of recent progress. He noted "I have participated in 25 planning exercises for adaptive management of riparian and coastal ecosystems over the past 20 years; only seven…have resulted in relatively large-scale management experiments and only two of these experiments would be considered well planned in terms of statistical design" (Walters 1997: 2–3). His critique is grounded, in part, on the question of what constitutes an experiment. As used here, we see it "…loosely as an action whose outcome we cannot predict completely in advance or specific beforehand" (Bernstein and Zalinski 1986: 1024). To Lee (1999), experimentation has three components: (1) a clear hypothesis, (2) a way of controlling factors extraneous to the hypothesis, and (3) an opportunity to replicate the experiment to test reliability. However, the general disappointment about the effectiveness of implementing adaptive management derives from more than a definitional conundrum. There is a growing appreciation of the various cultural, institutional, social-psychological, and political-legal challenges confronting adaptive management (Miller 1999). But despite these challenges, there is a growing body of experience and scholarly commentary reporting alternatives for addressing them.

Key Premises of Adaptive Management

A foundational premise of adaptive management is that knowledge of ecological systems is not only incomplete but elusive (Walters and Holling 1990). Moreover, there is a growing conviction that expanding knowledge through traditional scientific inquiry will always be limited by resources and time. When these limiting factors are linked to the contextual conditions of resource scarcity, potential irreversibility, and growing demands, the need for new ways in which understanding and learning not only occur but directly inform decisionmaking and policy processes becomes apparent (Bormann et al. 1994b). Adaptive management offers both a scientifically sound course that does not make action dependent on extensive studies and a strategy of implementation designed to enhance systematic evaluation of actions (Lee and Lawrence 1986).

As noted earlier, adaptive management has attracted attention for its emphasis on management experiences as a source of learning. This has produced a variety of phrases that emphasize the idea that adaptive management is learning to manage by managing to learn (Bormann et al. 1994a). This idea is not new; in a variation of the phrase, Michael (1973) entitled his book *On Learning to Plan—and Planning to Learn.* Whatever the particular phrase, the central idea is the presence of an iterative process that links knowledge to action (Friedmann 1987) and, conversely, action to knowledge (Lee 1993).

A critic of adaptive management might contend it is little more than a variant of Lindblom's (1959) "disjointed incrementalism" or, as commonly described, "muddling through" model. Natural resource management long has demonstrated an ability to build on previous actions and outcomes; policies are always subject to revision in the light of past performance (Kusel et al. 1996). Some learning occurs irrespective of the particular management approach taken; Gunderson (1999c: 35) commented, "trial-and-error is a default model for learning…people are going to learn and adapt by the simple process of experience." However, what distinguishes adaptive management from Lindblom's incrementalism is its **purposefulness** (Dovers 2003); agreed-upon goals and objectives serve as a basis against which progress can be measured and lessons gained. Adaptive management mimics the scientific method by highlighting uncertainties, specifying and evaluating hypotheses, and structuring actions to test those hypotheses through field application (Gunderson 1999c). In Walters' (1997) terms, adaptive management replaces management learning by ad hoc, trial and error (an incremental, evolutionary process) with learning by careful tests (a process of directed selection).

Use of the scientific method to improve understanding of the effects of natural resource management actions is not without limits and liabilities. Although adaptive management "rests on a judgment that a scientific way of asking questions produces reliable answers at lowest cost and most rapidly, this may not be the case very often" (Lee 1999: 4) and might even be the opposite; i.e., slow and costly. Although Walters (1997: 10) agreed that environmental management changes needed to resolve key uncertainties might prove unacceptably costly, he argued "most debates about cost and risk have not been…well founded, and appear instead to be mainly excuses for delay in decision making." It must also be recognized that the capacity of adaptive management to resolve value-based conflicts (e.g., forest management to meet economic as opposed to environmental objectives) might prove no more effective than traditional planning approaches.

There are many definitions of adaptive management (Bormann et al. 1999, Halbert 1993). As Failing et al. (2004) have observed, this widespread use of the term has propagated various interpretations of its meaning and, as a result, there are only vague notions about what it is, what is required for it to be successful, or how it might be applied. Not surprisingly, given recent attention by the scientific community, many definitions frame the discussion around a structured process that facilitates learning by doing; i.e., "adaptive management does not postpone action until 'enough' is known, but acknowledges that time and resources are too short to defer *some* action" (Lee 1999: 5). Holling (1978) and Walters (1986) specified two major components to the adaptive management process:

1. An effort to integrate existing interdisciplinary experience and scientific information into dynamic models to frame predictions about the impacts of alternative policies; this step performs three key functions:

- Problem clarification and enhanced communication among scientists, managers, and other stakeholders.
- Policy screening to eliminate options unlikely of doing much good because of inadequate scale or type of impacts.
- Identification of key knowledge gaps that make predictions suspect.

2. Design of a specific management experiment.

Failure to focus on problem definition can lead to inappropriate attention to symptoms and solutions.

A third component to be added to this list links the results of a management experiment with the policymaking process; i.e., in light of the actions taken in an experimental setting, how do those results translate into changes in ongoing land management practices. In many ways, this third component is where the idea of "adaptive" comes into play, based on feedback from the results of experimentation.

These components contain important implications. Step 1 emphasizes the importance of problem framing, i.e., getting the question(s) right (Bardwell 1991, Miller 1999). This is a crucial phase; as Walters (1986: 9) noted, in system analysis terms, "bounding the problem" is where "most resource policy analyses go astray." For example, Smith et al. (1998) described how conflicts over appropriate management strategies for salmon in the Pacific Northwest are confounded by differing assessments regarding the underlying causes of the salmon's decline. Managers emphasize habitat loss, commercial fishers point to predators, and others identify water pollution. Failure to focus on problem definition can lead to inappropriate attention to symptoms and solutions (Van Cleve et al. 2003). Framing effective strategies in the face of such differences is also challenging because it is ultimately a social undertaking, involving a variety of perspectives and experiences; it must transcend its limitations as a technical-scientific endeavor. For example, Butler et al. (2001) argued that it is important that resource users (e.g., fishers) understand the benefits and costs associated with an adaptive approach. Without such information, adaptive adjustments can become nothing more than "tinkering in pursuit of fruitless equilibrium" (p. 797). Finally, the problem-framing phase needs to encourage a deliberate and informed "working through" process (Yankelovich 1991) in which options and their costs and efficacy are identified, debated, and evaluated. It can best achieve this through a process of informing all concerned of the inevitable risks and uncertainties involved. This helps focus future inquiry on the most important questions (or to gaps in knowledge that carry the greatest liability for the resource and stakeholders).

Two further comments on this process can be made. First, although step 1 refers to model development, it is the modeling **process** that is particularly important as it is the means through which the three principal functions of step 1 are achieved.

Whether a specific model emerges from this or not is not necessary; the modeling process helps facilitate learning, which in turn, informs future decisions. McLain and Lee (1996) noted that evidence from case studies in British Columbia and the Columbia River basin supports the idea that models can be useful for enhancing information flow by stimulating discussion among stakeholders about values, goals, objectives, and management options.

Second, this learning process is information-intensive and requires active, ongoing participation from "those most likely to be affected by the policies being implemented" (Lee 1999: 7). This emphasizes the social and political aspect of adaptive management. Lee (1993: 161) noted "Managing large ecosystems should rely not merely on science, but on *civic* science; it should be irreducibly public in the way responsibilities are exercised, intrinsically technical, and open to learning from errors and profiting from successes." Civic science, he argues, is a political activity; "Ecosystem-scale science requires political support to be done…Learning in such a setting cannot take place without active political support; there are too many ways for things to go wrong without it" (Lee 1993: 165). This view was reiterated in FEMAT: "People will not support what they do not understand and cannot understand that in which they are not involved" (FEMAT 1993: VII–113). It is this political element of adaptive management that provides Lee's "gyroscope" (i.e., "the pragmatic application of politics") to the companion notion of the "compass" of science (i.e., "the idealistic application of science to policy") (Lee 1993: 10–11).

Alternative Models of Adaptive Management

Walters and Holling (1990) suggested three ways in which adaptive processes could be structured. First, there is an evolutionary or trial-and-error model[2] (Holling 1978; Kusel et al. [1996] used the term **incremental adaptive management** and Hilborn [1992] referred to it as a **reactive** approach). Under such approaches, the results of external decisions and choices are used to frame subsequent decisions that, we hope, lead to improved results. In many ways, this form of adaptive management is reminiscent of muddling through, in which some learning inevitably results from whatever management experience is undertaken. There is no purposeful direction to it and one simply reaps whatever benefits derive from earlier experiences.

Second, there is the concept of passive adaptive management; Bormann et al. (1999) used the term **sequential learning**. In it, historical data are used to frame a single best approach along a linear path assumed to be correct (i.e., there is a belief

[2] "Models," as used in this report, include a variety of depictions intended to simplify complexity.

that the underlying assumptions and antecedent conditions that were applicable earlier still prevail). This model applies a formal, rigorous, albeit post facto analysis to secondary data and experiences as a means of framing new choices, understanding, or decisions.

Passive adaptive management can be informative. Walters and Holling (1990) reported on work in the Florida Everglades focused on the effects of various interventions in the region's water regime. The work was driven by the single hypothesis that wildlife in the area require a natural pattern of water availability. This led to changes in both the timing and distribution of waterflows, with the intention that the plan would be the first step in a longer, iterative testing process that could lead to shifts in hydrological regimes (fig. 4). This could produce, over time, important benefits for the ecosystem. Nonetheless, Walters and Holling (1990) argued that alternative hypotheses should have been framed; e.g., what were the effects of natural changes in nesting habitat outside the area? Such alternatives could have led to different analyses and, potentially, to new management strategies.

Two fundamental problems limit passive adaptive approaches. First, such approaches can confound management and environmental effects because it is often unclear whether observed changes are due to the way the land was treated or to changes in environmental factors (e.g., global warming). Second, such analyses

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Figure 4—The timing and distribution of waterflows in Florida's Everglades is the focus of an adaptive management study designed to protect the region's ecosystem.

can fail to detect opportunities for improving system performance when the "right" model and the "wrong" model predict the same results and the system is managed as though the wrong model were correct.

Adaptive management is a sociopolitical action as well as a technical-scientific undertaking.

Active adaptive management is a third model. It differs from other versions in its purposeful integration of experimentation into policy and management design and implementation (Kusel et al. 1996). In other words, policies and management activities are treated as experiments and opportunities for learning (Lee 1993). Active adaptive management is *designed* to provide data and feedback on the relative efficacy of alternative models and policies, rather than focusing on the search for the single best predictor. Bormann et al. (1999) referred to active approaches as examples of **parallel learning** because they involve the design of suites of policies that can be directly and simultaneously compared and evaluated.

Adaptive management is inevitably a sociopolitical action as well as a technical-scientific undertaking. Kusel et al. (1996) addressed the social dimension in terms of the relationships among scientists, resource managers, and the public. They argued that adaptive processes, as opposed to traditional resource management approaches, are "fundamentally about changing the relationships between these three groups" (Kusel et al. 1996: 612–613). **Participation-limited adaptive management** focuses on the interface of scientists and managers. Here, citizens stand apart from the dialogue and interaction between scientists and managers and are connected only via traditional public information venues, such as public meetings. This model is consistent with the historical reliance on the expert-driven, command/control approach that characterized social reform planning during much of this century. In contrast, **integrated adaptive management** can dramatically change the relationships among participants, with the public engaging as peers and partners with their manager and scientist colleagues to build active working relationships among themselves (Buck et al. 2001). Such relationships are central to the ideas of social learning.

In summary, the literature reports a variety of ways to undertake adaptive management, although there are no standard templates to guide decisions about what is best. The focus on formal learning, however, coupled with creation of forums that facilitate improved problem identification and framing; mutual, ongoing learning; and informed debate about alternatives, options, and consequences are central elements that an adaptive approach seeks to foster.

But the question of how to structure and design an adaptive management process is only one challenge confronting resource managers. Next, we turn to a variety of issues, challenges, and problems identified in the literature; each of these must also be addressed effectively if adaptive approaches are to be effective.

Learning: A Driver and Product of Adaptive Management

The concept of learning is central to adaptive management and is grounded in recognition that learning derives from action and, in turn, informs subsequent action. Lee (1999) argued that the goal of implementing management experiments in an adaptive context is to learn **something**; he also argued that surprise is an inevitable consequence of experimentation and that it is often a source of insight and learning. Yet, such observations beg the question as to what learning is. What is implied when we say we have learned? Does any change in the phenomena being studied represent learning or only certain changes? Is learning measured at the individual level, at some small collective (e.g., a planning team), or at a larger, organizational level? A related question concerns the idea of organizational learning. Is it simply the sum of individual learning within the organization, or does collective learning take on an emergent quality (i.e., properties that can be attributed to a system as a whole, but not to any individual components [Clayton and Radcliffe 1996]) that exceeds the sum of that held by individuals within the organization? What distinguishes change based on learning from other change (Parson and Clark 1995)? Further, how do we best organize to learn? Michael (1995: 484) contended "there are two kinds of learning: one for a stable world and one for a world of uncertainty and change." In a world of rapid change and high uncertainty, acquiring more facts—data—might not be as important as improving the capacity to learn how to learn, or what Ackoff (1996) has described as deutero-learning. In other words, what might have once facilitated learning might no longer do so.

Four commonalities emerge from the learning literature. First, learning is initiated when some dilemma or tension appears regarding a problem. For example, previously held assumptions might prove unfounded or dysfunctional and there is a need to learn how to proceed (Mezirow 1995). Or, new problems emerge for which little is known. In either case, the discrepancy between what is known and what is needed creates tensions that can only be resolved through learning. Of course, learning itself can be anxiety-producing (Michael 1995), so the need for and benefits of learning must outweigh the anxiety produced during the learning process.

Second, much learning derives from experience and, in particular, from experiences in which mistakes were made. Mistakes or what operations research would call "negative feedback" have the potential to be powerful sources of insight. Dryzek (1987: 47) described it as a "highly desirable quality." Such feedback and the learning it can produce, is a central premise of adaptive management (Lee 1993). However, as we shall discuss in more detail later, risk-aversion at both the individual and institutional levels can combine to hamper such learning. A management culture that ignores or even punishes failures and mistakes can seriously retard the learning process.

Third, learning almost always involves change. This begins by acknowledging a dilemma, discussed above, that initiates learning behavior. The subsequent learning must then be transferred into the organizational system in such a way that future behavior (policies, programs) reflects the new information. Also, because an organization is imbedded in a wider biophysical and socioeconomic environment, where change is ongoing, it must also be open to continuous learning that permits it to operate effectively as that wider environment changes. Again, this is the fundamental premise of the adaptive management process. However, individual and institutional behavior is often biased toward maintenance of the status quo, and such continuous change can be difficult and anxiety-producing (Parson and Clark 1995). As Dovers and Mobbs (1997) concluded, adaptive, learning institutions do not always survive.

Learning manifests itself in distinctive forms, including data, information, knowledge, understanding, and wisdom.

Fourth, learning involves what is referred to as reframing. Reframing is the process of reinterpreting the world in light of alternative perspectives and values. In simple terms, it involves seeing problems in a different way. Because reframing can lead to critiques of current policies, processes, or structures, it can be psychologically uncomfortable and resisted by others. Nonetheless, the reframing process is an essential component of a learning organization and can be facilitated by purposefully incorporating diverse perspectives on planning teams (Yorks and Marsick 2000).

Learning manifests itself in distinctive forms, including data, information, knowledge, understanding, and wisdom (Ackoff 1996). **Data** are simply "1s and 0s" stored in a spread sheet. They reflect and describe actual observations. **Information** includes data, but provides details regarding who, what, when, and where. **Knowledge** concerns questions relative to "how to" and offers insight as to how a system might be managed. **Understanding** clarifies questions related to cause and effect; here, we begin to understand why systems act and respond as they do. Finally, **wisdom**, as Ackoff (1996: 16) suggested "is the ability to perceive and evaluate the long-run consequences of behavior." Adaptive management, in a contemporary sense, is particularly concerned with advancing learning at the knowledge, understanding, and wisdom levels.

What Is Learning?

Opinion is divided on the question of what it means to learn. The debate turns on whether the appropriate indicators of learning involve a change in cognition (a change in knowledge), a change in behavior (observable changes in organizational practices and policies), or both (Tsang 1997). Given an emphasis in the adaptive management literature on the role of action informed by knowledge, it seems that appropriate indicators of learning necessarily involve both cognition and behavior. Knowledge that lacks a link to action would seem to constitute little more than facts on the shelf; conversely, action that lacks a base in improved knowledge is little more than hopeful activity. Thus, learning would seem to require both a cognitive dimension as well as an observable behavioral manifestation grounded in improved knowledge. It is also clear that significant barriers grounded in organizational processes, belief systems, or other factors act to stymie the acquisition of improved knowledge or its implementation into action. Inkpen and Crossan (1995) drew attention to how organizational norms and sanctions can operate to stymie learning or thwart behavioral change, effectively maintaining the status quo.

Learning encompasses knowledge acquisition; to say we have learned implies that we know more than previously (which might include that we now know how little we knew). Michael (1995) argued that learning implies more than increasing the stock of facts: it suggests we know what needs to be done, how to do it, whether it worked, and how to apply learning to emerging consequences. In other words, learning is not an end in itself, but a means to informing subsequent action. He also argued that learning involves what "must be unlearned" (p. 461). We all have certain trained incapacities, and learning must acknowledge and accommodate these. However, to do so can evoke feelings of psychological discomfort, denial, anger, and fear (Miller 1999). Michael (1995: 468) added "…most people under most circumstances are not all that eager to learn…most…are content with believing and doing things as they have always been done" and individuals (including scientists) are rewarded for maintaining and sustaining certain beliefs and behaviors because these are "the way things are and should be."

The literature identifies a number of factors that facilitate or constrain the learning process. Various categories can be defined: structural/organizational (e.g., laws, policies, organizational structure), sociocultural (e.g., values and beliefs), emotional (e.g., concerns with risk and failure), and cognitive (e.g., whether additional information leads to learning or simply overload).

The literature also discusses the concept of learning styles. People learn in different ways. For example, learning differs in terms of **perception** (the way in which information is taken in) as well as in the way we **order** that information (the way we use the information we perceive). There are differential capacities in dealing with information in a concrete versus abstract or conceptual manner. And, there are a variety of ways in which people best organize the information around them: as facts, as principles, in terms of relevance, or in terms of underlying reasons.

Learning occurs through various means. A classroom teacher, for example, facilitates the learning process for his or her students. In terms of new knowledge (i.e., learning) about the world, Lee (1999) and Marcot (1998) suggested that experimentation is not the only way to learn, or even the most obvious way. Table 1 depicts different learning modes.

The processes through which learning occurs change as people age. This has led to a significant literature of adult learning theories. As with many of the literatures we examine in this review, this is a large, diverse area. However, for our purposes, this literature suggests that a key feature of the learning process for adults is that learning occurs not so much through incremental accumulation of understanding (e.g., more facts), but via "leaps" of understanding when existing information is examined in a new light. In particular, this process is triggered by a critical reexamination or reframing of an individual's past experiences and underlying beliefs and assumptions about the world. This critical assessment, in turn, leads to a reassessment of previous understanding and, more importantly, to a realization that new options and alternatives exist and that previous presumed constraints and bounds on one's thinking no longer prevail. Reflection is a key element of this process because it offers people an opportunity to determine whether previous assumptions still are relevant and applicable to the decisions that face them (Mezirow 1995). These views of learning are especially important in an adaptive context, given that one's assumptions are open to critical review by other parties in the problem-framing stage and previous experiences, subject to new perspectives and insight, can provide opportunities for identifying plausible hypotheses (policies) for critical examination in the field.

Perhaps the most controversial issue with regard to the notion of learning and the processes and structures that facilitate it links to two related questions: is learning a technical or social process (or both) and, as noted earlier, is organizational learning simply the sum of individual learning within that structure or is it an emergent product that is more than the sum of the learning of individuals within the organization?

Is Learning the Result of Technical Processes, Social Processes, or Both?

Advocates of learning as a technical process argue that it primarily involves processing information. For example, Argyris and Schön (1978: 2) took the position that learning "involves the detection and correction of error." In this view,

Table 1—Modes of learning

Each mode of learning	makes observations…	and combines them…	to inform activities…	that accumulate into usable knowledge.	Example
Laboratory experimentation	Controlled observation to infer cause	Replicated to assure reliable knowledge	Enabling prediction, design, control	**Theory** (it works, but range of applicability may be narrow)	Molecular biology and biotechnology
Adaptive management (quasi-experiments in the field	Systematic monitoring to detect surprise	Integrated assessment to build system knowledge	Informing model-building to structure debate	**Strong inference** (but learning may not produce timely prediction or control)	Green Revolution agriculture
Trial and error	Problem-oriented observation	Extended to analogous instances	To solve or mitigate particular problems	**Empirical knowledge** (it works but may be inconsistent and surprising)	Learning by doing in mass production
Unmonitored experience	Casual observation	Applied anecdotally	To identify plausible solutions to intractable problems	**Models of reality** (test is political, not practical, feasibility)	Most statutory policies

Source: Lee 1999: 3.

management organizations, such as the Bureau of Land Management, constitute social technologies designed to perform a specific set of tasks; i.e., they represent a working model of a theory for solving a particular and specific set of problems. To the extent that this system works well, it reflects the notion of **single-loop learning** (Argyris and Schön 1978). Single-loop learning occurs when individuals perceive a mismatch between their intentions (i.e., what they wanted to have happen) and actual events (i.e., what actually takes place) and then take steps to correct that action. Such a process is driven by existing assumptions about how a system works and that the organization has the capacity to detect error or problems and solve them.

However, new problems often emerge or are reconfigured in ways that are neither recognized nor soluble by the theory embodied in the current organizational structure. For example, the FEMAT (1993) social assessment chapter addressed the changing nature of the demands, uses, and values associated with forests in the

Pacific Northwest and the increasing inability of current organizations and policies to deal with those changes. To overcome these types of problems requires rethinking the fundamental purposes, rules of operation, and assumptions on which an organization is founded so that it has the capacity to more accurately diagnose the problems of theory driving the search for answers to practical problems. This involves a capacity for critical self-examination; it requires what Argyris and Schön defined as **double-loop learning**. Such learning addresses basic questions of why problems occurred in the first place, whether the management solution is correct, and if not, how to make corrections (British Columbia Ministry of Forests 2000). Through hypothesis testing and theories about how the world works, and the comparison of the results of these tests against experience, the potential for informed, grounded revision is enhanced. But, as Argyris and Schön (1978) warned, organizations often inhibit this type of learning because it requires critical assessment of current organizational assumptions, beliefs, and norms.

The concept of double-loop learning has important implications for adaptive management. First, it reemphasizes the importance of sound problem-framing processes (Bardwell 1991). The way in which questions and problems are framed directly affects the way in which solutions are defined and pursued. Second, as noted above, redefining the questions and problems confronting an organization can be a painful process; it often reveals liabilities and shortcomings in organizational culture and structure that, if left untended, leave that organization at risk. For example, in the case of the conflicts between environmentalists and timber interests in the Pacific Northwest during the 1990s, reliance on technical assessments and studies—key elements of contemporary resource management culture—has done little to resolve the crippling debate; "the failure of technical studies to assist in the resolution of environmental controversies is part of a larger pattern of failures of discourse in problems that put major societal values at stake. Discussions of goals, of visions of the future, are enormously inhibited" (Socolow 1976: 2). Under these conditions, any management approach, including adaptive management, that fails to embrace the social and value-based dimensions of a problem as well as technical dimensions, will be limited in its ability to foster resolution.

An alternative conception of learning focuses on learning as the product of social processes. Here, learning results from participation and interactions with others in social life (Easterby-Smith and Araujo 1999). The distinguishing feature of this conception is that learning is a process of social construction; i.e., people "construct" reality in ways meaningful to them. From this perspective, scientific data do not hold objective, unequivocal meaning, but are given meaning and interpretation by people. Thus, in natural resource management, problems characterized by complexity and uncertainty also will be characterized by varying interpretations and, by inference, different solutions.

Within natural resource organizations, knowledge is continually constructed and reconstructed as different people interact with one another and as new information becomes available. Thus, a social constructivist perspective also focuses attention on the ways in which institutional structures and processes can facilitate, enhance, or constrain the construction and dissemination of learning. Thus, the notion of "learning to learn," an idea promoted by Ackoff (1996) in the theoretical literature, as well as in the Northwest Forest Plan, becomes an important feature.

Clearly, the emphasis in adaptive management on learning, although important, also introduces an extraordinarily complex arena. At the core of this is the reality that learning needs to derive from **both** technical and social processes. For instance, we might hypothesize that the lack of learning is attributable to the lack of data and the associated knowledge. In other cases, the lack of learning derives not from the lack of information, but the manner in which it is presented (abstract vs. concrete), the social processes and structures (or lack thereof) to facilitate communication and discussion among organizational members, or because of its presentation as a set of principles as opposed to its potential relevance to a particular problem. In any case, the information is effectively inaccessible and learning fails to occur.

Organizational Learning or Learning Organizations?

A second, correlate question regarding learning concerns the relationship between individual learning and a more collective form of learning that ascribes to the organization.

Two predominant arguments are found in the literature: (1) organizations do not learn; what is called "organizational learning" is simply the sum of individual learning, and (2) organizations as a system can learn, with that learning reflecting an emergent quality that exceeds the sum of individual learning.

Proponents of the first argument argue that "organizational learning" only occurs when individual learning becomes institutionalized into organizational norms and memory (Watkins 1996). Organizational learning, in this schema, becomes successful when structures exist to encourage individual learning and there are processes for transferring and codifying that learning into the organization.

The alternative view contends that organizational learning surpasses the sum of individual members. For example, Yorks and Marsick (2000: 253) argued that "groups can learn as discrete entities in a way that transcends individual learning within the group." This perspective views organizations as systems that have the capacity to produce learning characterized by an emergent quality; i.e., the collective learning is more than the sum of individual learning. As suggested earlier, the notion of emergent properties derives from systems thinking; from this perspective, individual learning becomes a necessary, but not sufficient, condition for organizational learning. It further contends that "new" learning emerges through the interaction of organizational members who collectively create new knowledge not attributable to any one individual. It thus also becomes closely linked to the idea of learning as the product of social processes.

Although knowledge is clearly linked to the learning process, it is also an issue in and of itself and there is a significant literature surrounding it. Knowledge is defined in a variety of ways; e.g., Webster's dictionary defines it as "the sum of what is known…the body of facts accumulated…in the course of time." But a common view of the concept of knowledge is that it reveals the way in which we know the world.

The concept of adaptive management implies the **production** of knowledge (through policy and management actions); it also implies that such knowledge is **transmitted or distributed** among various interests (scientists, managers, and citizens) and that it is **used**. In our assessment of adaptive management, the issue of knowledge is critical. In terms of knowledge production, questions arise as to where knowledge is created and by whom. In the positivist model that underlies modern scientific inquiry, research scientists are seen as the principal knowledge producers. The formal knowledge that emerges from scientific inquiry is a powerful form of knowing; done properly, it is characterized by being replicable and reliable. Scientific inquiry attempts to analyze the world through formal concepts and theories, involving the systematic dissection of problems into smaller components (reductionism) and isolating and controlling external factors (Holzner and Marx 1979, Kloppenburg 1991). There is also a presumption that scientific inquiry is independent of social context; i.e., it is value-free and not subject to social influence (Gurvitch 1971). The value of such inquiry and knowledge is deeply imbedded in modern resource management philosophy and institutions; it is a fundamental element of the social-reform movement in planning (Friedmann 1987) and the foundation of modern forest management.

There is growing recognition of the importance of alternative forms of knowledge or knowing. Known variously as "personal," "local," "experiential," or "indigenous" knowledge, this form of knowing emerges from experience gained through living, working, and playing in the world. Buttolph and Doak (2000) argued that such knowledge, rather than being less valid or legitimate, highlights other ways of seeing and knowing (fig. 5). Yet, such knowledge often is trivialized, marginalized, or rejected in modern planning processes. Kloppenburg (1991: 529) suggested that

Gary Wilson, USDA Natural Resources Conservation Service.

Figure 5—There are many ways of "knowing" the world around us. Knowledge grounded in technical understanding and the personal or experiential knowledge gained from living and working in a place are both needed.

Citizens and managers are seen not only as the source of values and objectives... but also the source of improved understanding and knowledge.

scientific knowledge has come to hold "undisputed intellectual hegemony" with local knowledge relegated to the "epistemic peripheries." Thus, the core precept of social reform planning—that science serves society—is predicated on the caveats that (1) only a certain form of knowledge (formal science), controlled by a certain group of people (scientists), is admitted to the decisionmaking arena and (2) science possesses accurate insight as to society's needs.

Yet, there is also growing recognition of the limits of formal, scientific knowledge in resolving the complex issues confronting society. Often, such knowledge is inadequate for the kinds of analyses required and for the development of functional predictions and useful management strategies (Friedmann 1987). Herrick and Sarewitz (2000) argued further that high levels of scientific complexity mean that predictive scientific assessments inherently are limited in their ability to guide policy development. They contend that a more appropriate and useful role for such assessments would be in conducting **ex post** evaluations, a role consistent with adaptive approaches that seek insight through critical analyses of policy implementation results.

Recognizing the limits of formal knowledge is critical to fashioning programs of knowledge creation, distribution, and utilization in an adaptive management model. In this model, citizens and managers are seen not only as the source of values and objectives or as reviewers and reactors to proposals, but also the source of improved understanding and knowledge about the complex systems with which we are concerned. If barriers to the recognition, acceptance, and legitimization of alternative forms of knowledge exist—cognitive, structural, or procedural—the adaptive process will be adversely affected.

Finally, the literature highlights the importance of two forms of knowledge; **explicit** knowledge (so-called articulated or substantive knowledge, composed of facts, data, etc. and recorded in books, reports, etc.) and **tacit** knowledge (the intuition, perspectives, beliefs, and values created as a result of experience). As Saint-Onge (1996) noted, tacit knowledge forms a "mental grid" within which explicit knowledge is filtered and interpreted. "[T]acit knowledge is made up of the collective mindsets of everyone in the organization. Out of its experience, the organization assumes a unique set of beliefs and assumptions through which it collectively filters and interprets how it sees the world and reacts to it" (Saint-Onge 1996: 10). Thus, tacit knowledge becomes a critical factor in shaping the paradigm underlying how some group (e.g., resource managers) establishes professional standards, behavioral norms, and conceptual approaches to problem-solving (Kuhn 1970, Wondolleck 1988). In short, it can be a powerful, formative, and enduring type of knowledge.

Assessing knowledge, from whatever source, and using it to build understanding, framing such understanding into questions and hypotheses, formulating options and alternatives, and testing, monitoring, and validating the outcomes of these alternatives requires explicit design (Haney and Power 1996). The issue of adequate design permeates the adaptive management literature; in essence, it addresses a straightforward question: How and when do we know we have learned something? Does the action taken lead to the results observed, or were results due to other, perhaps unknown, factors or chance (Bednar and Shainsky 1996)? Real learning is dependent on a capacity to discern the answer to such questions. This challenge explains why the protocols, methods, and philosophy of science have attracted attention in the adaptive management literature, for it represents a method of inquiry grounded on establishing cause-and-effect relationships. As Lee (1999: 4) noted, "in principle, the scientific approach leads to reliable determination of causes; in practice, that means being able to learn over time how management does and does not affect outcomes…an experimental approach may be costly and onerous in the near term, but it is probably the only way to root out *superstitious* learning—erroneous connections between cause and effect."

Adequate research design to facilitate sound learning in adaptive management experiments often is lacking (Walters 1997). In part, this derives from a persistent lack of formal and systematic documentation. Lee (1993) pointed to the critical need for an intellectual paper trail that provides an explicit record of the chain of reasoning underlying any action. Lacking such documentation, it is difficult if not impossible to later review assumptions, data, methods, analytical treatments and so on to help understand why differences between outcomes and predictions occurred.

In northeast Victoria, Australia, Allan and Curtis (2003) reported on a project designed to use an adaptive approach to developing alternative options for the management of salinity. The implementation of on-the-ground works, such as tree planting, became the highest priority, but program administrators failed to recognize that such plantings could be viewed as experimental treatments. Coupled with a lack of formal monitoring, the sum effect has been that it has proven difficult to assess the efficacy of different salinity management options and an opportunity to learn more systematically from implementation has been lost.

Walters (1997) identified design of management experiments as the second key step in the adaptive management process. He concluded, with some notable exceptions, that literature reporting well-designed field applications of adaptive management is sparse. In particular, few efforts included either adequate controls or designs for replication. He also was critical of efforts that have not progressed beyond continued investments in baseline information gathering and in complex simulation modeling. He concluded "what probably drives these investments is the presumption that sound predictions (and, hence, good baseline policies) can somehow be found by looking more precisely, in more mechanistic detail, at more variables and factors" (Walters 1997: 3).

Walters' comments suggest limits to the benefits derived from more data or better models. In discussing adaptive management planning models for riparian and coastal ecosystem situations, he described some of the complex technical issues that need to be accommodated in experimental design. One example involves problems that derive from cross-scale linkages between physical/chemical and ecological processes. Hydrodynamic and chemical processes that operate on short time scales and fine spatial scales must interact with ecological processes in the marine and estuarine setting that operate over long periods and broad spatial scales. To resolve the burdensome computational process, the various subcomponent models are sometimes decoupled, but the process of disconnecting inextricably connected systems leads to problematic outcomes. He concluded "we must rely on empirical experience, not modeling or physical principles, to tell us how much averaging and selecting we can safely do" (Walters 1997: 5).

Lee (1993) identified three circumstances that reinforce the need to consider large-scale experimentation. First, large-scale ecosystems manifest emergent properties that do not occur or cannot be detected at smaller scales; salmon abundance in the Columbia River system is different from that in any stream within the larger system. Second, some effects are too small to observe at the laboratory scale; e.g., the introduction of a new chemical as a constituent of an agricultural fertilizer might not result in the immediate death of fish when lab tested, but when released in a larger, more complex system, could lead to adverse effects. In the absence of explicitly designed controls, these effects might go undetected until it is too late. Third, ecosystem-level interventions might already be underway in the form of existing policy decisions, or decisionmakers might be unwilling (or unable) to postpone action until more is known. Such events provide opportunities for large-scale experimentation, as long as it is recognized that the outcomes of the experiments are poorly understood and the potential for significant adverse impacts (e.g., extirpation) exists.

Lee (1999) argued that explicit, well-designed experimentation also helps address what he describes as two social misdirections of learning. First, the concept of the "regression to the mean" needs to be kept in mind. Many environmental issues with which we struggle today initially attracted attention because of their extreme condition (e.g., declining fisheries), but in a dynamic world, extreme events often are followed by less-extreme ones; "there is a regression to the mean, not because something has been remedied but simply because the mix of fluctuating causal factors has changed…[producing]…fertile ground for erroneous conclusions" (e.g., because we presume some intervention either caused or resolved the problem, when in fact, it was driven by external conditions or cycles) (Lee 1999: 4).

Second, he elaborated on the idea of superstitious learning, the illusion that something has been learned when "evaluations of success are insensitive to the actions taken" (Levitt and March 1988: 326). Explanations for why something worked or failed often are incorrect; we simply might not understand why things worked as they did, and the relation to any particular intervention or event is only coincidental. Lee concluded that when "resource managers are held to standards that have no grounding in ecological science, the more likely it is that accountability itself will induce superstitious learning" (1999: 5).

Lee (1993: 74) concluded "for some policy questions, statistical concepts promote understanding of the nature of the policy judgments required." His argument derives from the idea that although technical and statistical analyses are necessary, their presence is not sufficient to fully inform policymakers of the effects of their actions. He elaborated on this in a discussion of the distinction between the statistical concepts of type I and type II errors. A type I error occurs when what one believes to be true actually is false. This is a fundamental precept on which Western law is founded. As a society, we accept that it is better to occasionally let a guilty party go free than it is to punish an innocent person. Science is also a field in which avoidance of type I errors is part of the culture; we tend to be conservative in accepting something as true. In the case of environmental management, we impose high standards of proof because we are reluctant to accept something as true (e.g., the minimum acceptable level of water quality for salmon survival), because if we later find this to be false, we might have already imposed irreversible impacts on the species.

Type II errors occur when something is rejected that later turns out to be true. For example, a scientific panel convened in New Brunswick, Canada, sought to determine whether the use of pesticides to control a spruce budworm epidemic was implicated in the deaths of children from a disease called Reye's syndrome. Central to their deliberations was the question of what constituted scientific proof of harm. The provincial government took the view that only **incontrovertible** scientific proof of harm would lead them to change their spraying policy (Miller 1993). A survey in the province identified over 3,000 cases of illness with symptoms similar to Reye's syndrome (at the time, Reye's syndrome was not a reportable illness in the province and most physicians were unfamiliar with it). A subsequent screening, focused on identifying the specific disease, reduced this to about a dozen, excluding from consideration the possibility that pesticides might have been a factor in the etiology of some, or all, of the excluded cases. A scientific panel reviewing the data concluded no incontrovertible scientific proof existed to establish a causal link between spraying and the disease. Their conclusion reveals the difficulty in determining the etiology of a rare disease; it provided little in terms of understanding the effects of spraying on more common viral diseases plaguing the community. By focusing on a narrow hypothesis (Reye's syndrome), the "panel appears to have a committed a type 2 error by accepting false negative findings…"; the analytical methods chosen to conduct the study provided an "opportunity to look for clearly defined needles in a poorly documented haystack" (Miller 1993: 567). Reliance on a narrow, analytically confined problem definition served to obscure the real problem, providing instead a dubious scientific basis for sustaining the status quo policy position.

What are the implications for adaptive management? It reveals the kind of tension that exists in many natural resource management debates today, including those between forest management and endangered species management. On the one hand, the role of regulatory agencies, such as the Fish and Wildlife Service, is to avoid type I error; i.e., they want to avoid approving an action, taken to be sound (true) based on the best science, that later proves to be unsound (false). For example, a proposal to test an alternative silvicultural technique in riparian zones might be supported by considerable evidence and theory showing it would have beneficial effects on stream conditions. However, a strong predisposition to avoid type I errors would deny such a proposal on the grounds that implementation of the experimental treatment might endanger salmon. On the other hand, denying the experiment might engender a type II error, given that the experiment might prove more beneficial to salmon than the current prescription. Moreover, denial limits opportunities for learning in the face of uncertainty (Wildavsky 1988). Nonetheless, there remain concerns about the social and environmental costs of allowing type II errors to occur, and the argument is made that a shifting burden of proof calls for an unequivocal demonstration that no adverse consequences will eventuate from some policy (M'Gonigle et al. 1994). The resulting tension between these perspectives creates a "Catch-22" dilemma: permission to experiment is denied until such time as clear, rigorous, and unequivocal scientific evidence is available, but permission to undertake the work that might produce such evidence also is denied. This dilemma leads to a discussion of risk and uncertainty.

Risk and Uncertainty

The concepts of risk and uncertainty are inextricably linked to adaptive management. In the most basic terms, if there were no risk or uncertainty, there would be no need for adaptive management. It is only when we are faced with uncertainty as to what is the most appropriate course of action that the concept of adaptive management becomes a strategy that offers a means of acting. Although the terms of risk and uncertainty often are used interchangeably, they are not synonyms. Risk is typically defined as the possibility that an undesirable state of reality might occur as a result of natural events or human activities (Renn 1992). Risk definitions typically involve a known probability distribution; e.g., we know there are only 5 chances out of 100 that a particular catastrophic event will occur in the next 100 years.

Risk is...a social construct. ...Uncertainty involves situations in which the probability distribution is not known.

Risk is increasingly recognized as a social construct, holding different meanings for different people. Risk analysis and assessment involve efforts to estimate both the probabilities of occurrence and the severity or seriousness of such occurrences, along with the distribution of those effects. Risk assessment, then, becomes more than a technical endeavor, involving social judgments of importance of varying events along with equity issues related to the distribution of costs and benefits (Mazaika et al. 1995). The challenge is all the more formidable because many of the consequences with which we are concerned are not only unanticipated, they cannot be anticipated (Schwarz and Thompson 1990).

Uncertainty is a more complex issue. Typically, uncertainty involves situations in which the probability distribution is not known. One major concern is when risk and uncertainty are treated as synonyms; e.g., treating a situation as one involving risk when, in reality, it is a situation of uncertainty. Walters (1986) suggested three types of uncertainty: (1) that which arises from exogenous (i.e., external) disturbances; (2) uncertainty about the values of various functional responses (e.g., how production rates of a species vary according to size of the stock); and (3) uncertainty about system structure, or more basically, what are the variables one should consider.

In some situations, uncertainty is assumed away; e.g., former Secretary of the Interior Bruce Babbit's promise of "no surprises" in the implementation of new policies for management of endangered species (Reichhardt 1997). Another response is to replace the uncertainty of the resource issue (e.g., Is the species threatened?) with the certainty of a process, be it a new policy or new institution. Gunderson (1999b) described the 9-year adaptive management experiment in the Florida Everglades where the uncertainty of chronic resource issues (e.g., water levels and distribution) has been replaced by the certainty of a planning process and formalization of interactions between management agencies and stakeholders. These processes are not without benefit—they have helped spawn ideas for future action—but whether they also produce learning or reduce risk remains unknown. To protect certain species in the Pacific Northwest, guidelines were instituted calling for surveys before ground-disturbing effects take place, extensive regional surveys within specified timeframes, and the development of management plans for these species (Nelson 1999). However, the survey and manage requirement also has stifled experimental management and research policies that could provide understanding needed to ensure species survival.

Bioregional assessments, such as FEMAT, have been driven by growing unease regarding the risks and uncertainties (regarding both biophysical and socioeconomic systems) facing society. FEMAT (1993) concluded that the levels of risk and uncertainty facing policymakers are greater than acknowledged (they are also why an adaptive approach was seen as essential). Accounting for risk is an essential part of such assessments because of the stochastic nature of processes that characterize ecological and socioeconomic systems. The risks associated with predicting outcomes can be offset to some degree by explicit portrayal and discussion of the underlying cause-and-effect relationships and working assumptions about those relationships (Thomas 1999: 19).

Uncertainties are inevitable, which is why surprise (Gunderson 1999c, Lee 1993) must be formally incorporated into the adaptive management process. Lee (1995) identified two critical elements confronting society's efforts to achieve sustainability: biological uncertainty and institutional complexity (which we turn to shortly). He argues that in moving the "unsustainable vitality of industrialism to a sustainable order, learning from experience is the only practical approach" (p. 228). He noted the difficulties facing those who seek guidance for what to do; namely, data are sparse, theory is limited, and surprise is unexceptional. Wilson (2002) argued that removing uncertainty from public discussion can retard learning by engendering the belief that adequate knowledge exists (e.g., Gunderson's [1999b] "spurious certitude"). If the pretense of surety dominates policy discussions (Dovers and Mobbs 1997), science can be discredited when events lead to contrary outcomes, thus diminishing the ability to manage sustainably. Uncertainties play a key role in the adaptive management process; highlighting them helps frame hypotheses and initiate actions to test them (Gunderson 1999c). If results confirm the hypotheses, then actions and policies can be adjusted accordingly. If we fail to confirm the hypotheses, nonetheless we have acquired useful information that can inform revised hypotheses, which can be subsequently tested.

However, this process, however logical and straightforward, depends on two key conditions; there must be both permission **and** a willingness to experiment. This means explicitly confronting uncertainty and risk. Unfortunately, uncertainty is not always acknowledged. "Judged from a traditional point of view, uncertainty and the lack of predictive capabilities equal ignorance" (Pahl-Wostl 1995, cited in Wilson 2002: 332). If acknowledging and operating under uncertainty are deemed unacceptable—within the organizational culture, through external sanctions such as statutes, or because of public scrutiny and intervention—then adaptive management is not possible. In other words, if action in the face of uncertainty must be accompanied by an assurance that nothing will go wrong, then we have a recipe for inaction. As Wildavsky (1988) argued, requiring that no action be undertaken without a prior guarantee of no risk is a restrictive decision criterion. Volkman and McConnaha (1993) contended that invocation of the Endangered Species Act in the Columbia River basin effectively has halted any attempt at active adaptive management experimentation, in large part because of the uncertainties of experiments on fish. A consequence of such a stance is "no new trials, no new errors—but also no new experience and hence no new learning" (Wildavsky 1988: 31). Unfortunately, as Huber (1983) has remarked "Statutes almost never explicitly address the lost opportunity costs of screening out a product" (cited in Wildavsky 1988: 35). In other words, the costs of lost learning are seldom accounted for when experimentation is restricted or prohibited.

Resistance to experimentation can also derive from those who perceive adverse impacts on their interests. For example, Johnson and Williams (1999) described how the short-term risks to harvest levels (fish, wildlife) associated with experimentation can mobilize opposition to adaptive approaches. Implementation of a regulatory experiment can mean that traditional harvest objectives are replaced with learning objectives, with a result that hunters or fishers bear the costs of the experimentation in the form of reduced take levels.

Lang (1990) offered an alternative typology of uncertainty:

1. Uncertainty concerning the specific problem and its context. This leads to conflicts over what data are needed, what new research should be undertaken, how forecasts might be improved, and how strategies such as risk assessment might better inform discussions.
2. Uncertainty about how to address the problem, with respect to both ends and means. This means that clear policy guidance is required, but it also implies a thorough assessment about what the problem is before the search for solutions begins (Bardwell 1991, FEMAT 1993).
3. Uncertainty concerning what others might do about the problem. This means that dealing with uncertainty must also embrace processes of collaboration and coordination.

These different forms of uncertainty are interrelated. For example, to act without clearly understanding what the problem is likely will result in a failure to reduce uncertainty. To act in an absence of understanding what others are doing risks inefficiency, duplication, and the possibility of working at cross purposes. Such concerns underlie the social, political, and collaborative nature of the challenges facing adaptive management (Buck et al. 2001, Lee 1993).

Dealing with risk and uncertainty are major challenges to adaptive management. Despite the difficulty of operating under such conditions, principles to guide organizational behavior do exist. Ludwig et al. (1993: 36) suggested such principles are "common sense"; e.g., consider a variety of hypotheses and strategies; favor actions that are robust to uncertainty, informative, and reversible; monitor; etc. However, effective and informed operation in the face of uncertainty is confounded when institutions responsible for adaptive management implementation are, at their core, risk averse; the term is not used in a pejorative sense, but simply means that organizational behavior emphasizes the prevention of harm (Wildavsky 1988).

Estill (1999: 20) (emphasis added) argued that "one of the **primary** roles of Forest Service managers in American society is to guard against risk…protecting against risk is one of the few principles managers can use to identify appropriate points of balance and compromise in gut-wrenching situations." Her comments are not without merit, but they imply an organizational capacity for control that is neither possible nor realistic. "The primary expectation of adaptive management is the unexpected…systems are unpredictable" (Gunderson et al. 1995b: 490). It hints at the kind of spurious certitude to which Gunderson (1999b) referred and ignores how embracing risk (and uncertainty) is requisite to learning and discovery (Michael 1995).

Institutional Structures and Processes for Adaptive Management

Holling hypothesized that success in managing a target variable for some commodity output leads inevitably to "an ultimate pathology of less resilient and more vulnerable ecosystems, more rigid and unresponsive management agencies, and more dependent societies" (1995: 8). Our attention now turns to the issue of institutions—including those "rigid and unresponsive management agencies"—but also the array of laws, policies, and other rules by which we live. Why have institutions, designed to better serve our needs and wants, become barriers to the very goals to which we aspire?

Institutions generally are taken to include the array of mechanisms society employs to achieve desired ends (Cortner et al. 1996). Scholars (e.g., Ostrom 1986) have described institutions as sets of rules, as standards of behavior, or as political structure, yet there is little agreement of what the term means or how to undertake studies of them. Some argue that institutions also include norms and values and their interaction with the rules and behaviors (McCay 2002). Institutions are both formal and informal and profoundly affect how society defines problems of significance and organizes itself to formulate responses to those problems.

Wilson (2002) offered insight into this question and although his focus was on marine management, his conclusions seem applicable in other resource contexts. He contended that the scientific uncertainty associated with managing complex systems has created a more difficult conservation problem than necessary because current governing institutions assume more control over natural processes than in fact is possible. He concluded that managing complex, uncertain systems that manifest highly adaptive qualities requires that the governing institutions also be adaptive and learning-driven.

In a critique of efforts to implement adaptive management policies in riparian and coastal ecosystems, Walters (1997: 3) identified four reasons for the low success rates observed. "All," he noted, "in some sense, are **institutional** reasons" (emphasis added): (1) modeling for adaptive management planning has been supplanted by ongoing modeling exercises, (2) effective adaptive management experiments are seen as excessively expensive or ecologically risky, (3) there is often strong opposition to experimental policies by people protecting self-interests in the bureaucracies, and (4) there are value conflicts within the community of ecological and environmental interests.

Gunderson concurred, noting how a "rigidity or lack of flexibility in management institutions and extant political power relationships has precluded adaptive experiments" (1999c: 35), even in situations, such as the Everglades, where the ecological system had sufficient resiliency to accommodate such experimentation. Lee (1993) devoted attention to the need for improved institutional structures and processes to facilitate the practice and exercise of civic science. In his assessment, the challenges of overcoming "inappropriate social organization" (p. 153) loom as a major barrier to the successful implementation of adaptive management. Organizations and policies often are entrenched (e.g., Western water law) in the pursuit of some particular goal, yet institutions find learning leads to a change in goals, which in turn trigger changes in order, structure, power, and other institutional currencies. Such changes produce ambiguity and stress, and a common response is to resist the changes that produce those effects. Lee (1999: 7) observed that "adaptive management is an unorthodox approach for people who think of management in terms of command."

In a review of six case studies from North America and Europe, Gunderson et al. (1995b: 495) reported that one of the major insights revealed during their analyses was the "extreme nature of the recalcitrance or inertia of institutions, and the almost pathological inability to renew or restructure." They concluded that the extent and depth of the resulting institutional rigidity has led to a failure to effectively engage and resolve underlying resource conflicts. Based on a study of adaptive management efforts in New Brunswick, British Columbia, and the Columbia River Basin, McLain and Lee (1996) concluded that efforts fell short of the promise of adaptive management because of an over-reliance on rational-comprehensive planning models, a tendency to discount nonscientific (i.e., personal or experiential) knowledge, and a failure to create processes and structures to facilitate shared understandings among stakeholders.

Scholars generally are in accord as to the central role of institutions in implementing adaptive approaches. Indeed, Gunderson (1999a: 54) argued that if there is any hope for the future of natural resource management, it must be founded on "developing and creating new ways to think about and manage issues of the environment…it is time to rethink the paradigms or foundations of resource management institutions." Yet, McLain and Lee (1996: 446) observed "the adaptive management literature pays little attention to the question of what types of institutional structures and processes are required for the approach to work on a large-scale basis." Lee (1995: 230) also acknowledged the institutional challenge; "…it is not clear how the adaptive approach can work in the presence of institutional complexity."

Yet the reality is that we do have institutions in place—management agencies, laws, policies, standards and guides, norms and belief systems—and we need to consider how the adaptive management concept, with all its compelling appeal and logic, can be made to work. In particular, we face the challenge of framing innovative and effective alternatives to structures and processes that have long been in place and that have a long history of successful implementation. This results in a "if it ain't broke, why fix it?" mentality. Wilson (2002: 332) described the dilemma facing management institutions in framing innovative models for the future:

> We can create institutions nicely tailored to a particular scientific theory and preconception of the nature of the uncertainty (we believe) we face, or we can design institutions on an alternative basis, one that assumes as little as possible about the nature of causal relationships and emphasizes the role of collective learning and institutional evolution. The appropriateness of one or the other approach would appear to depend on the state of our scientific knowledge or, alternatively, our ability to test and validate.

McLain and Lee (1996) argued that the rationale for adaptive learning in management systems rests on three key elements: (1) rapid knowledge acquisition; (2) effective information flow; and (3) processes for creating shared understandings. These constitute a useful framework within which to examine some of the literature relative to the institutional challenges of implementing adaptive management.

Reliance on models results in a tendency to frame problems as technical when often they involve value-based issues.

Increasing Knowledge Acquisition

The concept of scientific adaptive management rests on the notion that the formal methods of scientific inquiry, based on hypothesis testing, represent the most effective and efficient means of acquiring new knowledge. However, evidence from case studies from across North America and around the world question this assumption. A variety of factors contribute to this problematic assessment. As noted earlier (e.g., Walters 1997), heavy reliance on models has contributed to a bias in knowledge acquisition of quantifiable data. This leads to distortion in the problem-framing stage, resulting in a tendency to frame problems as technical in nature when often they involve value-based issues (e.g., what goods and services are desired from the forests of the Pacific Northwest?). Despite the prevailing conception of objective science, many issues confronting resource managers and scientists today are **trans-science**: "Though they are, epistemologically speaking, questions of fact and can be stated in the language of science, they are unanswerable by science; they transcend science" (Weinberg 1962; cited in Lowe 1990: 138). Allen and Gould (1986) arrived at a similar conclusion, describing a set of problems they define as wicked that arise from disputes over questions of importance and preference, rather than technical merit. Genetic or bioengineering and large-scale environmental modifications are examples of such undertakings.

Thus, increasing the rate of knowledge acquisition is confounded by differences in problem perception and the corollary issue of the types of knowledge required in addressing such problems. Challenges also derive from deeply imbedded convictions that scientific knowledge is more valid than other forms of knowing (e.g., personal or experiential knowledge) and that decisions based on scientific knowledge will lead to better decisions (McLain and Lee 1996).

Finally, the literature points to the cost of data acquisition for adaptive management as a major hurdle; the necessary monitoring and evaluation efforts to support adaptive approaches are expensive in both money and time. The risks associated with adaptive experimentation are judged excessively costly. McLain and Lee (1996) noted that the costs of monitoring and evaluation were especially controversial in the New Brunswick spruce budworm experiments because only one stakeholder was responsible for both the action and its evaluation. In the Pacific Northwest, the Northwest Power Planning Council attempted to avoid this by involving a wide range of stakeholders in the monitoring and evaluation process (McLain and Lee 1996). This proved costly, raising questions as to whether it would prove possible to continue to do this into the future. Although Walters (1997) acknowledged that the costs of adaptive experimentation can be great, he contended that costs in the form of risks to resources are even greater. He argued that the debate about costs and risks lacks adequate evaluation and scrutiny, suggesting that cost concerns tend to be used more as an excuse for avoiding contentious decisions.

There is a complex asymmetry in the distribution of the risks and costs of adaptive management. For instance, Walters (1997) noted that the costs of experiments that might benefit fish typically are borne largely by economic interests (agriculture, industry). It has been estimated that losses to commercial and recreational fisheries in British Columbia owing to experimental reduction of hatchery salmon releases could range from $10 to $100 million per year (Perry 1995). Although acknowledging that costs can be substantial for economic interests, Walters (1997) argued that these interests will inevitably face costs associated with change, given the nature of shifting public interests and concerns. He observed (Walters 1997: 11):

> If…there is even a 10% chance that legislative or legal decisions will result in massive and permanent policy change, the expected cost (0.1 x cost of massive change) of trying to maintain current policy would be radically higher than the cost of an experiment to demonstrate that radical change is unnecessary.

The tension between short-term costs and long-term benefits produces a complex situation. Any benefits of treatments undertaken today to manipulate biophysical systems likely will not appear until later; their costs, however, are borne by today's individuals, organizations, and society. There are both financial and risk costs involved. As Walters (1997: 11) noted, the "legacy of response information (i.e., learning) from these treatments will mainly be useful to the next generation of managers and users." The time differential between incursion of costs and receipt of benefits contributes to tensions between managers and scientists, on the one hand, and political and public officials on the other. For example, Lee (1993) described a goal of the Columbia River Basin Fish and Wildlife Program as doubling salmon populations over an unspecified time. This goal implies that salmon restoration must be seen as a long-term undertaking, measured in generations of salmon. These long-term undertakings are being dealt with in a political and budgeting world of 1- to 3-year cycles and the similarly short tenure of members of the Northwest Power Planning Council (McLain and Lee 1996).

The timeframes involved and the asymmetry between costs and benefits also have implications for how experimentation risks are perceived, particularly by resource managers. Volkman and McConnaha (1993: 6) argued that because the benefits of learning about flow-survival relationships on the Columbia River are less clear than the costs posed by dramatic flow manipulations, the concept of adaptive management faces an unusually difficult test in practice; i.e., "how (can) biological risks and political considerations be accommodated while taking an aggressive approach to learning?" Gray (2000), reviewing progress on the North Coast AMA, concluded that managers perceived the "inordinate amount of supporting data, energy, and political support" needed to modify any of the standards and guidelines "not worth their while" (p. 18). At one level of analysis, such unwillingness makes sense; the potential costs of an experiment can be substantial, immediate, and personal, whereas any benefits are long-term, uncertain, and diffuse. However, this complex issue warrants more attention and we shall return to it in discussing the attributes of an adaptive institution.

The issue of rapid knowledge acquisition also raises questions about who participates in the knowledge creation process and how. Wondolleck (1988) argued that resource management organizations must provide opportunities for joint fact-finding. “To facilitate both meaningful and satisfying participation by national forest users in agency decision-making requires that each group and individual be operating with equal information” (p. 198). It is critical that people not only understand the implications of different outputs, but that they are “a part of the process that goes about obtaining and analyzing this information” (Wondolleck 1988: 198).

Enhancing Information Flow

Once information is acquired, it must be communicated to stakeholders—those charged with decisionmaking and implementation responsibilities and those whose interests might be affected by an impending decision. In traditional agency planning processes, the information communication process is often restricted to the former group (i.e., decisionmakers and implementers). In democratic systems open to public scrutiny, a host of stakeholders influence the decisionmaking process; in effect, they possess veto power. McLain and Lee (1996), for example, pointed to how adaptive management modelers in New Brunswick assumed that federal and provincial foresters and politicians were the key political actors in the debate over spruce budworm spraying, thereby marginalizing members of the environmental movement. Later, environmentalists moved to mobilize public opposition to the spraying program, effectively stymieing implementation.

The efficient flow of information to relevant parties, both internal and external, is impacted by information complexity. Environmental problems, and potential solutions to them, require qualified, technical expertise. This problem is confounded by the inability of many research scientists to communicate results and potential implications clearly. Resource managers, faced with heavy workloads, different priorities, and limited staff and time, often are not eager to wade through research papers and reports, particularly given that doing so might require them to change their behavior (Michael 1973).

Efforts to span boundaries and create more efficient and effective flows of information have attracted attention. Addressing the challenge of an organization striving to adapt to change, Michael (1973) noted two underlying aspects that require attention. First, organizations often work to eliminate the need for boundary spanning in the first place (and its turbulent consequences) by attempting to control their environment; e.g., a resource management agency tries to convince a skeptical public that its programs are appropriate and sound. Second, and somewhat contrary to the first, the "societal conditions that create the need for [boundary spanning] mean that the potential for controlling the environment will be low" (Michael 1973: 238).

The idea of boundary spanners (i.e., people to link across functions such as research and management) has attracted the attention of natural resource agencies. Ideally, these would be people with sound backgrounds in both management and science. Although there are arguments as to where these individuals might reside organizationally (i.e., within the research or management organization?), in general, the idea is that they would help communicate and interpret research results to managers, provide feedback to researchers on the results of the application of results, and play a coordinating role among the respective players.

The presence of an institutional champion for the project was identified as a key factor.

The concept of spanning has drawn only limited attention in the adaptive management literature. One notable exception is reported from Australia, involving application of an adaptive management strategy for the water cycle in the urban fringe of three areas. In each experiment, the presence (or absence) of an **institutional champion** for the project was identified as a key factor. For example, in the Tuggerah Lakes project, north of Sydney, the presence of such a champion was deemed critical in obtaining acceptance of the adaptive management approach by both the local council and community participants (Gilmour et al. 1999). The authors noted that the absence of such a champion, or in one case, the loss of that person to another job, resulted in little enthusiasm and a reduced likelihood of successful implementation. They concluded there is a strong need for a person within the lead management agency to act as the change agent—the institutional champion. Such persons should be sufficiently influential in the decisionmaking process to ensure a continued focus on the experiment-review-feedback cycle; they also need excellent communication skills to work at multiple levels within and outside the organization. The relative scarcity of such individuals makes efforts to implement adaptive management strategies vulnerable to organizational change.

An absence of champions also can detract from the ability to capitalize upon learning and knowledge from outside the immediate area of concern. Ewing et al. (2000: 455) argued that "ensuring the incorporation of, and access to, R & D [research and development] outcomes from nonlocal projects is…problematic since there is not necessarily a 'champion' who is aware of other research and ensures that it is incorporated." They cited the absence of a local champion in a rural planning exercise in southwest Western Australia as having an adverse impact on efforts to ensure effective, ongoing communication between, and within, various subgroups working on the project.

In reviewing efforts to implement adaptive management in the operation of the Glen Canyon dam and its effects on the Grand Canyon ecosystem, the National Research Council evaluation team observed "an advocate is needed for the adaptive management experiments themselves, particularly regarding their scientific coherence and the long-term integrity of the Grand Canyon ecosystem. There is currently no voice among the stakeholders that represents the interests of these scientific experiments" (National Research Council 1999: 61).

The critical role of key individuals in fostering and facilitating the flow of information, and serving as champions of adaptive management also was recognized by Gunderson et al. (1995b). They cited three roles for such individuals: visionary activist, respected integrator, or rebel bureaucrat. The latter two roles are especially critical, given their position within the bureaucracy. Such persons have a particular capacity to speak "truth to power" (Wildavsky 1979), an important role when the results of adaptive experiments run counter to prevailing policy and the status quo. In an early evaluation of adaptive management in Canada, the lack of a "wise person" to shepherd projects was identified as a major factor contributing to project failures (ESSA 1982). Duinker and Trevisan (2003) concluded these individuals were especially critical in gaining understanding and support among front-line staff that might otherwise have been reluctant to participate cooperatively in the project. These advocates served as teachers who helped create and sustain the organizational support necessary for effective implementation.

Feedback is a key process in enhancing information flow, particularly in an adaptive management context. The flow of information from an action back into the decisionmaking process provides a basis for evaluating that action and for guiding future actions. In particular, negative feedback, reporting on the negative consequences of some action, is especially informative; i.e., "learn from your mistakes." Such feedback is critical in situations involving complexity and uncertainty. As Dryzek (1987: 47) noted,

> negative feedback is the presence of deviation-counteracting input within a system…In an environment of complexity and uncertainty, one cannot completely understand that environment…As a substitute for perfect understanding of the insides of the "box" (i.e., the environment), any intelligent choice mechanisms will be so structured as to respond to signals emanating from the "box."

As an ideal, feedback is the process through which decisionmakers acquire the information necessary to deal with uncertainty. Walters (1986: 233) observed that "it is a truism to state that the best management decision to make at any point in time is some function of all the information available at that time." He also argued that effective feedback policies are designed not only to report on the results of previous actions, but also provide some anticipation of future responses to those actions. In short, feedback informs decisionmakers not only about what has occurred, but what is likely to happen in the future.

When effective feedback processes are absent, adaptive management is handicapped. Yet, organizational receptiveness to feedback, particularly negative feedback, often is hampered by structural and cultural barriers that resist acknowledging information contrary to existing practices, policies, and beliefs (Miller 1999). In some cases, this stems from efforts to avoid overloading people with excessive amounts of information, especially given that the implications of that information might not be clear. Often, however, resistance stems from more deep-seated sources. Michael (1973: 271) argued "People have structured organizations (and organizations have structured people) to avoid unfamiliar feedback…Organizations arrange to receive a minimum of turbulence-generating feedback, and to use as little as possible of that to generate further turbulence." He added "Feedback which is disrupting because it is unfamiliar is also avoided by structuring the feedback retrieval process so that it selects from the environment only those signals that are compatible with the structure and norms of the organization." In sum, feedback is not assimilated, processed, and evaluated evenly; the process is highly selective, filtering out, discounting, or ignoring that which stands contrary to contemporary policies, beliefs, or dogma. As Schiff (1962) has recounted with regard to the role of fires in longleaf pine forests of the Southern United States, research inconsistent with prevailing policy was suppressed, and the published work only surfaced 6 years after completion. Feedback was interrupted because of its conflict with the dominant ideology.

With regard to the concept of feedback, there is a lack of clarity as to the effects of differing characteristics of that feedback. For example, in applications of continuous improvement models in a business context, often there is relative clarity and agreement as to what information is critical in a feedback loop and what implications it contains. Moreover, such feedback becomes apparent relatively quickly in the system; changes in demand for products, impacts of price changes or changes in product quality, etc. However, in ecological systems, feedback is often both delayed, perhaps substantially so (years or decades) and the meaning and implications of change are often neither clear nor agreed upon. Indeed, the very complexity of ecological systems that has made the concept of adaptive management appealing also contributes to the limits of the utility of feedback in assessing performance, causation, or management implications. Although it is correct that adaptive processes have been productively used in business contexts, fundamental structural differences in the underlying complexity of ecological systems mean that feedback processes must be understood to be inherently uncertain. As Roe (1998: 96) has remarked "The more you search complexity, the more perverse feedback cycles you will find."

Given the critical role of feedback in the adaptive management model, what can be done to overcome or mitigate these hampering effects? Michael (1973) suggested two important strategies, one internal and the other external. First, he called for creation of organizational structures and norms that sustain and reward learning. This means cultivating a capacity and acceptance of self-criticism that encourages critical thinking and openness to new information. It is also a critical step in restoring trust among competing interests (Michael 1995). Second, it is important in the external environment that there be a capacity to force openness and responsiveness to feedback. Here, the onus is on the ability of voluntary or other external organizations to both provide feedback and to insist upon organizational attention to it.

Creating Shared Understandings

McLain and Lee (1996: 445) concluded "the scientific adaptive management approach has failed to provide adequate forums for the creation of shared understandings among stakeholders." The emphasis here is not on trying to create a single perspective, or even a consensus of values and meanings, but to create civic places where respect, legitimacy, and credibility of diverse interests and perspectives can be fostered (Shannon 1987). However, such forums are notably absent in the natural resource arena and across society in general.

Yankelovich (1991) called for creation of forums designed to facilitate the process of **working through**, a phrase drawn from psychology that describes the process of coming to grips with change. In part, this involves processing information, but even more so, it involves confronting the pressures and conflicts that engulf individuals and organizations and which they must, somehow, accommodate. He went on to point out "society is not well equipped with the institutions or knowledge it needs to expedite working through. Our culture does not understand it very well and by and large does not do a good job with it" (p. 65). The concept is especially germane here, for in the process of creating shared understandings and achieving the condition where individuals and organizations have a capacity to understand, respect, and legitimize diverse interests, values, and perspectives, new processes and institutions might be needed. The lack of such processes and institutions, however, can constrain the ability to implement adaptive management.

Walters (1997) contended that self-interest and unresolved value conflicts often combine to stymie adaptive management. For example, Allan and Curtis (2003) described efforts to use electromagnetic mapping as a means of assessing the extent to which salinity had affected agricultural lands in northeast Victoria, Australia. Although introduction of the technique raised community interest in the salinity issue, the lack of a framework describing what the mapping was intended to achieve, how the information could be used, and how it related to other information collected in the area contributed to confusion and a subsequent disillusionment with the program.

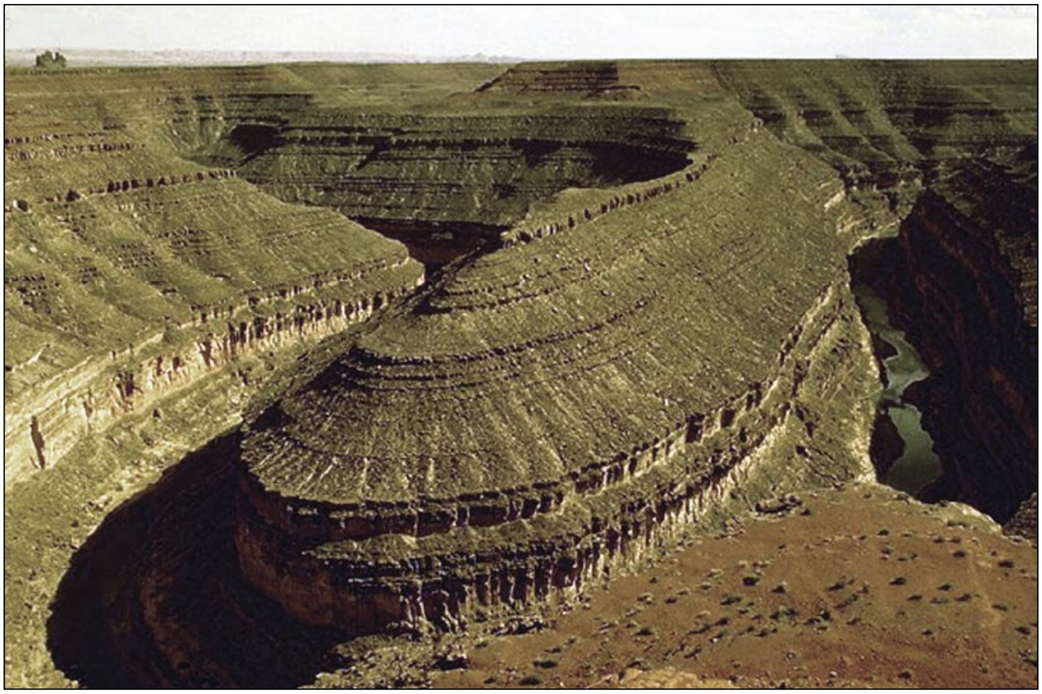
But this leaves the vexing question: If current institutional structures and processes lack capacity to behave adaptively, what type of organization would be capable of doing so? We examine this issue next.

Institutional Attributes Facilitating Adaptive Management

Two central issues confront efforts to more effectively implement adaptive management. First, what would an adaptive management organization look like (and implicitly, how would it differ from existing structures)? Second, what transformation processes must be undertaken?

We can examine these questions from two perspectives. First, there is a body of empirical work examining the various factors associated with "successful" applications of adaptive management as well as those where adaptive management has fallen short of expectations. Second, there is a more theoretically-based literature that discusses the necessary attributes of adaptive organizations. Combined, the literature provides important insight about the steps needed to implement adaptive approaches in natural resource management.

Ladson and Argent (2002) conducted a comparative assessment of three projects in the United States in which adaptive approaches were used—the Columbia, Colorado, and Mississippi Rivers—and compared those results with efforts to implement adaptive approaches in Australia's Murray-Darling Basin. Their purpose was to gain a better sense of the conditions that affect efforts to implement adaptive management. They concluded there were different degrees of success in the three case studies, but that the Colorado River program—involving efforts to evaluate the impacts of alternative low-flow releases through Glen Canyon Dam on ecological conditions in Grand Canyon National Park—was the most successful (fig. 6). They identified seven variables that contributed to this success: (1) the relatively simple jurisdictional situation (the area involved only the state of Arizona and Grand Canyon National Park); (2) few points of possible legal or political intervention in the river's management; (3) credible science was present, with all reports subject to peer review and an independent scientific panel overseeing research efforts;



National Park Service

Figure 6—An adaptive management project on the Colorado River focuses on the impacts of alternative low-flow releases through Glen Canyon Dam on ecological conditions in Grand Canyon National Park.

(4) system modeling on the Colorado was "complex enough to obtain credibility but simple enough that it could be completed and used in a reasonable time frame" (p. 96); (5) managers could point to early achievements in experimental management, such as a 1996 beach-building flood that gained both scientific and political support; (6) a sense of community among the various stakeholders that enabled a consensus regarding goals and objectives of the project; and (7) the project was, in a sense, the "only game in town," requiring that all interested stakeholders participate in the process.

Mapstone (2003), describing experiences in implementing strategies for reef line fisheries on Australia's Great Barrier Reef, expanded on the desirable contextual situations for successful implementation of adaptive management. These included (1) the presence of options for alternative management strategies (an idea closely aligned to Bormann et al.'s [1999] concept of "multiple pathways"), (2) specific objectives for assessing performance, (3) effective monitoring and feedback systems, (4) cross-sectoral support from stakeholders, (5) clear and open mechanisms for information transfer, (6) assurance of continuity of organizational and governmental commitment, and (7) protection against political expedience. Meppem and Bellamy (2003), reviewing efforts to implement a 4-year research and development project on integrated resource use planning in the central highlands of Queensland, Australia, added three additional "cornerstones of a healthy adaptive management system": (1) support for individuals and sectors to develop their own planning capacity, (2) facilitating understanding of both socioeconomic and biophysical processes within the systems, and (3) strong institutional arrangements that facilitate negotiations among interests.

Consistent with theories of adaptive management, negative feedback on the performance of alternative approaches can be important sources of insight. In Ladson and Argent's (2002) critique of adaptive management on the three American river systems, they were particularly critical of the situation on the Columbia River. Here, they found four contextual conditions that constrained efforts, including (1) "modeling wars" between specialists, with the result that excessive attention focused on details of modeling, rather than its use as a basis for problem framing; (2) institutional complexity involving both multistate and multinational jurisdictions; (3) the stultifying effects of the Endangered Species Act, which constrained experimentation; and (4) the complex web of values at stake, leading to a resistance to changes in the status quo. The vast scale of the Columbia River experiment also increased the likelihood that the institutional, socioeconomic, and biophysical complexity found across the region would lead to unintended consequences, exacerbating concerns among stakeholders about impacts on their interests and values (Butler et al. 2001).

Meppem and Bellamy (2003) also acknowledged problems from the central highlands project in Queensland, including (1) lots of plans but little on-the-ground evidence of implementation, (2) lack of understanding of relationships within and between systems, (3) an organizational inability to respond to change (i.e., an inability to move beyond the status quo), and (4) inadequate problem definition, driven in part because not all stakeholders were involved.

Earlier, we noted that traditional planning models and management organizations increasingly are subject to criticism as lacking a capacity (in terms of underlying philosophy as well as structure and process) to facilitate what is commonly defined as ecosystem management. Table 2 contrasts the qualities of two perspectives. It suggests that the underlying operational assumptions, organizational structure, and methods of operation of the alternatives stand in stark contrast. In particular, the traditional model is predicated on a world characterized by clarity in problem definition; on the ability to resolve problems through scientific, rational, quantitative, and objective means; and on a strong sense of order. In short, it is a model firmly grounded in the social reform planning tradition (Friedmann 1987).

This does not discount the value of traditional planning models in natural resource management. Nonetheless, organizing effective management programs

Table 2—Traditional resource management versus ecosystem management

	Traditional management	Ecosystem management
Nature	To be dominated and mastered	Complex, changing, interrelated
Ethics	Compartmentalized; interrelationships marginal	Holistic, interrelationships important
Science and models	Deterministic, linear, static, steady-state equilibrium	Stochastic, nonlinear, dynamic, variable-rate dynamics, with temporary equilibria upset periodically by chaotic moments that set the stage for the next temporary equilibrium
	Robust, well-defined theory; discrete data and highly predictable outcomes	Embryonic, beginnings of theory, theory and practice intertwined, interrelated data, and unreliable outcomes
	Maps, linear optimization, monetized cost-benefit analysis, quantitative	Geographic information systems, relational databases, nonlinear simulation (time and space dependent), quantitative and qualitative evaluation for social, economic, and political aspects
Management and organization	Centralized, rigid; little focus on incentives or innovation	Decentralized, interrelated teams, adaptive, flexible; focus on incentives, innovation, shared learning
	Hierarchical, top-down bureaucracy	Adaptive, bottom-up, cooperative, open
Planning	Comprehensive, rational	Interrelated, chaotic, looking for order in chaos, imaginative
Decisionmaking	Rigid, command-and-control, authoritarian, expert-driven	Deliberated, inclusive
	Science provides "the answers"	Science provides information; alone, it cannot provide answers
		Adapted to context of problems, interrelated to other problems, considers externalities
Participation	Influence, money	Discursive, deliberative
Leadership	Authoritarian, leaders designated	Situational; leaders arise from the community when needed

Source: Cortner and Moote 1999: 38.

requires a critical review of existing structures and processes and their capacity to deal with the world around us. This world is dominated by complexity and uncertainty, and these qualities compromise the ability of many contemporary organizations to frame effective approaches, given imbedded norms of risk-aversion and resistance to change. Lee (1993: 85) has summarized the key institutional challenges that account for this reluctance.

Adaptive management conditions	Rigidities that complicate experimentation
There is a mandate to take action in the face of uncertainty.	Experimentation and learning are at most secondary objectives in large ecosystems. Experimentation that conflicts with primary objectives will often be pushed aside or not proposed.
Decisionmakers are aware they are experimenting.	Experimentation is an admission there may be no positive return. More generally, specifying hypotheses to be tested raises the risk of perceived failure.
Decisionmakers care about improving outcomes over biological time scales.	Costs of monitoring, controls, and replication are substantial and they will appear especially high at the outset when compared with the costs of unmonitored trial and error. Individual decisionmakers rarely stay in office over times of biological significance.
Preservation of pristine environments is no longer an option, and human intervention cannot produce desired outcomes predictably.	Remedial action crosses jurisdictional boundaries and requires coordinated implementation over long periods.
Resources are sufficient to ecosystem behavior.	Data collection is vulnerable to external disruptions, such as budget cutbacks, policy changes, and controversy. After changes in leadership, decisionmakers may not be familiar with the purposes and values of an experimental approach.
Theory, models, and field methods are available to estimate and infer ecosystem-scale behavior.	Interim results may create panic or a realization that the experimental design was faulty. More generally, experimental findings will suggest policy changes; controversial changes could disrupt the experimental program.

Adaptive management conditions	Rigidities that complicate experimentation
Hypotheses can be formulated.	Accumulating knowledge may shift perceptions of what is worth examining via large-scale experimentation. For this reason, both policy actors and experimenters must adjust the tradeoffs among experimental and other policy objectives during the implementation process.
Organizational culture encourages learning from experience.	Advocates of adaptive management are likely to be staff, who have professional incentives to appreciate a complex process and a career situation in which long-term learning can be beneficial. Where there is a tension between staff and policy leadership, experimentation can become the focus of an internal struggle for control.
There is sufficient stability to measure long-term outcomes; institutional patience is essential.	Stability is usually dependent on factors outside the control of experimenters and managers.

A useful framework for conceptualizing the decisionmaking environment occupied by natural resource agencies is described by Thompson and Tuden (1987) and also used by Lee (1993, 1999). Thompson and Tuden argued that when organizations make choices, they face two issues. First, choices are based on understanding **causation**. Do we understand why things work and can we predict what will happen when action is taken? Although Shannon and Antypas (1997) characterized uncertainty along a continuum (from relative surety to the unknown), Thompson and Tuden provided a simplified scheme, asking whether there is agreement or disagreement (fig. 7).

Second, choices involve the nature of agreement regarding **preferences about outcomes**. This is a goal-oriented dimension; Shannon and Antypas (1997) described this as ambiguity. A major challenge confronting society today is that there is no clear, unequivocal sense of social purpose or single, unified public interest (Schubert 1960). Rather, the world is composed of numerous, often contradictory demands, creating an ambiguous context within which decisionmakers operate.

Despite the limits of treating uncertainty (causation) and ambiguity (preference) as dichotomous variables, Thompson and Tuden's schematic helps frame an understanding of the institutional choices confronting organizations implementing adaptive approaches. Consider the following. In cell A of figure 7, agreement exists on both causation and preferred outcomes. Here, decisionmakers are faced with issues primarily of a technical or computational nature; as a result, decisionmaking is routinized. Under such conditions, the most appropriate institutional structure is the bureaucracy, embodying specialists operating in a formal, hierarchical, and routinized environment.

Different approaches are called for depending on whether there is disagreement about preferences for outcomes or about causation.

In cell B, although there is accord on preference, disagreement exists about causation. For example, although there is considerable agreement about the importance of maintaining old-growth conditions in forests, there is considerable disagreement about **how** this can best be accomplished (e.g., different thinning strategies, role of fire). Here, organizations must rely on expert judgment to help guide the decision-making process. Because of differences in problem perception and interpretations of the scientific evidence, the collective wisdom of the decision unit needs to be brought to bear on the problem. The decisionmaking strategy is judgment by majority and the preferred institutional structure to facilitate such choices is the collegium. Castleberry et al. (1996) provided a useful example by describing how the use of expert opinion among a variety of stream ecologists helped establish instream flow requirements.

In cell C, the situation is opposite to that in cell B; here, agreement exists on causation, but not on preference. When conflict exists over goals, inevitably there will be winners and losers; some will find their goals satisfied, others will not. This presents decisionmakers with a world where the choice process is driven by bargaining and negotiation, where compromise (the art of politics) must be practiced.

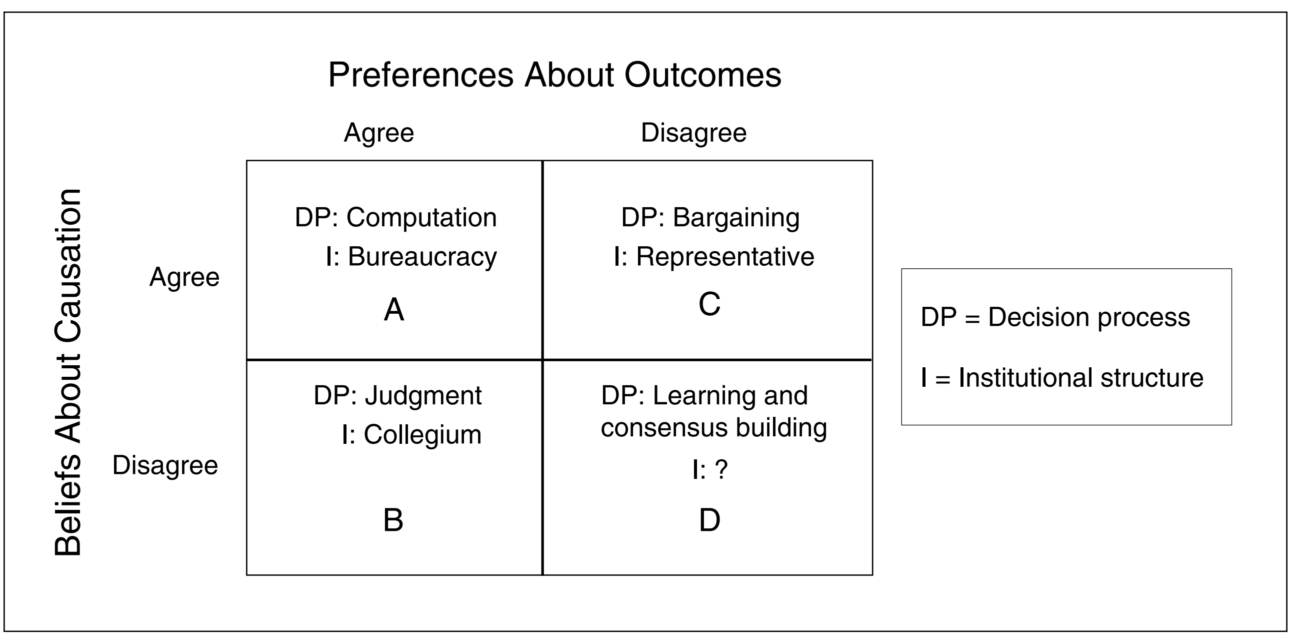


Figure 7—Thompson-Tuden model.

It also means that decisionmakers need to be aware of what interests and values are involved, and who those losers and winners are. Thus, it is important that decision-making processes involve as wide a representation of the multiple interests involved as possible (the United States Congress would be an example).

This brings us to the conditions that define cell D. Here, both causation and preference lack agreement; i.e., there are high levels of uncertainty and ambiguity. Thompson and Tuden described this as "a…dangerous situation for any group…; certainly by definition and probably in fact, the group…is nearing disintegration" (1987: 202).

Yet, this is a common situation today. For many resource managers, technical complexity, coupled with variation in natural processes, makes understanding causation problematic. Experts often disagree about what data mean, further confounding the exercise of informed decisions (Schwarz and Thompson 1990, Yankelovich 1991). In a pluralistic society, with high levels of political ambiguity, the search for preferred outcomes (e.g., some agreed-on purpose of public forests and forestry) faces formidable barriers. Fragmentation, intense political rivalries, and strategic posturing stymie efforts to find accord. Yet, despite this uncertainty and ambiguity, bureaucratic institutions, founded on the assumptions of certainty and clarity of purpose (the conditions of cell A), still dominate efforts to make choices. The result is a growing mismatch between current institutional structures and processes and the character of the decision environment within which those institutions operate.

However, "if not a bureaucracy, then what?" Thompson and Tuden described the context implied by cell D as one in which there is a state of anomie, of normlessness, where former goals and values have lost their meaning. But the search for appropriate institutional structures and processes capable of operating in such an environment reveals little of promise. Thompson and Tuden could only recommend a "structure for inspiration," an institution in which a charismatic leader offers a new set of ideals or preferences that "rally unity out of diversity" (1987: 202).

Lee (1993: 108) offered "two conceptually distinct strategies for intervening in a conflict (i.e., the conditions of cell D): either attempting to move toward agreement on causation, leaving preferences to be reconciled later; or attempting to move first on preferences." The second strategy involves consensus-building; contending parties strive to turn some initial consensus of goals into a plan to which all can agree. In short, he suggests through **planning** that it is possible to convert cell D conditions to those of cell B, where there is goal agreement. Alternatively, contesting parties strive to

> alter the character of the dispute by obtaining agreement on causation…This intervention method may be called **settling**, since the aim of the negotiation is not to achieve final resolution of conflict, but

> rather to hammer out joint actions within a relationship in which all parties are aware of and retain opposed interests…The reason parties…try to work together is that they have to (Lee 1993: 108–109).

In both cases, rather than developing a specific strategy for operating in the cell D domain, efforts are made to reframe the basic problem so that it fits elsewhere where decision processes and institutions are available.

Roe (1998) objected to Thompson and Tuden's conclusion, arguing there is something "which sticks in the throat" (p. 3) about hoping for revitalized institutions dependent on the appearance of inspirational, charismatic leaders. Rather than rejecting analysis, he argues that analysis remains the only viable option. What requires reassessment is the manner in which analysis is undertaken; "The analytic methods required for these sometimes desperate situations are…not those taught in most of our method courses and seminars…yet we proceed ahead today as if the old methods will get us across this complex public policy terrain" (Roe 1998: 4). The distinguishing characteristic of a more useful analytical approach is one that triangulates; i.e., that uses multiple methods, procedures, or theories to gain insight as to appropriate responses to complex policy questions. It also implies that multiple forms of governance might be required; traditional hierarchical/bureaucratic (command-and-control) systems, market-based systems, local self-governance. This would facilitate creation of a diverse set of decision rules affecting incentives, information flow, and compliance that would enhance the capacity to operate effectively in this turbulent domain (Dietz et al. 2003). On the other hand, the diversity of rules, structures, and processes might result in confusion and chaos that exacerbates turbulent conditions.

The challenge of finding institutional structures and processes capable of operating effectively in a world of uncertainty and ambiguity is formidable. Johnson and Williams (1999: 10) argued "…unresolved value judgments, and the lack of effective institutional structures for organizing debate…present the great threat to adaptive…management as a viable means for coping with…uncertainty." Yet, the literature contains important insight as to the desirable attributes such a structure might possess. Many of these qualities are consistent with the vision of adaptive management outlined in FEMAT.

Could adaptive management represent the kind of innovative strategy for more effectively operating in the ambiguity and uncertainty of a cell D world? It is probably not possible to answer the question definitively at this time, but the potential is there nonetheless. From a social and political perspective, adaptive management offers an opportunity for a more collaborative, multiparty and multi-interest approach, beginning at the problem-framing stage and extending through monitoring and evaluation. From a technical perspective, it offers the experimental foundation needed to operate more effectively relative to uncertainty and provides a means by which action can take place in the absence of a full understanding of consequences and implications.

Operational-level problems derive from inadequate or inappropriate organization of economic and public affairs and manifest themselves as ineffective management programs, insufficient or flawed information, inadequate legal processes, poorly-defined standards, etc. As Caldwell (1990: 72) noted, "the objective at this level is to rectify behavior without attempting to alter prevailing economic or institutional arrangements." In response to such problems, managerial organizations employ a variety of mechanisms designed to enhance efficiency: increasing incisive internal action, exercising increased control over what goes in and out of the organization, or strengthening management supervision and oversight (Michael 1973).

Because the nature of problems confronting organizations (of whatever structure) are systemic rather than operational, the required changes similarly must be systemic. Systemic environmental problems result from the underlying assumptions, goals, and values of modern technological and economic systems and priorities. Effective solutions must be similarly framed; adding another decimal point to the data or writing a new standard and guideline is inadequate to deal with the underlying causes of such problems. Rather, Caldwell (1990: 73) wrote, "the remedy (to systemic problem resolution) is sought in progressive adaptation and innovation in institutional arrangements."

Costanza et al. (2000: 153) identified several principles of governance around which a reconstituted organization capable of responding to complex environmental challenges might be built. These include:

1. **Responsibility**—Access to environmental resources carries attendant responsibilities.
2. **Scale-matching**—Institutions match the scale of the environmental problem.
3. **Precaution**—In the face of uncertainty about irreversible environmental impacts, humans should err on the side of caution.
4. **Adaptive management**—Decisionmakers acknowledge uncertainty and continuously gather and integrate information, with the goal of adaptive improvement.
5. **Full-cost allocation**—All internal and external costs and benefits of resource use are identified and appropriately allocated.
6. **Participation**—All affected stakeholders are engaged in the formulation and implementation of decisions concerning environmental resources.

These principles are consistent with attributes for effective environmental administration suggested by Paehlke and Torgerson (1990):

1. **Non-compartmentalized**—Organizations should resist the "bureaucratic tendency toward compartmentalization" (p. 292) and develop the capacity to embrace diverse disciplines as well as affected authorities.
2. **Open**—Institutional decisionmaking is open and transparent. Given citizen access through legal processes as well as access to information through electronic means, the ability of organizations to bound debate and discussion within bureaucratic walls is unlikely.
3. **Decentralized**—Environmental management focuses on local, idiosyncratic issues. It must be sensitive to, and aware of, local knowledge and initiative, but also acknowledge external factors and large-scale processes. The resulting "paradox of scale" (Lee and Stankey 1992: 35) places responsibility for ecological regulation in small-scale institutions, while locating coordinating responsibilities in collaborative structures at the ecological scale of the regulated system.
4. **Anti-technocratic**—Although scientific understanding is necessary for environmental administration, it is insufficient for handling environmental problems. Organizational processes must be conducted in a manner that educates both citizens and experts.
5. **Flexible**—The emergent quality of many environmental problems necessitates development of an adaptive capacity and an ability to operate under uncertainty and ambiguity.

Dietz et al. (2003) also examined the conditions necessary to foster what they described as "adaptive governance," a term selected to help convey the difficulty of control, the need to proceed in the face of uncertainty, and the importance of dealing effectively with diverse values, perspectives, and knowledge. They suggested that the requirements for operating in such a context include the provision of knowledge, a capacity to deal with conflict, developing strategies to induce compliance with rules, providing infrastructure, and fostering a capacity to operate in the face of change.

Collectively, the principles and concepts contained in these analyses (and others; see Dietz et al. 2003) lead to two basic conclusions. First, although various concepts have been posited in the literature, there is a growing consensus on the attributes institutions need to operate effectively in today's complex and uncertain environment. Second, the nature of effective institutions defies pressures for standardized models; Dovers and Mobbs (1997) suggested the precise nature of institutions capable of implementing adaptive management will always be a function of a particular context. Indeed, there is evidence that institutional diversity might prove as important as biological diversity for long-term survival (Ostrom et al. 1999). It is also apparent that institutions must be able to change (i.e., adapt) as the larger social and ecological context within which they exist change; Andries et al. (2004) have argued that this adaptive capacity within institutions is essential to ensuring their effectiveness.

However relevant the kinds of changes discussed above might appear, they also constitute changes in traditional natural resource management culture and beliefs (table 2) and in the relationship between management organizations and the public. Therefore, efforts to change likely will face resistance. Danter et al. (2000: 539) noted, "making such organizational changes creates significant changes in agency values and culture." Such values and the culture of natural resource management are deeply ingrained; collectively, they form a belief system highly resistant to change. But as we confront the issue of how best to facilitate adaptive management, we need to recognize that adaptive mechanisms, structures, and processes—qualities that often stand in sharp contrast to traditional management—are required (Grumbine 1997). It also means an increased capacity for learning must be present.

Michael (1995) described nine attributes of a learning organization:

1. **The organization understands that language impacts understanding.** Language can be a barrier (it discourages understanding and learning) or bridge (it facilitates understanding and learning). People concerned with adaptive management need to pay attention to how we express ourselves and learn the language of **others.**
2. **Organizations operate on fundamental premises and assumptions about the world.** Both the Bureau of Land Management and Forest Service define themselves as problem-solving organizations. Such a belief can be used to act adaptively; these ideas serve as the basis for valuing learning.
3. **Such organizations explicitly acknowledge that the world is uncertain and that they need to accept error**. Typically, errors are treated as evidence of incompetence, miscalculation, and failure (Michael 1973). People who make errors, it follows, should be punished lest they become indifferent. Such a belief discourages the search for new knowledge—for thinking and acting adaptively—because such efforts often result in errors. Harvey (1988: 59) wrote "when we make it difficult for organization members to acknowledge their mistakes and have them forgiven, we have designed organizations that reduce risk taking, encourage lying, foment distrust, and,

as a consequence, decrease productivity." Learning organizations operate in contrast to this.

4. **Learning organizations actively work to reduce the individual's fear of failure**. If error is inevitable, and if people associate such an outcome with sanctions and punishment, it is not surprising that risk-taking, innovation, and creativity suffer. Learning organizations explicitly acknowledge these fears and recognize concerns about power, status, and security. This makes it possible to discuss them openly, to deal with them positively, and to build intra-organizational trust. Lacking such acknowledgement, there will always be distrust and fear of others (e.g., they'll use new knowledge to their advantage and my disadvantage), thereby discouraging learning.
5. **Learning needs facilitators, not chairpersons.** Group and organizational learning requires guidance and a capacity to recognize and productively respond to subtle motives and behaviors that play out in any group. Direction from leaders often suppresses, rather than facilitates, learning.
6. **Learning organizations recognize the importance of training people in group process skills.** "Learning to learn depends on…skills that enhance task group behavior…(and)…is a necessary prelude to other types of learning in which persons must work together" (Michael 1995: 480-481). Providing constructive feedback, reflective thinking (Schön 1983), and joining are teachable abilities and are necessary in learning organizations.
7. **Learning organizations provide short-term reinforcements and rewards**. Generally, people react positively to rewards and recognition. This is important both in and outside the organization. In the Applegate AMA, for example, we find examples of the beneficial role of positive feedback from the community for agency staff (Rolle 2002). Rewards and reinforcements are essential to sustain a learning environment.
8. **We learn best when we educate others**. Teaching requires that one possess a comprehensive grasp of the topic. It also requires recognition that teaching means more than imparting knowledge to others; it involves the reciprocal processes of listening, processing, and evaluating. Learning organizations view members as educators (fig. 8).
9. **Crises can be opportunities for learning**. Typically, organizations view their mission as one of preventing crises from occurring (Wildavsky 1988). However, crises are an inevitable part of the ecological processes around us, making the idea of prevention and control of such forces an

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Figure 8—Learning involves more than acquiring more facts. It occurs best when there is a reciprocal process in which individuals listen, process, and evaluate information from one another. In this sense, effective learning organizations treat everyone as educators.

> illusion (Holling 1995). Such occurrences are opportunities for learning, and learning organizations capitalize on them by asking "How might we respond differently if we had the opportunity? Why did this event occur? or "What functions does it play?"

Danter et al. (2000) provided an example of the challenges facing the U.S. Fish and Wildlife Service (FWS) as it grappled with implementation of ecosystem management. They described four key areas facing the agency: (1) shifts in professional emphasis, (2) interdisciplinary collaboration, (3) the role of decisionmaking, and (4) organizational values and culture.

Professional emphasis was shifting from stable, linear, and largely internal processes to constantly changing, nonlinear, and external pressures, conditions deemed largely outside the experience of most agency personnel. Demands for interdisciplinary collaboration were also stressful, as the bureaucratic structure, organized along compartmentalized, disciplinary boundaries, and exercising considerable control (at least in theory), was challenged to not only share (coordinate) information with external interests, but actually work collaboratively. Danter et al. (2000: 539) argued this shift from specialized and compartmentalized expertise to an interdisciplinary focus requires a "fundamental transformation of agency culture, power relationships, and professional norms." Decisionmaking, undertaken with the expectation that it would facilitate an increase in predictability and a reduction in surprise, was forced to recognize the inevitable provisional nature of knowledge and the need for ongoing, adaptive management. Finally, traditional agency values and culture, featuring top-down control and communication, a concern with efficiency, and the bureaucratic organization itself were challenged.

Danter et al. (2000: 540) concluded "ecosystem management itself requires transformational leadership after implementation because of the adaptive, nonlinear nature of ecosystem management." Although leadership is often defined in a bureaucratic and hierarchical manner, it is more appropriately seen as processes that establish direction, align people, and motivate and inspire—with the goal of producing change (Kotter 1995, Stankey et al. 2003a). Leadership, as opposed to management skills, among upper- and mid-level FWS officials, was the critical attribute in making the transition from a traditional management paradigm to ecosystem management as well as in maintaining an ongoing capacity to sustain that change. Danter et al. (2000: 544) noted:

> Ecosystem management demands continuous agency change, in that stable, linear, and predictable organizational processes will be replaced by adhocracy. For this reason, **after** implementation of ecosystem management, agency governance must be **more** leadership oriented than was previously required under earlier resource management models [emphases added].

The literature confirms the view of many observers that the major challenge facing adaptive management is fundamentally institutional in character. Such institutions are built on major premises and beliefs deeply imbedded in educational systems, laws, policies, and norms of professional behavior (Miller 1999). Although easy to say, institutional change is hard to do; Wilkinson (1992) described how the "lords of yesterday"—mining laws, timber and water resource development policies, and other natural resource laws and policies—framed a century ago, persist today, despite widespread recognition of the need for change.

Summary and Conclusions

In summary, what can be drawn from this extensive literature on adaptive management? In some cases, findings seem marked by consistency, whereas for others, the results are mixed or inconclusive. Yet, there are discernable patterns that foster efforts to assess the performance of adaptive management in the plan and the steps needed to increase its effectiveness.

1. **Although the concept of adaptive management is widely acclaimed in the literature as a model for resource management under conditions of risk and uncertainty, it remains primarily an ideal rather than a demonstrated reality.** In a review of bioregional assessments, Johnson and Herring (1999: 361) concluded "adaptive management is more of an abstraction than an acceptable enterprise, and institutions still do not allow managers to risk failure." Similarly, Lee (1999: 2) concluded "adaptive management has been much more influential as an idea than as a way of doing conservation." Although ideas are important and can serve as the basis for change and innovation, major challenges remain in translating adaptive management from rhetoric to reality. An important first step is to acknowledge that much remains to be done and that past experiences in incremental adjustments in light of new information typically do not meet the rigorous standards implied by contemporary notions of adaptive management.
2. **There are many definitions of adaptive management. Often, the term includes any process in which incremental adjustments occur. Typically, however, these do not involve the core characteristics of an adaptive approach as envisioned in the Plan or as discussed in the contemporary literature.** Although organizations long have relied on past experiences as a source of information to change subsequent policies and actions, such efforts generally lack the explicit hypothesis testing, monitoring, and evaluation that characterize contemporary definitions of adaptive management. In essence, adaptive management, as a process to accelerate and enhance learning based on the results of policy implementation, mimics the scientific method. Successful implementation of experimentally driven adaptive management requires incorporation of these distinctive characteristics, as opposed to simply a continuation of learning by incrementalism and trial and error. As Van Cleve et al. (2003: 21) noted "adaptive management is a very powerful, yet poorly understood natural resource management tool…but (it) must be understood by those who use, support, fund, and challenge it." Adaptive management, as described in the contemporary literature, is not simply the latest term embracing ad hoc or laissez faire management (MacKay et al. 2003). However, the literature reports few examples of formal structures and processes for implementing adaptive management. In the worst case, adaptive management has become a code phrase for "we'll make it up as we go." One unfortunate outcome of these disparate conceptions is that they confound efforts to

undertake a comprehensive appraisal and evaluation of progress in implementing adaptive management.

3. **Experimentation is the core of adaptive management, involving hypotheses, controls, and replication**. Although adaptive management invites experiments involving tests of alternative resource management policies and institutional arrangements, it is rare to find examples of such experiments, particularly involving controls and replication. Such characteristics are difficult to impose in the complex, multijurisdictional settings commonly found at the landscape level. However, there has been a reluctance or even resistance to experimenting with alternative institutional structures and processes, such as integrating local knowledge into decisionmaking processes.
4. **Adaptive management requires explicit designs that specify problem-framing and problem-solving processes, documentation and monitoring protocols, roles, relationships, and responsibilities, and assessment and evaluation processes**. This suggests that various ways to implement adaptive approaches exist, differing by context, organizational capacity, resources, etc. Unfortunately, clear documentation describing details of the experimentation process often fails to be undertaken, thereby diminishing the potential for feedback and learning. Guidelines and protocols to aid managers and policymakers in fashioning useful adaptive management models generally are lacking (an exception to this is Salafsky et al. 2001).
5. **Adaptive management is irreducibly sociopolitical in nature**. Effective implementation must involve the active involvement and support of the full set of partners and stakeholders. An inclusive approach is required not only to build understanding, support, credibility, and trust among constituent groups (Van Cleve et al. 2003, MacKay et al. 2003), but also to ensure adequate problem-framing and access to the knowledge, experience, and skills held by these groups. Because natural resource management problems are social in origin and potential solutions are framed in a social context, effective management programs must embrace both biophysical and social elements. Agee (1999: 292) argued adaptive management can only work "if simultaneously adopted in the sociopolitical world" and although "the political world does not have to embrace uncertainty itself…it must fund activities that reduce or define uncertainty…" This has proven challenging because of the reluctance of parties to work collaboratively and because organizational and professional biases continue to define problems in technical, scientific terms (Miller 1999).

6. **An adaptive management approach is grounded in a recognition and acceptance of risk and uncertainty**. When working in a complex, chaotic, and contingent world characterized by imperfect knowledge and unpredictability, improved management and policymaking is dependent upon a learning process undertaken in a deliberate, thoughtful, and reflective manner (Buck et al. 2001). A key element of this is explicit acknowledgement and acceptance of the limits of understanding and the risks that accompany decisions undertaken in the face of such uncertainty. Yet, management organizations have been reluctant to do this; concerns with political and legal criticism and sanctions often lead to a denial of uncertainty and an unfounded confidence in the tentative, provisional nature of most policies (e.g., the S&Gs).
7. **Learning is a key output of the adaptive management process**. Learning can include improved technical knowledge regarding biophysical and socioeconomic systems and their interactions as well as greater insight as to how new understanding can be communicated, enhanced, and incorporated into organizational policies, programs, and procedures. Learning is driven by treating management policies as hypotheses and the resulting knowledge as input to subsequent actions. However, as Failing et al. (2004) have argued, the probability of acquiring useful information (i.e., learning) must be weighed against the likely impact of that information on decisions, and the costs incurred in acquiring that information. Adaptive management is both a good investment and an appropriate strategy when the probability of gaining useful information is high **and** the consequences of that information for pending decisions is also high. If the probability is high, but the consequences of information for decisions are low, there is a risk of investing scarce resources into a management strategy with a low probability of significant impact. In short, adaptive management is not always necessarily an appropriate strategy for proceeding in the face of uncertainty.
8. **Adaptive management focuses attention on the meaning and significance of learning**. Despite the importance of learning, it remains fundamentally inferential in nature; i.e., it must be inferred based on observations of behavior or communications that suggest learning. Parson and Clark (1995) suggested four questions to facilitate determination of whether learning has occurred: (1) Who or what learns; i.e., where does learning reside in an organization? (2) What kinds of things are learned; i.e., in terms of Ackoff's (1996) five dimensions of learning, does learning

manifest itself as more data, improved understanding, wisdom, etc.? (3) What counts as learning; i.e., does learning occur at the cognitive or behavioral level or both? What criteria, established through what processes, help identify whether the outcomes of an adaptive management approach constitute an adequate basis for changing or maintaining a policy or management strategy? (4) Why bother asking; i.e., are the results merely interesting or do they have consequences for organizational behavior?

9. **Effective adaptive management is open and responsive to varying forms and sources of knowledge**. This requires processes and structures that enable alternative forms of knowledge to be obtained and incorporated into the decisionmaking process. Performance here is spotty, with public involvement venues and processes geared primarily to informing citizens of organizational intent or of obtaining some sense of public support or opposition to potential plans or policies.
10. **In the presence of risk and uncertainty, the adaptive management process provides a capacity to act in an informed, judicious manner**. This involves an acknowledgment that mistakes and failures are normal when working in uncertain situations, rather than unwanted feedback deriving from incompetence or inability (Schelhas et al. 2001). It highlights the importance of documentation, which provides a basis for examining differences between predicted and actual outcomes. All too often, negative outcomes are viewed as liabilities or even denied, rather than being seen as a source of learning and insight that could inform and improve subsequent decisionmaking.
11. **A variety of institutional barriers confront effective implementation of adaptive management**. These include legal and political constraints (e.g., Endangered Species Act), socio-psychological barriers (e.g., risk-aversion; Miller 1999), and technical-scientific constraints (e.g., lack of adequate knowledge bases or appropriate monitoring protocols) (Stankey et al. 2003a). McLain and Lee (1996: 446) noted that "the adaptive management literature pays little attention to the question of what types of institutional structures and processes are required for the approach to work on a large-scale basis." There clearly is no single template or model most suited to an adaptive approach. However, the literature identifies several qualities that would characterize an adaptive institution; an atmosphere that is open, participatory and inclusive, integrative, collaborative, risk tolerant, and flexible. The search for design principles upon which adaptive institutions are founded will continue to draw attention (Andries et al. 2004). Ultimately,

however, decisions about appropriate institutional structures and processes are linked to the specific context within which an adaptive approach is being considered.

12. **Effective implementation of adaptive management requires organizational leadership and political support, coupled with skilled advocates and champions at the field level**. A sustained commitment to adaptive management requires leadership and ongoing capacity-building efforts by organizations. Such commitment must be present at all organizational levels. Creation of the AMA coordinators and lead scientists was an important action in efforts to implement an adaptive approach in the Plan, and the loss of organizational commitment and support for these positions seriously constrains the future of adaptive management in the Plan.
13. **A commitment to adaptive management requires transition strategies that enable the transformation from a command-control system to one built upon learning, collaboration, and integrative management**. Ongoing assessments of needed changes in organizational structures and processes are essential. However, strong legal, organizational, and psychosocial forces work to sustain the status quo and resist efforts to change (Miller 1999). The ability of agencies to implement the systemic changes required in reframing existing conceptions of resource management—the role of citizens, managers, and scientists, the reality of dealing with a world characterized by chaos, complexity, and uncertainty, rather than order and predictability, etc.—remains problematic. Yet, as Holling (2004) has argued, transformational learning is necessary to enable truly novel strategies and processes to take root. Although such changes are inherently uncertain and unpredictable, they are essential to creating and sustaining the innovative environment within which an adaptive approach can successfully operate.

Implementing successful structures and processes to support adaptive management and the transitions through which organizational members must pass are formidable but essential. What is involved here is a need for **transformation**, a process with which the private and corporate sectors are well-acquainted (Blumenthal and Haspeslagh 1994, Holling 2004, Kotter 1995). These transformations often involve tensions among competing interests both internal and external to the organization. Bridges (1991) defined change as an objective and observable state that differs from the way things previously were. But the potential effectiveness of a change depends on the way individuals in the organization work through the **transition** from one state of conditions to another.

Transition is a psychological process; it begins with an ending. Traditional ways of operating within the organization have changed and members must come to grips with that fact. This is never easy, but it is an essential first step. Bridges (1991: 4) noted "nothing so undermines organizational change as the failure to think through who will have to let go of what when change occurs." Bridges described the second step in transition as negotiating through the neutral zone, a time and place of instability, ambiguity, and uncertainty. This can be threatening. What used to work no longer does; the rules that used to apply no longer fit. During this period, "anxiety rises and motivation falls," polarization among people increases, and the organization can become vulnerable to outside attack (Bridges 1991: 35–36). But it is also a creative period. Because old ways no longer work, there is a need to find new ways that do, and these provide organizational members with opportunities for creativity, innovation, and reinvention. Finally, the third step involves arrival at a new state of affairs. And the cycle begins again.

Although barriers continue to face implementation of adaptive management, the concept remains an important, even essential, component of efforts to deal more effectively with today's complex, uncertain world. In the absence of an adaptive grounded approach, rule-based planning—administrative or legal—will continue to dominate management, with a further diminution of the ability of managers to modify actions and policies in light of new knowledge and experience. To avoid this will call for renewed innovation and leadership from all interested parties: managers, policymakers, scientists, and citizens.

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