An Effectiveness Monitoring Program for the Northwest Forest Plan: New Approaches to Common Monitoring Problems

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Abstract.—The Northwest Forest Plan is a large-scale ecosystem management plan for federal lands in the Pacific Northwest of the United States. An effectiveness monitoring program has been developed to determine the extent to which the goals and objectives of this Plan are being achieved. Priority resources identified for ecological monitoring include late-successional and old-growth forests, northern spotted owls, marbled murrelets, and aquatic and riparian ecosystems. The challenge in developing the monitoring program has been to integrate all of these critical components into one efficient and responsive program. Our method has been to develop a common prospective monitoring approach, conceptual framework, indicator selection strategy, monitoring design, and data assessment and reporting process. This paper discusses how our proposed approach addresses some common problems encountered by other monitoring programs. We discuss four major areas of utility to others developing ecological monitoring programs: linkage to decisionmaking, basis for indicator selection, ecological foundation for monitoring, and data quality and accessibility.

The Northwest Forest Plan (Forest Plan) represents one of the largest and most comprehensive ecosystem management plans in the world (USDA/USDI 1994). This 100-year plan encompasses 24 million acres of forested lands on 25 management units administered by the U.S. government (18 national forests and 7 Bureau of Land Management Districts) covering northern California, western Oregon, and western Washington. Much of this federal land is intermingled with state and private ownerships. A primary management goal on all lands has been timber management. The Forest Plan was developed in 1993 at the direction of President Clinton to help resolve the conflict over timber management and protection of natural resources such as the northern spotted owl. The plan addresses both ecological and socioeconomic goals to maintain and restore biodiversity, late-successional and old-growth forest ecosystems, sustainable levels of renewable resources, and rural economies. Since forest management is more than a timber management issue, the plan encompasses multiple resource values, and includes management for thousands of terrestrial and aquatic species as well as natural and human-caused processes. The scale and magnitude of this plan represents unique challenges in ecosystem management, adaptive management, and ecological monitoring.

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Forest Plan Monitoring

Monitoring all these resources is required by the Forest Plan (USDA/USDI 1994), by applicable laws, and by the courts (Dwyer 1994). Of the three types of monitoring required by the Forest Plan, our efforts to develop a monitoring program addressed only effectiveness (status and trend) monitoring; implementation (compliance) monitoring was developed earlier, and validation (cause and effect) monitoring has not yet been addressed. The primary question effectiveness monitoring addresses is "To what extent are the goals and objectives of the Forest Plan being achieved?" Because of the huge number of resources and issues that could be monitored, initial direction was given to focus on high priority ecological issues, specifically late-successional forests, the northern spotted owl (*Strix occidentalis caurina*), the marbled murrelet (*Brachyramphus marmoratus*), and riparian and aquatic resources; future planning will focus on biodiversity, socioeconomics, and tribal resources. The monitoring results from these efforts will not only address the status of each resource, but will also collectively help address the adaptive management question about the effectiveness of the Forest Plan in meeting its ecological and socioeconomic goals at periodic intervals over the 100-year period.

To develop a monitoring program of this scope, the agencies involved in the Forest Plan established a team of knowledgeable scientists and resource experts. After an extensive review of the scientific literature, including monitoring of literature from a variety of disciplines, they realized there are not many large-scale or successful

ecological monitoring efforts that can help in developing and implementing a program of this nature. Most documented efforts are conceptual, or they focus on planning and indicator development. Reviews of these programs have documented the problems with both developing and implementing successful monitoring, and the team used the ideas gained from these experiences to develop a framework for an implementable monitoring program to support the Forest Plan (Mulder *et al.* 1999).

LESSONS FROM EXISTING ECOLOGICAL MONITORING PROGRAMS

Although the term monitoring is widely (and maybe too loosely) used, there is little successful experience that contributes to developing a large-scale, long-term monitoring program of the scope and magnitude of the Forest Plan. Monitoring is routinely mentioned in the ecosystem and adaptive management literature as integral to these concepts, but little is said about the difficulty of developing or implementing a monitoring program and little guidance is provided to develop an implementable program that produces the data needed to manage natural resources. In government, monitoring of natural resources has not been routinely nor consistently applied, particularly for large-scale or multiple resource issues (Bella 1997). In most cases, monitoring is handled as unrelated ad hoc activities left to local handling, and funded if or when funds are available. We believe this is due mostly to a lack of understanding of what monitoring is or needs to be, a failure that is not helped by the understatements about monitoring in the literature.

In the development of this monitoring program, existing and planned monitoring programs were reviewed to serve as examples in developing the program for the Forest Plan, but few examples of successful monitoring programs for large-scale ecosystems were found (Noon *et al.* 1999). Most ecological monitoring has focused on single resources often because single issues drive current concerns (which affects funding availability), but also because it is easier to design a program that addresses individual issues. These efforts collect considerable but not necessarily useful data or data that can be integrated across multiple resource values. This review also noted that these types of programs have not contributed to informed management decisions or proved valuable in averting biological crises (NRC 1990, U.S. GAO 1988). In particular, EMAP, one of the largest monitoring programs, has not only shown little evidence of success, but has also been heavily criticized both scientifically and technically (for example, NRC 1995). The review concludes that a fundamental reason for continued failure in the consistent application of monitoring programs may be that the costs are perceived as high in relation to the output, particularly when the output is perceived as an indication of the failure of managers. Thus, there is a reluctance to invest in monitoring by managers, policymakers, and the public.

Monitoring is also more complex than most people or agencies realize, particularly at this scale, and our lack of understanding of ecosystems adds to the complexity. Monitoring is often presented in conceptual or theoretical terms but with insufficient supporting foundation, is vague about what to measure, or lacks focus on key (measurable) variables. Monitoring programs regardless of their scale have mostly (and often extensively) focused on sampling design and methods to measure indicators, but with little thought given to why those indicators need to be measured, what thresholds of change (in the indicator) would result in changes in management, or what types of change (in management) could be made. From the management side, monitoring normally is not institutionalized as a resource program, and so lacks connections to the agency or its decision and budget processes. Agencies exert considerable effort toward data collection, but little if any effort is made on data quality, management, assessment, or reporting to effectively use those data. In summary, it is not surprising that there is little understanding, and in particular, little interest in monitoring. The result, as the review points out, is that most monitoring is given low priority, usually not fully implemented, and almost always insufficiently funded.

APPROACH RECOMMENDED FOR EFFECTIVENESS MONITORING FOR THE NORTHWEST FOREST PLAN

Given the above concerns, the task facing the team was how to construct a monitoring program for the Forest Plan that would address multiple resource issues, would do so in a (relatively) cost-effective manner, and would demonstrate utility toward informing management decisions and policy about future resource management. The lessons learned through our exercise, as discussed in this paper, are applicable to most types of monitoring programs. Rather than providing a summary of the proposed program (Mulder *et al.* 1999), this paper shows how our approach addresses the common problems encountered by other ecological monitoring programs. The four common problems we have selected to discuss are as follows:

1. No link to decisionmaking,
2. Poor basis for indicator selection,
3. Little ecological or scientific foundation, and
4. Lack of emphasis on data quality and accessibility

It is believed that these concepts will be of general utility to others developing ecological monitoring programs.

Linkage to Decisionmaking

The long-term viability of a monitoring program is very much dependent on its support from management. To be supported, a monitoring program must demonstrate its value to management on an ongoing basis. Of particular importance is to make monitoring results an integral component of the decisionmaking process. Developing this linkage to decisionmaking is a challenging task. Our approach considers three separate concepts–all of which contribute to establishing this linkage. These include organizing monitoring within the framework of adaptive management, developing a prospective approach to monitoring that anticipates the results of management decisions, and defining a process of reporting whereby monitoring data are turned into useful information or knowledge for decisionmaking through specific activities.

Adaptive Management

The traditional approach to natural resource management has been to focus considerable effort on initial planning and the implementation of those plans without an ongoing evaluation of the outcomes of those activities. The adaptive management approach has been suggested as a way to improve management over time by allowing for periodic changes in management actions when deemed appropriate (Walters 1986). The role of monitoring in adaptive management is to detect long-term environmental changes, to provide insights to managers about the ecological consequences of these changes, and to help determine if observed changes dictate corrections to management actions (fig. 1).

As shown on the bottom of the figure, a management action leads to a change in environmental condition. The purpose of the monitoring program is to record these changes through measurements and observations. These data must then be summarized and interpreted to assist in improved future decisions. For example, if certain action thresholds for priority resources have been reached, then this information can be reported to management for their evaluation. The adaptive management cycle continues as new decisions are implemented leading to other changes in the environment that are also monitored. Given this model, it is evident that monitoring is conceptually a core component of the adaptive management process. Our approach is constructed to facilitate the adaptive management process for decisionmakers.

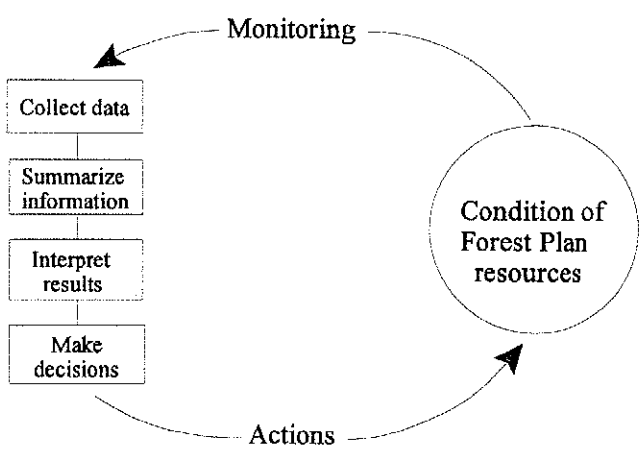

Figure 1.—*Adaptive management cycle where monitoring plays a major role by taking measurements and making observations of key resources to assist in decisionmaking (Adapted from: Keune and Mandry 1996).*

Prospective Monitoring

Monitoring is defined as the "measurement of environmental characteristics over an extended period of time to determine status or trends in some aspect of environmental quality" (Suter 1993). Two different approaches have been suggested to monitoring–retrospective and prospective or predictive (NRC 1995). The retrospective or effects-oriented monitoring approach evaluates changes over time and seeks to explain these changes. Predictive or stress-oriented monitoring also seeks this understanding and then attempts to predict future changes before they become serious. The retrospective approach focuses primarily on measuring ecological effects such as population changes in specific species resulting from stressors that are causing significant ecological effects. The goal of the monitoring program is not only to evaluate current condition, but also to predict future conditions based upon different management scenarios (fig. 2). The prospective approach includes the monitoring of the ecological stressors such as the loss or fragmentation of habitat in addition to the ecological responses to these influencing factors. The prospective approach then anticipates future change based upon a clear understanding of the relationship between stressors and ecological responses.

Given the long delay projected by the Forest Plan between the time that management actions are taken and the response of the ecosystems to those actions, the approach selected for effectiveness monitoring includes retrospective monitoring but has a primary focus on prospective monitoring. During the initial phases of monitoring, measurements of stressors and associated effects of interest will be conducted to assist in the construction of predictive models. Over time, monitoring will emphasize stressor indicators with the use of these predictive models to estimate emerging effects including ecosystem recovery due to the removal of stressors. With an emphasis on anticipated cause-effect relations, an earlier and more focused management response to environmental change is expected. It is also felt that by providing options to

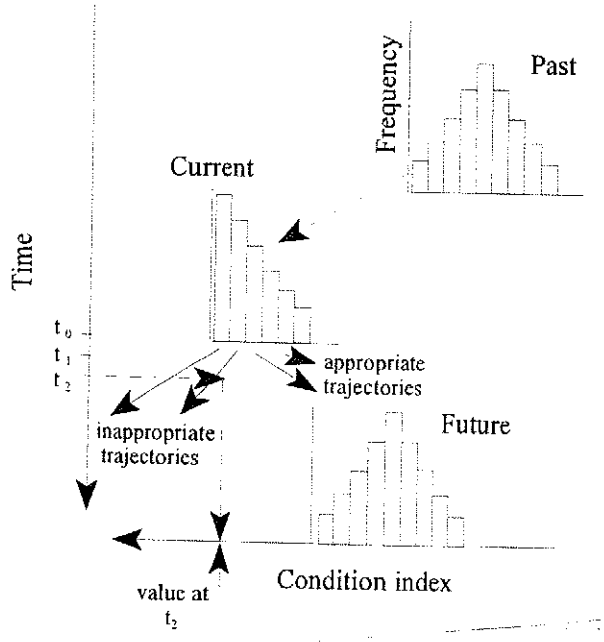

Figure 2.—*Illustration of indicator values showing environmental condition on the landscape at various times where current-to-future changes are a consequence of management intervention (From: Noon* et al. *1999).*

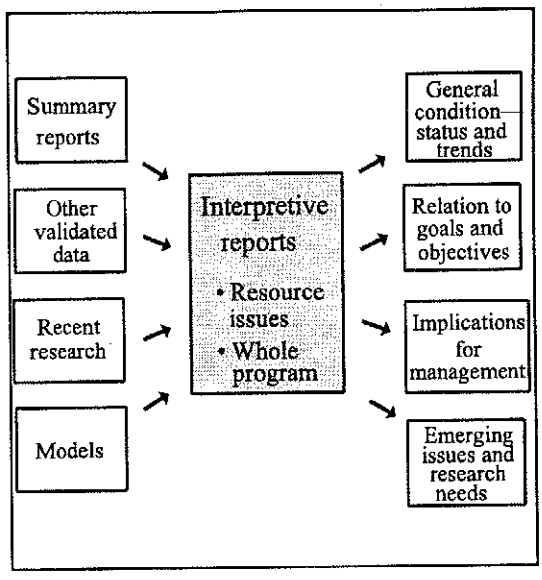

Figure 3.—*Information sources and topics addressed in effectiveness monitoring (From: Palmer and Mulder 1999).*

management regarding potential future scenarios, monitoring will become a more integral component of decisionmaking.

Reporting

The purpose of reporting in monitoring is to change measurement data into useful information and knowledge for improved management decisions. Many monitoring programs have collected vast amounts of data without making this important step of interpreting their utility. Our suggested approach is to consider the reporting process as a series of steps (fig. 3). Data are first turned into information when they are collated and summarized. Summary reports would be prepared each year for monitoring data collected for each priority resource module of the effectiveness monitoring program. This is an important first step in the reporting process and provides the added benefit of ensuring that data are organized, validated, analyzed, and reported on a regular basis.

To turn the information provided in summary reports into the knowledge required by decisionmakers, an important second step needs to be taken; the preparation of periodic interpretive reports. These reports consider summary reports, historical as well as all other available data, results of implementation and validation monitoring, research, and ecological models to answer important monitoring questions (fig. 3). This step requires significant effort and planning, but the products of these efforts should be of considerable interest to land managers, policymakers, and scientists. The first interpretive report for the effectiveness monitoring program, planned for the year 2000, will provide the baseline for measuring future change.

Indicator Selection

The environmental attributes measured or estimated from a combination of other measurements in a monitoring program are often called "indicators" under the assumption that their values are somehow indicative of the quality, health, or integrity of larger systems (Hunsaker and Carpenter 1990). The selection of indicators for a monitoring program is a very critical step. Even if a monitoring program is fully funded and implemented for many years, it will not achieve its objectives if the wrong indicators are chosen.

Many different approaches have been used for the selection of indicators for monitoring programs. One approach is to select indicators that monitor important values or resources of interest to management. Another approach is to select indicators that make use of the latest technology such as remote sensing and then attempt to interpret monitoring results. Another common method is to convene a workshop and have experts suggest indicators for monitoring and then select priority ones through consensus.

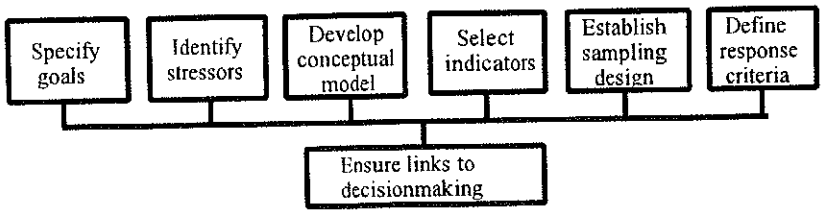

Figure 4.—*Steps in the selection of indicators and development of a monitoring program (From: Noon* et al. *1999).*

Due to our decision to adopt a prospective monitoring approach, a seven-step process (Noon *et al.* 1999) was developed for the selection and implementation of indicator measurements in effectiveness monitoring (fig. 4). The first step is to specify the goals of the monitoring program. The approach we used was to request that each priority resource module develop a list of monitoring questions they would attempt to answer through their monitoring efforts. The process of selecting and reviewing these monitoring questions resulted in a clear definition of the goals for the monitoring program. It was interesting to note that the monitoring questions also suggested attributes or indicators to measure. For example, one monitoring question from the late-successional forests module was: What are the amounts and distribution of forest age classes (including late succession and old growth) at the landscape scale?

The second step is to identify the environmental stressors (natural and anthropogenic) that may compromise the integrity of the ecosystems and their component species and resources. Examples include fire, landscape fragmentation, sediment loading, overharvesting, water diversions, or pollution. To aid in the process of indicator selection, the ecological resources likely to be affected by any given stressor should be identified. It is helpful to consider these for landscape, community-ecosystem, population-species, and genetic components of ecological hierarchies.

The third step is to develop a conceptual model of the relationships between the stressors and ecological responses. This step is often overlooked but is critical to the selection and interpretation of indicator information. Indicators should be selected based on a conceptual model that clearly links stressors and indicators with pathways that lead to effects on ecosystem structure and function (see following section for more discussion on the conceptual model). Once the conceptual model has been completed, candidate indicators can then be selected for monitoring (fourth step).

The fifth step is to establish a sampling design to estimate status and trends for the indicators. One of the most difficult challenges is to determine the value of change in an indicator that indicates a significant biological effect with an acceptable level of uncertainty. With an understanding of the natural spatial and temporal variation in the indicator, a sampling design can be developed to estimate status and trends in the resources of interest.

The sixth step is to determine expected values and trends in the indicator that will trigger a management response. It is recognized that establishing response criteria is difficult due to our incomplete understanding of ecosystems, the lack of pristine ecosystems for benchmark conditions, and nonlinear relations between indicator values and ecosystem processes. The final step, as noted earlier, is to link indicator results to the decisionmaking process through reporting efforts that include data summarization and interpretation with tools such as modeling and statistical decision theory (Conroy and Noon 1996). However, to ensure that this link will take place, it is important to consider the linkages to the decisionmaking process during all previous steps as depicted in figure 4. These last steps are difficult due to our lack of understanding of ecosystems, and require further research.

Ecological Foundation

When developing an ecological monitoring program, it is important to base the scientific approach on a foundation in ecology. Our approach has been to develop a conceptual model for the overall program that can be used as a basis for the establishment of more detailed models for each of the priority resource modules (fig. 5). One conceptual model we have chosen simplifies ecosystem

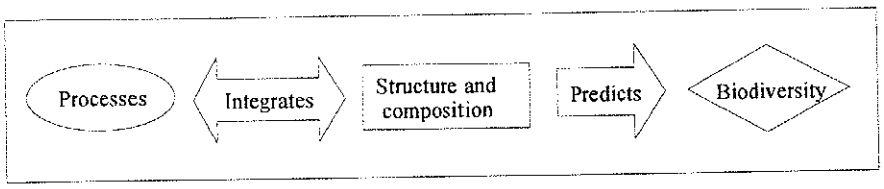

Figure 5.—*Generalized conceptual model illustrating the basis for identifying biological indicators from structural and compositional elements (From: Noon* et al. *1999).*

monitoring by focusing on the structure and composition elements (both landscape as well as stand and microsite characteristics) that express the underlying process and function of the ecosystems (Noon *et al.* 1999). By evaluating these elements in terms of habitat suitability, we hope to provide a substitute for the direct monitoring of numerous biotic populations.

The decision to monitor habitat rather than biotic populations is based on pragmatic as well as theoretical considerations. Our goal is to provide a transition from intensive, individual species monitoring to a more extensive ecosystem approach. The theoretical argument is based on the belief that animals respond to habitat adaptively (Noon 1986). Where an animal selects to live is believed to be an evolved behavioral response stimulated by structural and compositional features of the landscape. The pragmatic argument is that a habitat focus is more in line with land management agencies' missions to manage vegetation communities (habitat), not species populations directly. Monitoring vegetation change is less costly and builds upon existing forest inventory programs. In addition, future changes in forest composition and structure can be predicted through the use of available forest succession models.

The transition to the use of habitat as a surrogate for biotic populations assumes that variables exist that allow for reliable inferences about the integrity of biotic populations of interest. During the initial phases of our monitoring program, we plan to construct predictive models relating habitat to populations. These models will be subject to validation. This validation will be conducted at all spatial scales including the scale of the individual, the local population, and the overall population. A gradual transition will then occur from the monitoring of individual species to the monitoring of habitat with a periodic re-evaluation of the reliability of the predictive models.

Data Quality and Accessibility

The effectiveness monitoring program will build as much as possible upon existing monitoring and inventory programs to help reduce costs. Therefore, it will be important to identify those monitoring programs that can provide essential information for effectiveness monitoring. A diagram identifying the different types of existing programs is presented in figure 6. Our approach will be to first identify those programs providing critical information. Formal ties to these programs will be established including direct data linkages and quality assurance oversight to foster data quality and comparability. Additional effort will also be undertaken to identify those programs providing useful information to effectiveness monitoring for use in interpretive reports.

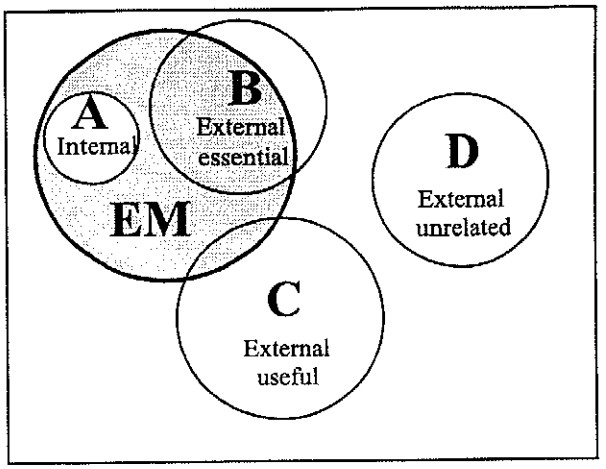

Figure 6.—*Illustration of how data collection activities are related to effectiveness monitoring. EM = data collection needs of effectiveness monitoring; type A = data collection initiated solely for the effectiveness program and internal to it; type B = data collection, initiated for other purposes, that makes a significant contribution to the data requirements of effectiveness monitoring; type C = data collection that provides useful, but not critical data; and type D = data with no apparent connection to the effectiveness monitoring program (From: Palmer and Mulder 1999).*

Finally, regional monitoring programs of the scope of effectiveness monitoring for the Northwest Forest Plan will rely on data collected by a large number of different groups over a long period of time. To be of value, these data must be reliable and comparable. One approach to ensuring data quality is to establish a structured quality assurance program. Quality assurance has been defined as "an integrated system of management activities involving planning, implementation, assessment, reporting, and quality improvement to ensure that a process, item or service is of the type and quality needed and expected by the customer" (ANSI 1994). Although the development of structured quality assurance programs is more common in environmental monitoring programs funded by regulatory agencies, this is a new activity for ecological monitoring programs conducted by land management agencies. However, it was felt that this approach must be followed for effectiveness monitoring to be successful.

CONCLUSIONS

The answer as to whether our approach to addressing the issues presented above will overcome the rather poor legacies of other monitoring programs can come only over time from the test provided by implementation of the program for the Forest Plan. To accomplish this, a

number of technical, institutional, and philosophical barriers or challenges need to be overcome; we didn't or couldn't attempt to address them all. For now we believe our focus on a structured and comprehensive approach to development and implementation of a monitoring program for the Forest Plan provides a template for success and is cost effective. The approach emphasizes a scientific foundation for monitoring design, based on the use of conceptual models supported by ecological theory and empiricism to identify appropriate indicators for measurement. This allows a gradual transition from an intensive, single issue focus to an extensive, ecosystem approach that provides periodic reports and interpretations of monitoring results to inform decisionmaking through an infrastructure built around data quality, management, assessment, and reporting.

Future Challenges

Other challenges must also be addressed. Many critical scientific questions surrounding the underlying theory and concepts of ecosystem monitoring can be addressed only through concurrent research that supports the monitoring program, such as developing and refining indicators, developing and testing indicator thresholds for management change, developing predictive models to assess management options, and addressing uncertainty in the monitoring results to help in decisionmaking. The difficulty of addressing these issues is compounded by the large spatial scale of the Forest Plan. As such, research and monitoring are inseparable programs, a fact that unfortunately is not part of our current agency culture.

By far the most critical challenge may be how to institutionalize monitoring into agency cultures as a full resource program with permanent staff, management, and long-term funding—a task that needs to be addressed by management, not research. However, moving to initiate such a fundamental change in agency operations depends on how managers, policymakers, and the public respond to the proposals in this plan. In times of budget shortfalls, the outlook is not positive. Key to this may be in understanding the role and importance of monitoring in adaptive and ecosystem management, and the need for the science community to help provide a basis for understanding, accepting, and desiring a monitoring program and its results. Monitoring and adaptive management should be viewed as synonymous and integral to successful resource management whether it be in support of ecological or socioeconomic goals and where the cost is an accepted part of doing business.

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