9. Putting Monitoring First: Designing Accountable Ecosystem Restoration and Management Plans

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ABSTRACT

Recovery of Puget Sound rivers and their native fish fauna will depend upon carefully documenting the ultimate effectiveness of restoration actions. Yet, as currently designed and implemented, monitoring programs are predestined to fail in this task. Consequently, our attempts to implement iterative, adaptive restoration or management actions will also fail unless managers and researchers: (1) alter their current conceptual models about the relationship between monitoring and management/restoration; (2) design and implement monitoring programs before planning restoration/management actions; (3) recognize the need for hierarchical monitoring programs and learn how to implement them; and (4) eliminate myths about monitoring, including the assumption that we can generate reliable new information about management and restoration actions simply by observing their outcomes. In order for monitoring programs to provide reliable and timely information required by iterative and adaptive approaches to ecosystem restoration and management, monitoring programs must serve as a scientifically rigorous framework for “Empirical Management” of natural resources. To accomplish this, managers and researchers must work together first to design hierarchically-structured monitoring experiments and then to plan on-the-ground management and restoration actions that serve as experimental manipulations in the context of the monitoring experiment. Unlike current approaches, this empirical approach has the potential to generate rigorous new scientific information about the efficacy of implemented actions and therefore could support adaptive, iterative improvement in management and restoration plans.

INTRODUCTION

> [A] functional long-term monitoring program can become the key component for bringing together the efforts of management organizations, decision makers, and researchers that intend to improve and protect natural ecosystems. (Wissmar 1993, p. 219)

The widespread decline of native salmon populations in Puget Sound watersheds and the quality and quantity of their aquatic habitats is indicative of the cumulative effects and unintended consequences of past and present land-use and water-use decisions over the last 150 years (Chapters 4 and 5). Current and future listings of native salmon, trout, and char under the Endangered Species Act will require explicit recovery plans to be designed and implemented throughout the Pacific Northwest. In addition, as a result of court-sanctioned settlement agreements, water quality management plans (i.e., Total Maximum Daily Loads) are now legally required to be developed for the literally hundreds of locations within Puget Sound waterways that fail to meet current criteria associated with water quality standards. These recovery and management plans will affect land- and water-use decisions at all levels of government, and potentially, society at large.

Recovery of Pacific salmonid habitats should involve a two-pronged strategy that emphasizes protection of the remaining intact aquatic systems while making intelligent, strategic decisions on restoring important ecological processes and functions of riparian and nearshore habitats. Development of effective and timely salmon recovery strategies requires innumerable decisions regarding future land and water use that are ideally based on adequate scientific understanding of the ecology of freshwater and marine ecosystems in Puget Sound and its catchment. Unfortunately, such decisions are routinely made with an imperfect or even wholly inadequate understanding of ecosystem response to protection and restoration actions. While in some cases decisions are made without considering information that already exists (see Chapter 6); in other cases management decisions are uninformed because the information necessary to *fully* inform the decisions does not (and may never) exist. Ecosystems are simply too complex to expect perfect understanding of the dynamics, structures, and feedback loops occurring therein.

Adaptive management—incorporating management activities into scientific experiments and modifying future management actions based on experimental results—is a widely embraced mechanism to make management decisions in light of uncertainty while learning from these decisions. Although adaptive management is generally applied to resource management decisions having to do with extraction or exploitation, we assert that restoration is as much a form of management as resource extraction, equally as fraught with uncertainty, and thus equally as reliant upon our ability to learn from our mistakes. Thus, if ecosystem management efforts (including salmon recovery) are to succeed, monitoring the outcomes of protection, restoration, and resource-extraction actions needs to be factored into the mix of planning and implementation to form a truly effective and integrated strategy (Currens et al. 2000).

In this chapter, we examine the broad role of monitoring as an applied science, which helps guide salmon recovery planning and other forms of management, particularly by providing a means to reduce uncertainties associated with past, present, and future land-use decisions controlling aquatic habitats. We argue that: (1) monitoring the outcome of actions is a fundamental underpinning of an iterative and adaptive process designed to manage resources in the face of uncertainty; (2) widespread myths about monitoring currently ensure that monitoring programs will not succeed; and therefore, (3) iterative, adaptive approaches to resource management cannot succeed without fundamental changes in the design, implementation, and integration of monitoring programs.

Many millions of dollars have already been spent in the PNW on river enhancement projects aimed to aid recovery of native fish, and less often, the processes responsible for shaping rivers and riparian areas. Although very few systematic evaluations have been made of the success or failure of such projects, published accounts suggest a significant disconnect between on-the-ground implementation of such projects and any subsequent, explicit attempt to evaluate the outcome or success (Frissell and Nawa 1992; Beschta et al. 1994; Kondolf 1995; Frissell and Ralph 1998; and Chapter 12). Management actions—even those taken in the name of restoration—should be subjected to rigorous scientific scrutiny to ensure that we gain a better understanding of their ultimate and proximate contribution to recovery.

TWO FLAVORS OF ADAPTIVE MANAGEMENT

> There is abundant evidence of poor or unsuccessful management of ecosystems, but little evidence of successful management. (Ludwig 1996, p. 16)

When resource management or restoration decisions are based on imperfect knowledge, there will always be risks associated with these decisions. Conceptually, "adaptive management" (Holling 1978) has been widely embraced as a means of dealing with these risks. Yet critical assessments (e.g., Halbert 1993;

Table 1. Three fundamental conclusions of a critical assessment of adaptive management (from Lee 1999).

Adaptive management has been more influential as an idea than as a practical means of gaining insight into the response of ecosystems inhabited and used by humans.

Adaptive management should be used only after all parties to the dispute have agreed on a list of key questions that are to be answered by the approach. Efficient and effective social learning and consequent change in behaviors, of the kind that could be facilitated by adaptive management, are likely to be of strategic importance in determining the fate of ecosystems as humanity searches for a sustainable economy.

Walters 1997; Johnson 1999; Lee 1999) have concluded that adaptive management is difficult to initiate and maintain over periods of time sufficient to show success (Table 1). We believe that adaptive management has failed largely because many processes implemented under the label "adaptive management" have only superficial similarities to the concept outlined by Holling (1978). To illustrate, we contrast Holling's Adaptive Management (HAM), a science-based process, with the more commonly initiated process, which we term "socio-political adaptive management" (SPAM).

Holling's Adaptive Management is a complete resource-management paradigm designed to provide a means of addressing the uncertain ecological risks associated with land-use and water-use decisions. In theory, Holling's Adaptive Management builds a credible scientific foundation by envisioning land-use activities (e.g., laying out timber sales, setting prescribed fire, building roads, stream restoration, and so on) as experimental manipulations that are implemented within the context of well-designed monitoring experiments. This strategy seeks to simultaneously generate economic value *and* scientific understanding of ecosystem response to human activities (see also Holling and Meffe 1996; Walters 1997).

Socio-political adaptive management concepts emerge from socio-political decision-making processes (Chapter 6). Socio-political adaptive management concepts generally assume that an *independent* monitoring effort will be able to document any negative ecological impacts associated with continued land use, even though monitoring is not typically viewed as a series of well-designed experiments. In part because of their genesis in the policy-making realm, socio-political adaptive management concepts often are scientifically incomplete and ineffective. Often, they are based on only casual or uninformed interpretations of Holling's Adaptive Management.

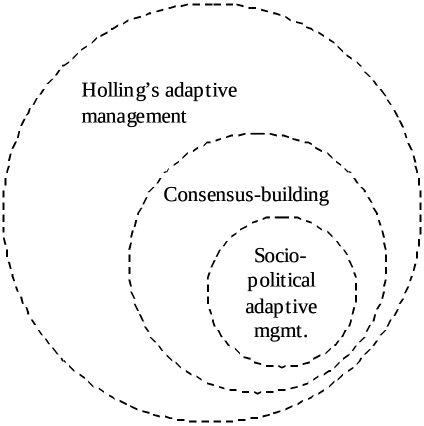

Figure 1. Venn Diagram of relationship between Holling's Adaptive Management, consensus-building, and socio-political adaptive management.

To understand the difference between Holling's Adaptive Management and socio-political adaptive management, it is useful to understand the relationship between these concepts and other socio-political processes such as consensus building. Consensus building is an interpersonal and political process designed to facilitate decision-making in the divisive and contentious political environment that surrounds the development of natural resource management policies. Thus, where implemented within the context of a pre-existing science-based process such as Holling's Adaptive Management, consensus building is apt to be a valuable tool for implementing adaptive management (Figure 1). Yet, as in any complex decisions-making process based on both inadequate information and political compromise between parties with different views and objectives, there are situations where participants simply cannot reach consensus. Lack of consensus typically arises when human land-use activities that can create economic value (e.g., resource extraction) might degrade ecological values (e.g., degradation of habitat for salmon and other native biota). Often, these impasses arise when one or more participants in the consensus group can successfully characterize ecological risks as uncertain. These friction points can overshadow and potentially derail other decisions where consensus *is* possible unless there is a means of addressing fundamental points of disagreement. In the face of "uncertain" ecological risk and the "assured" economic benefits, the impasse is typically resolved by allowing land-use actions to proceed while enduring the ecological risks, but with assurances that the actions will be monitored to determine whether ecosystem values are harmed. The results of monitoring, then, are intended to catalyze any necessary future "adaptive" improvements in management action. Thus, arises socio-political adaptive management—a tool for facilitating consensus-building (Figure 1).

Consensus-building processes convened to design restoration strategies may suffer from similar tensions. For instance, political pressure to "do something positive" can overshadow the more deliberate and careful design and implementation of a restoration project done as part of an experimental evaluation program. Similarly, political pressure to implement piecemeal restoration strategies compatible with status-quo resource extraction (e.g., placing large wood to create artificial pools in streams) may preempt the more comprehensive but politically difficult task of restoring a balance between stream flow, sediment sources, and riparian vegetation at a watershed scale.

WEAKNESSES OF SOCIO-POLITICAL ADAPTIVE MANAGEMENT

> "[L]ong-term monitoring and planning are often considered to be more a philosophical exercise than one of practical value." (Ziemer 1998, p. 131)

Explicitly recognizing the role of the socio-political adaptive management concept in consensus-building processes underscores Lee's (1999) first conclusion (Table 1) by revealing that socio-political adaptive management has little utility beyond facilitating consensus-building processes. Any resulting consensus-based management/restoration plan is unlikely to induce adaptive social learning and changes in behavior.

There are two reasons for this failing. First, consensus-building processes typically focus first and foremost on the nuts-and-bolts of determining allowable or acceptable management actions (e.g., defining best management practices, determining when they should apply, and deciding which should be mandatory and which should be voluntary). Therefore, the consensus process results in a relatively complete blueprint for management actions, but no more than a statement of need for a monitoring plan and a requirement that it be developed in the future. Although management actions and monitoring programs are originally envisioned as interdependent activities (Figure 2a), management actions typically are designed to proceed prior to implementation of the monitoring program (Figure 2b). The process may be well-intentioned and earnest, but the substance and schedule of the monitoring plan is often poorly defined. Thus there is little economic or political impetus to carry through on the monitoring component of the agreement. Given that adequate monitoring is both time-consuming and expensive, planned monitoring programs are sometimes not implemented; even when implemented, they may be short-lived. This

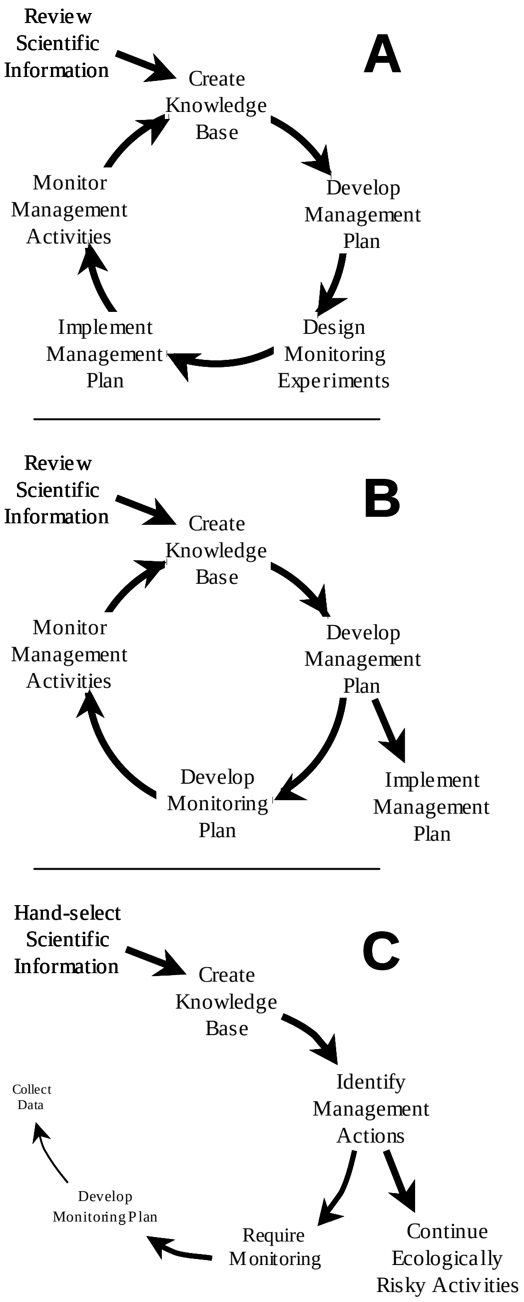

Figure 2. Schematics of socio-political adaptive management: a) as per-ceived by participants in consensus-building processes; b) as typically designed during consensus-building; and c) as generally implemented, often as the direct result of "myths" associated with monitoring (see text).

results ultimately in the failure of the planned adaptive process and the loss of the opportunity to collectively explore the efficacy of agreed-to management decisions. Monitoring programs that do not last long enough to generate new information result in a linear rather than iterative process (Figure 2c). The burden of proof to show the harmful effects of management decisions thus remains with the ecological system at risk, with no real prospect for lessening that burden through learning.

Second, monitoring programs that accompany socio-political adaptive management plans typically fail to recognize that reliable new information can only be generated by conducting well-planned scientific experiments. This requires generating credible hypotheses and designing monitoring experiments to adequately test these hypotheses. Although some have argued that monitoring must be approached as an experiment with testable hypotheses (Walters 1986; Conquest and Ralph 1998; Currens et al. 2000), contemporary socio-political adaptive management plans tend to result in scientifically ineffectual monitoring programs (Walters 1997).

We illustrate this point by outlining several commonly held and deeply entrenched “myths” about monitoring and argue that most contemporary monitoring programs are built upon one or more of these myths, each of which can eliminate necessary scientific rigor from monitoring programs.

Myth 1: We can monitor anything, it’s just a matter of figuring out how.

Because of real-world limitations arising from political, technical, and budget realities, some ecosystem responses are more easily measured over time than others. Yet managers often set management benchmarks without considering our ability to accurately and repeatedly determine the status and trend of the benchmark (e.g., Poole et al. 1997). Natural resource management goals, such as salmon recovery, need to be framed in terms of what we can (and will) measure so that we can determine success or failure. In contrast with contemporary management planning, management goals (in the form of benchmarks) should be set *after* determining what we are politically, technically, and financially able to measure.

Myth 2: We can learn from our management actions alone.

Landscapes and watershed processes that control the expression of salmon habitat can vary substantially in how they respond to disturbances (Reeves et al. 1995). For example, the frequency and magnitude of sediment inputs from steep unstable hillslope terrain will increase in proportion to logging and road building in comparison to similar timber harvest activities conducted in flat terrain with few erodable features. In part because of this variability, management actions conducted outside of the context of a rigorous experimental design do not generate new knowledge that is broadly applicable. In the absence of an experimental control, there is no way to determine whether the effect of the management action or the effects of other events and processes are linked to observed changes. Traditionally, land managers have taken a trial-and-error approach, where future decisions may be made based upon implementing a management action to "see what happens" and figuring they "would not do it again if the desired outcome is not achieved." If the outcome "looks good" based on limited, informal observation over a short period of time, the activity is assumed to have succeeded. This approach can lead to innumerable problems, such as the increasing frequency of perceived "acts of God" which result from delayed or cumulative effects of management activities.

Myth 3: Monitoring can be a separate activity from management; i.e., an adequate monitoring program can be developed in response to proposed management or restoration actions.

If monitoring is to generate new information, it has to be approached as an experiment that tests hypotheses about the effects of management actions. If monitoring represents such an experiment, management activities (whether intended to restore watersheds or extract resources) must be planned as experimental manipulations associated with the monitoring experiment. Thus, for monitoring to fulfill its requisite role in a rigorous, iterative and adaptive strategy for natural resource management, on-the-ground actions must be planned within the context of a monitoring experiment, not after-the-fact.

Interestingly, debunking any of these myths results in the same conclusion—monitoring programs must be designed *before* agreeing on management benchmarks, *before* determining what management actions are appropriate, and *before* laying out management or restoration activities across the landscape. In other words, for adaptive management to succeed, on-the-ground activities must be designed *within the context of* rigorous monitoring programs. Therefore, monitoring programs must be designed first.

HIERARCHICAL MONITORING DESIGN

There is a critical need to begin multiscaled monitoring—not just for

> point-source pollution but monitoring of key features of normal ecosystem function and indicators of the demands imposed by human society. (O'Neill et al. 1996, p. 24)

Designing a comprehensive and integrated monitoring program that will meet the needs of a salmon recovery strategy for Puget Sound rivers is a daunting task. In concept, such a monitoring program should address specific questions and identify meaningful variables that reflect the consequences of both protection and restoration actions on important components of aquatic environments. If properly framed, monitoring the outcomes of management decisions could increase our understanding of the variety of factors that either contribute to or pose impediments to recovery of river processes and the ecological functions they provide to native salmonids. Monitoring could act as an accounting system to establish an understanding of restoration actions and ecosystem response, elucidate the role of the past in shaping the present, and anticipate the added challenges of future expansion of human settlements throughout Puget Sound.

There is a hierarchy of ecosystem responses to human actions. Local conditions respond immediately to local actions, but the cumulative effects of multiple localized actions manifest themselves later in time and at progressively coarser spatial scales (hillslope, catchment, basin, and so on). Therefore, monitoring experiments must be similarly hierarchical to capture these multi-scaled responses. Although useful and requisite for improving site-specific management techniques, site-specific monitoring of individual management activities documents neither the cumulative watershed scale effects of site-specific actions *nor* the effects of site context on monitoring results. One cannot legitimately extrapolate local-scale results to a larger scale without understanding (1) synergistic interactions between multiple disturbances, (2) the influence of context on local results, and (3) the variation in context at coarser scales. For monitoring experiments to successfully document the array of potential management outcomes, the experimental framework must address patterns and process across spatial scales and link to the scale at which outcomes of management decisions are expressed (Naiman et al. 1992; Conquest and Ralph 1998; Bauer and Ralph 1999).

Variability across large land areas influences the results of monitoring efforts and confounds our ability to interpret resulting information. There are several schemes to stratify landscapes by determinant features (geology, climate, vegetation, elevation) that drive the expressions of habitat forming processes operating at large spatial and temporal scales (Frissell et al. 1986; Omernik and Bailey 1997; Bryce et al. 1999; Montgomery 1999, Montgomery et al. 1999; Chapter 8). Monitoring programs that incorporate a hierarchy of nested monitoring designs with spatially explicit experiments can address multiple objectives in an integrated fashion. We recommend a program that is designed at four distinct spatial scales: (1) the *basin* scale, incorporating major drainages (such as the Puget Sound or Snake River drainage basins); (2) the *watershed* scale, which focuses on watersheds of major tributaries within a given basin; (3) the *segment* scale, encompassing specific stream/riparian, floodplain, and hillslope complexes (for example, a discrete stream segment and its associated hillslopes); and (4) the *site* scale, encompassing a single management or restoration action (Chapter 12). Selection of sampling locations by scale would be further refined by identification of appropriate stratification schemes to minimize confounding influences of inherent variations in landscape characteristics. Table 2 is a hypothetical illustration of how this framework might be applied to a spatially integrated monitoring system to evaluate riparian zone management prescriptions for forest lands. For each spatial scale, it defines a purpose, identifies monitoring questions and objectives, suggests appropriate monitoring variables, and gives guidance on specific design criteria to aid selection of individual sampling sites (see also MacDonald et al. 1991; Conquest and Ralph 1998).

Monitoring applied at the *basin* scale would provide information on the status and trends of key indicators across the larger landscape. This provides information on spatial variability and therefore provides context to help with interpretation of related information gathered at the watershed scale. Similarly, information at the *watershed* scale provides context for *segment*-scale information, which in turn provides context for experiments at the *site* scale. An extensive network of monitoring locations, if properly designed, would provide information on the range of variability in key indicators, while reference sites would provide information on the potential range of expression and system potential that a given watershed may have. This would provide a basis for comparison to landscapes where intensive land uses such as forestry, agriculture, or urbanization occur.

At the watershed scale, multiple factors can be evaluated in an integrated monitoring network over multiple years. Examples of where this has been successful include Coweeta Watershed (Webster et al. 1992) and Carnation Creek (Hartman and Scrivener 1990). A number of segment-scale units should be developed in different areas to better support our desire to extrapolate findings from one area to other areas. It is at this level where *cumulative effects* of past, present, and future management actions could be evaluated with carefully designed paired watershed studies.

The effectiveness of particular ordinances governing management practices (e.g., forest practice rules for protection of riparian zones and stream temperatures or local government sensitive-area ordinances to protect against

Table 2. The hypothetical application of a nested hierarchy framework for monitoring the effect of alternative riparian zone management configurations on stream temperatures. The FFR refers to Washington States Forest Practice Rules and are used here only to illustrate the concept of how such a system might be structured.

Monitoring Spatial Scale	*Characteristics*	*Design Criteria*
Basin	*Purpose* · Provide estimates of the status and trends in riparian stand characteristics, riparian shading, and basin temperature regimes across drainage basins (e.g., Puget Sound Basin, Snake River Basin, etc.). · Allow stratification of status and trends by dominant land use and ecoregions. · Evaluate whole-basin trends in riparian stand characteristics, shade, and stream temperature in the context of land use history and the application of riparian best management practices. *Example Question*: What is the current status of riparian shade and water temperature across Washington's commercial forests? Are changes in this status occurring over time? *Objective of Question*: Estimate landscape patterns of response of riparian shade and diel water temperatures to the application of FFR riparian management prescriptions. *Example Monitoring Variables*: Seasonal and diel air temperature, seasonal and diel stream temperature, riparian stand characteristics, stream flow.	· Stratification and site selection criteria must allow for extrapolation of results to the majority of the commercial forest lands in Washington State, within relevant ecoregions. · Iterative sampling over an extended timeframe to allow for changes to occur. · Data collection and analysis must include probable covariates (linkages) to differentiate between changes due to FFR and other sources of variability (stream flow, weather, ecoregions, etc.). · Data analysis methods should be specified in the study design (power analysis) along with the time needed (years) for positive changes to occur. · A searchable database to store and provide ready access must be developed and its maintenance provided for.

Table 2 (continued).

Monitoring Spatial Scale	*Characteristics*	*Design Criteria*
Watershed	*Purpose* · Identify spatial and temporal distribution of water temperature within a watershed and its proximate response to adjacent land use and riparian management prescriptions. · Examine outcomes of stream adjacent clearing on riparian stand characteristics, shade, microclimate, and water temperature. *Example Question*: What are the cumulative effects of FFR riparian prescriptions for small streams on downstream water temperature characteristics? *Objectives of Question*: Determine if and how non-fish bearing streams help maintain cool temperatures in downstream fish bearing streams; evaluate the effectiveness of riparian prescriptions for non-fish streams in maintaining any downstream contribution. *Example Monitoring Variables*: Seasonal and daily water and air temperature through the riparian zone, and upstream/downstream of units; riparian stand conditions; stream flow; groundwater temperature; current and historic land use.	· Watersheds stratified by physiographic regions. · Criteria for selecting watershed must allow for extrapolation to a substantial portion of Washington's commercial forests. · Treatment and control (reference) watershed design, if possible. · Integrate with BMP effectiveness monitoring and with other studies within the basin. · Long-term monitoring time-frame · Studies must be designed to determine cause and effect. · Study design should include probable covariates so that data analysis may differentiate between natural variation (e.g. weather, streamflow, etc.) and effects of management activities.

Table 2 (continued).

Monitoring Spatial Scale	*Characteristics*	*Design Criteria*
Stream Segment	*Purpose* · Evaluate the effectiveness of riparian management prescriptions in meeting water quality standards and providing cool water habitat needs of native fish and amphibians. · Quantify how riparian stand characteristics (species composition, site class, structure, aspect, elevation, and buffer width) change in response to harvest prescriptions in terms of percent shade, groundwater, microclimate, and stream temperature. *Example Questions*: Are the FFR shade targets adequate for protecting the temperatures of aquatic habitats in stream segments? *Objective of Questions*: Test the effect of the various FFR regulations in maintaining cool water temperatures locally; identify variability in local water temperature response to FFR prescriptions due to riparian stand characteristics. *Example Monitoring Variables*: Seasonal and diel water and air temperatures throughout the riparian zone; riparian stand characteristics; stream flow and channel characteristics; groundwater temperature; upstream land-use history.	· Treatment control and/or pre- and post-treatment experimental design to isolate the effects of forest practices. · Sampling sites stratified by key physical variables that exert strong influence on riparian stand conditions. · Active monitoring approach to test effect of specific prescriptions. · Use power analysis to optimize sample size, magnitude of minimum detectable effect, and probability of Type I and II errors. · Study design must have unbiased site selection process.

Table 2 (continued).

Monitoring Spatial Scale	*Characteristics*	*Design Criteria*
Site	*Purpose*	
	· Determine if individual and collective management actions associated with timber harvest have a discernable effect on aquatic systems, including channel or bank stability, water quality, or fish habitat. *Example Questions*: Is bank stability disrupted within yarding corridors across streams? Do new or existing culverts associated with haul roads discharge sediment to the adjacent stream? Is blowdown of remaining riparian corridor trees excessive (i.e., > 15% of stand density) following adjacent timber harvest? *Objective of Questions*: Determine how specific aspects of a land-use activities cause proximal disruption to streams; determine how specific aspects of a land-use activities can be modified to mitigate or eliminate stream disruption. *Example Monitoring Variables*: Bank stability where bank as been disrupted; sediment yield associated with road crossings; blowdown rates associated with various riparian prescriptions in different settings.	· Site characteristics should be described relative to context. · Link to site scale cause-effect and consequence on biota. · For some questions, evaluation may be more empirical than subject to long-term monitoring. · Should help to provide the basis for monitoring at coarser scales that track cumulative net effects of distributed “site” scale events.

sediment input into stream courses or riparian zone "functions") can be assessed at the *segment* scale. Examples include the cumulative effect of several proximal management activities on response variables such as water temperature, habitat diversity, and channel stability.

Evaluation of individual management actions is best suited to monitoring experiments at the *site* scale. Site-specific activities such as culvert replacement, road drainage structures, or placement of large wood in streams can be evaluated on a case-by-case basis to assess effectiveness. When multiple site-scale evaluations are clustered within a framework of intensive segment- and watershed-scale sampling units, more information is revealed about the outcome of management practices applied to sites with different susceptibilities to disturbance. Moreover, the cumulative contribution of multiple restoration actions within a watershed can be more readily assessed.

THE EMPIRICAL MANAGEMENT PARADIGM

> [M]onitoring [must] be developed as a science in its own right, rather than be the uncritical application of convenient contemporary techniques (Schindler, 1987, p. 14).

We have argued that monitoring programs must possess specific characteristics in order for "adaptive" natural resource management strategies, including ecosystem restoration, to succeed. Monitoring programs must be designed as scientific experiments wherein management actions serve as experimental manipulations that test well-defined hypotheses. Additionally, monitoring programs must be designed in a manner that mimics the natural hierarchy of both individual and cumulative ecosystem responses to management actions (e.g., at the site, segment, watershed, and basin scales). These requirements emphasize empiricism as the basis for iterative management strategies that facilitate changes to institutional behaviors, responding to new information generated as the result of management actions. They call for a fundamental shift in the way natural resource institutions view monitoring: from a "follow-up" activity that responds to management actions to an organizational framework that provides guidance to designing management or restoration activities. Fundamentally, they underscore the need for monitoring programs that are designed *prior to* management and restoration planning, highlighting the importance of a proactive approach to iterative, self-correcting management actions.

For several reasons, we are reticent to refer to our proposal as a new means of implementing "adaptive management." First, the phrase "adaptive management" has been used so broadly that it is now virtually meaningless. It has been applied to nearly every form of proposed iterative management strategy, from Holling's Adaptive Management to the ill-defined and freewheeling form we term socio-political adaptive management (which is to say that the term refers to everything from HAM to SPAM). Second, the term "adaptive" connotes a *reactive* approach to management, perhaps contributing to the bastardization of the phrase "adaptive management" away from Holling's original (proactive) vision. We therefore use "Empirical Management" as a term to describe our proposed approach (Figure 3). The phrase "Empirical Management" emphasizes the need for up-front scientific experimental design in the form of a well-planned monitoring experiment that should apply equally well to traditional resource management or ecosystem restoration activities.

As originally conceived, adaptive management requires the development of "contingency plans" (Holling 1978; Walters 1997), that define ahead of time the change you will make if your implemented strategy fails to produce the desired results. This remains an important element of any iterative, self-correcting management strategy including Empirical Management. With its focus on up-front experimental design, however, Empirical Management provides a means of developing contingencies by allowing the simultaneous testing of multiple approaches within the context of a single, rigorous experimental design. This is especially important in cases where "new" land management guidelines are being used in hopes of increasing the level of protection to aquatic and riparian habitats associated with river systems. It is equally true where multiple stream restoration projects are advanced as part of an overall recovery strategy.

It makes little difference whether Empirical Management is truly a new approach, a modification of adaptive management, or simply a new name for

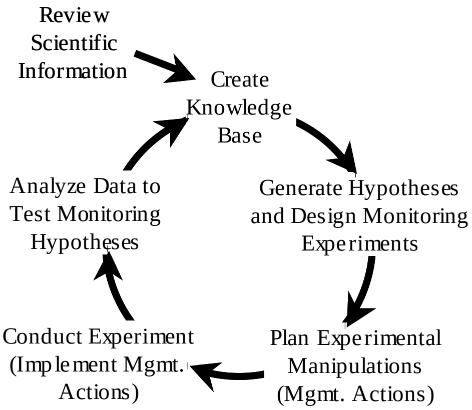

Figure 3. Schematic of the Empirical Management paradigm.

Holling's original vision. Regardless, the important characteristics of the Empirical Management process are: (1) developing the monitoring plan as the first step in the process of defining the management plan; (2) developing the monitoring plan as a statistically sound scientific experiment; (3) designing the monitoring experiment to capture ecosystem responses across spatial scales; and (4) using the experimental design of the monitoring strategy to guide management activities so that on-the-ground actions will serve as effective experimental manipulations at multiple spatial and temporal scales. Failing to consider any of these characteristics will substantially reduce the rate at which new information is generated and its overall quality.

CONCLUSIONS

> Many have begun to understand that you can't possibly manage what you don't measure. (Law Professor Deborah Ramirez, Northeastern University, speaking on the need for police departments to monitor racial profiling by their officers. All Things Considered, National Public Radio, July 12, 2001)

In order to implement Empirical Management or any similar strategy successfully, managers must broaden their expectations for management actions to include the need to generate new information. This is true for management actions and restoration activities alike. These actions must be implemented as experimental manipulations that support well-planned monitoring experiments designed to generate new information. This blurs the line between research and management/restoration, and it will likely require close collaboration between university research scientists, who have the requisite skills to design effective monitoring experiments, and land management agencies with the budgets and mandate to perform large-scale manipulations of ecosystems. Although this task is daunting, successful ecosystem management and restoration depends on learning from our mistakes and adapting our practices accordingly (McLain and Lee 1996; Lee 1999).

For a variety of reasons, contemporary approaches to adaptive management preclude iterative, self-correcting management approaches by promising but failing to implement adequate and integrated monitoring programs. In contrast, Empirical Management provides a framework for implementing management and restoration activities as part of an integrated monitoring experiment, thereby improving our ability to generate new knowledge about ecosystem response to resource management/restoration. If paired with an improved means of encouraging public acceptance of reliable scientific information, Empirical

Management may provide a means to facilitate an iterative, self-correcting management or restoration strategy. The importance of adopting an Empirical Management approach is illustrated by reconsidering Lee's (1999) three conclusions regarding adaptive management (Table 1). By putting monitoring first, Empirical Management could: (1) avoid the pitfalls of contemporary approaches to adaptive management (Figure 2c) that preempt development of new insights, (2) force all parties to agree on the list of key questions to be answered, and (3) provide reliable scientific information as the basis for social learning by integrating management/restoration actions into a well-designed monitoring experiment.

ACKNOWLEDGEMENT

Partial funding for this work was provided by Region X of the U.S. Environmental Protection Agency.

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