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The Strategy and Design of the Effectiveness Monitoring Program for the Northwest Forest Plan

Technical Coordinators

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Abstract

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This report describes the logic and design of an effectiveness monitoring program for the Northwest Forest Plan. The program is prospective, providing an early warning of environmental change before irreversible loss has occurred. Monitoring is focused at two resource levels: individual species and specific ecosystem types. Selection of prospective indicators for the status of species or ecosystems is based on the development of conceptual models relating resource change to reliable, early warning signals of change. Ecosystems, such as late seral stage forest communities, are monitored on the basis of critical structural and compositional elements that reflect the state of underlying ecological processes. The assumption is that systems retain their ecological integrity to the extent that key biotic and physical processes are sustained. For species of concern, the design integrates animal populations with their necessary habitat and projects changes in population status by monitoring significant changes in habitat at several spatial scales. Anticipatory forecasting of changes in population status assumes habitat to be a reliable surrogate for direct population measures. A surrogate-based approach requires an active period of model building that relates population to habitat variation to develop robust wildlife relation models. Essential components needed for program implementation, such as data collection, information management, report preparation, and feedback to management, are discussed. This discussion includes recommendations for staffing, funding, and establishing a long-term commitment for a large, interagency monitoring program.

Keywords: Northwest Forest Plan, ecological monitoring, effectiveness monitoring, adaptive management, regional scale, habitat basis, conceptual model, predictive model, integration, summary report, interpretive report, institutionalize.

Preface

Under the direction of an Intergovernmental Advisory Committee that oversees the implementation and management of the Northwest Forest Plan, interagency Federal teams have been developing a monitoring program to evaluate the success of the Forest Plan. This complex and challenging task has required a large commitment of time and agency expertise. This report represents another important step in implementing a comprehensive monitoring program for the Forest Plan, a program that eventually will cover the three types of monitoring required by the plan: implementation, effectiveness, and validation monitoring. Overall direction for monitoring under the Forest Plan began with the description of the key role of monitoring in adaptive management outlined in FEMAT (July 1993), defined in the interagency report entitled "Interagency Framework for Monitoring the President's Forest Ecosystem Plan" (March 1994), and summarized in the record of decision for the Forest Plan (April 1994).

This report is the second in a series that addresses effectiveness monitoring. The first report, "Effectiveness Monitoring: An Interagency Program for the Northwest Forest Plan" (July 1995), describes the general framework for effectiveness monitoring under the Forest Plan. The approach was accepted by the Intergovernmental Advisory Committee and approved as the appropriate direction for developing an effectiveness monitoring program. This second report, after taking into consideration all peer, agency, and other reviews, concludes development by the Effectiveness Monitoring Team of the overall strategy and guidance for effectiveness monitoring. The strategy described here has not changed from that reviewed and accepted by the Intergovernmental Advisory Committee; this document incorporates edits, clarifications, and further background material, as requested.

This report represents a further step in our understanding of and approach to ecosystem monitoring. It provides the scientific basis for the effectiveness monitoring program; separate reports or modules provide specific options for monitoring assigned priority resources: late-successional and old-growth forest, northern spotted owl, marbled murrelet, and aquatic and riparian ecosystems; and monitoring plans for survey-and-manage and other late-successional and aquatic species. Reports on other issues, such as socioeconomic and tribal, will be developed in the future. Our approach, described here, provides the template for designing these and other monitoring modules to help address the Forest Plan.

The effectiveness monitoring program will consist of many modules and their supporting guidance and plans. This report and the individual reports or modules for the individual resources respond to the assignment to identify a range of options for monitoring these issues from which the Federal agencies can select an appropriate approach (or approaches). Because of the complexity of the science related to this issue, the Federal research agencies (USDA Forest Service, Environmental Protection Agency, and U.S. Geological Survey—Biological Resources Division), at the request of the Intergovernmental Advisory Committee, took responsibility to establish the underlying scientific framework and develop monitoring options. Federal agency selection of a set of options will trigger the third and final stage in the development of an effectiveness monitoring program: assignment by the agencies of the plans, people, and funding to implement the program. The completed set of documents will function as integrated guidance to Forest Plan monitoring.

The Effectiveness Monitoring Team

Executive Summary

The Northwest Forest Plan is a large-scale ecosystem management plan for Federal lands in the Pacific Northwest, encompassing 24 million acres of federally managed forests over 18 National Forests and 7 Bureau of Land Management Districts in northern California, western Oregon, and western Washington. Three types of monitoring are mandated by the Forest Plan: implementation, effectiveness, and validation. The purpose of this report is to provide the strategy and design for effectiveness monitoring of priority resources identified in the Forest Plan.

The primary goals and objectives for the Forest Plan are both ecological and socioeconomic. In the context of the Forest Plan, the primary question that effectiveness monitoring is designed to answer is, “To what extent are the goals and objectives of the Forest Plan being achieved?” Following the goals and objectives of the Forest Plan, the basic scientific premise underlying the proposed program is to implement a predictive and integrated habitat-based approach to monitoring, intended to produce useful and timely results more efficiently and cost-effectively than past programs have.

The general approach for developing the effectiveness monitoring program has been to develop the scientific framework for monitoring; this document describes that approach. The approach has been used in developing monitoring strategies for specific priority resources identified by management, including late-successional and old-growth forests, northern spotted owls, marbled murrelets, and aquatic and riparian ecosystems. This document also provides the basis for designing future monitoring modules that may address other important resource issues (for example, socioeconomic, tribal, survey-and-manage species, or other species associated with late-successional or aquatic ecosystems).

The goals for effectiveness monitoring are to evaluate the success of the Forest Plan by assessing the status and trends of selected resources. These goals are consistent with emerging national and international frameworks for monitoring. The program outlined in this report is designed to build on and improve ongoing monitoring activities of regional as well as local forest management units to accomplish these goals. Its scope and complexity, however, mean that it will be significantly different from how agency activities have traditionally been monitored, a difference that will lead to a change in thinking about how to manage and operate a monitoring program.

Scientific Approach

The task of developing a monitoring system to detect and recognize significant change is complex because natural systems are inherently dynamic and spatially heterogeneous. Further, many changes in space and time are not a consequence of human-induced actions, and many are not amenable to management intervention. It is not surprising, therefore, that few examples exist of successful monitoring programs at the ecosystem scale. Environmental monitoring programs often are discussed in abstract terms, have little theoretical foundation, try to measure too many attributes, have vague objectives, and have no institutionalized connections to the decision process. In times of budget reductions, monitoring programs can be the first to be eliminated.

To be most meaningful, a monitoring program should provide insights into cause-and-effect relations between environmental stressors and anticipated ecosystem responses. Indicators should be chosen based on a conceptual model clearly linking stressors and indicators with pathways leading to effects on ecosystem structure and function. This process enables the monitoring program to investigate the relations between anticipated stressors and environmental consequences, and provides the opportunity to develop predictive models to anticipate trends instead of waiting until trends have been demonstrated.

The emphasis chosen for effectiveness monitoring of the Forest Plan may best be described as prospective monitoring. This approach incorporates causal relations between effects and stressors through the judicious selection of indicators. It starts with characterizing threats (stressors) to the ecological integrity and ecosystem functioning (effects) of the management unit. A conceptual model then outlines the pathways from the stressor(s) to the ecological effects. Attributes indicative of the anticipated changes in specific ecological conditions are then selected for measurement. The ultimate success of this approach depends on the validity of the assumed cause-effect relations between the stressor(s), their ecological effects, and the selected indicators of stress.

The essential steps, described in the scientific literature, that we followed in developing the approach to the effectiveness monitoring program for the Forest Plan were:

1. Specify goals and objectives

2. Characterize stressors and disturbances

3. Develop conceptual models—outlines the pathways from stressors to the ecological effects on one or more resources

4. Select indicators—detects stressors acting on resources

5. Determine detection limits for indicators—to guide sampling design

6. Establish “trigger points” for management intervention

7. Establish clear connections to the management decision process

Given the great diversity of species—plant and animal, vertebrate and invertebrate—monitoring of all biotic components of managed ecosystems is clearly impossible. Based solely on pragmatic considerations, only a few surrogate measures can be used that allow indirect (but reliable) inference to the integrity of the larger set of biological processes and components. A possible surrogate for the biota is to measure the pattern and dynamics of habitat structure.

The justification for using habitat structure as surrogate variables for predicting wildlife populations is based on both pragmatic and theoretical arguments. Habitat loss and fragmentation were the primary drivers or stressors behind creation of the Forest Plan. The theoretical argument is based on the belief that animals respond to habitat adaptively; that is, where an animal selects to live is believed to be an evolved behavioral response stimulated by structural and compositional features of the landscape. Predictive habitat suitability models will need to consider the relations between landscape pattern and life history characteristics of individual species and population-scale dynamics to provide a realistic portrayal of potential trends. The assessment strategy, which emphasizes both remotely sensed and ground-plot habitat data, should allow inferences about habitat quality at different spatial scales across a range of resource issues.

The foundation of our approach to effectiveness monitoring for the Forest Plan is to initiate a gradual transition from an intensive, individual species-resource focus to a more extensive, ecosystems approach. This transition assumes identifying and measuring surrogate variables that allow reliable inferences about the integrity of the primary resources. Such a fundamental shift means a movement away from the current crisis response to individual endangered species-resource issues, to a prospective evaluation of management decisions in an ecosystem context. The transition to a habitat-based monitoring program has several advantages:

- Monitoring vegetation change will be more cost-effective than directly monitoring populations of all the possible species for which agencies are responsible
- Existing forest inventory programs can be the foundation for monitoring programs
- A habitat focus is more in line with the mandates of the Forest Plan to manage vegetation communities (habitat), not species populations directly
- Estimating the trends in habitat structure and composition represents an anticipatory as opposed to a retrospective approach to ecological monitoring, and allows evaluation of alternative management strategies

Approach to Management

To be successful, a monitoring program must be able to collect data, summarize the data into useful information, and interpret that information to advance understanding and knowledge to improve management decisions. Key components of a structured monitoring program include data collection, information management, preparation of data summaries and interpretive reports, feedback to management, and program coordination and support.

Many inventory, monitoring, and research projects are currently collecting data of value to effectiveness monitoring in the region of the Forest Plan. Rather than duplicate these efforts, we recommend building as much as possible on ongoing data collection activities. Coordination among these programs will be encouraged through direct staff links, direct data links, and quality assurance systems.

Two types of reports are integral to the effectiveness monitoring program: data summaries and interpretive reports. Data summaries are brief, comprehensive reports of essential data collected for effectiveness monitoring and are to be produced annually for each resource being monitored. The key products of the effectiveness monitoring program will be periodic regionwide interpretive reports produced at 5-year intervals. The purpose of interpretive reports is to evaluate the ecological significance of status and trends emerging in the monitoring data in relation to the Forest Plan, and to provide statements of the implications of monitoring results, documented in the summary reports, to management; pertinent information from other sources or lands also would be considered. The resulting information is critical to adaptive management; it can be used to change plans, direction, or policies and contribute to budgetary and other decisions.

As the program develops, the challenges to success will expand because of the complexity of the data being collected. In addition to assisting in interpreting the monitoring data, research support will be needed to address emerging information needs, such as selecting new indicators and associated monitoring designs. Pilot or test studies also will offer important opportunities to test new methods and concepts, which will allow the monitoring program to be improved or adapted over time. The program must provide monitoring results that are legally defensible. Therefore, an information management and quality assurance system will be needed to assist in collecting, validating, storing, and retrieving data and in preparing reports.

Strategy for Implementation

Given the complexity of a monitoring program of this scale, magnitude, and importance, we propose that the initial goal be to develop the first regionwide interpretive monitoring report at the end of 1999. Not only will this product test the success of the program, but it also will provide the baseline for assessing future trends and offer an opportunity to adjust the program for future operation. The challenge to the effectiveness monitoring program will be to integrate all the critical components into an efficient and responsive program to meet this goal. This task is daunting, given the diversity of cooperating agencies, the number of resources being monitored, and the plethora of different monitoring groups. A primary concern has been to develop a strategy for integrating the assigned resources. Our approach has been to develop a scientific and management framework that fosters integration. The monitoring plans for each resource propose a common monitoring approach, conceptual framework, indicator-selection strategy and monitoring design, and data assessment and reporting process. Similarly, strategies to address research needs, pilot studies, data management, and quality assurance have been identified.

Because this program represents a step forward from how monitoring has been handled, specific steps will need to be taken to institutionalize all aspects of the program and to establish base funding to support program activities over the long-term. Assigning permanent monitoring staff and establishing core agency teams including program managers is critical to foster integration, management, and coordination for the monitoring program. If the approaches to staffing, data sharing, and quality assurance are followed, integrating all the monitoring efforts is likely and the information necessary for adaptive management of the Forest Plan will be available.

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Chapter 1: Introduction to Effectiveness Monitoring

Barry S. Mulder and Craig J. Palmer

Background and Purpose

In 1993 President Clinton directed the Forest Ecosystem Management Assessment Team (FEMAT) to develop long-term alternatives for resolving the conflicts over managing forest ecosystems on USDA Forest Service and Bureau of Land Management (BLM) lands in the Pacific Northwest. The analysis of the FEMAT alternatives (FEMAT 1993) in an environmental impact statement (USDA and USDI 1994a) led to adoption of the land-allocation strategy contained in the "Record of Decision for Amendments to Forest Service and Bureau of Land Management Planning Documents Within the Range of the Northern Spotted Owl" (ROD; USDA and USDI 1994b), commonly known as the Northwest Forest Plan (or Forest Plan).

The Forest Plan is a large-scale ecosystem management plan for Federal forested lands in the Pacific Northwest that covers parts of northern California, western Oregon, and western Washington (fig. 1). It encompasses 24 million acres of federally managed forest lands over 18 National Forests and 7 BLM Districts. The scale of the Forest Plan represents unique challenges in ecosystem management, adaptive management, and monitoring.

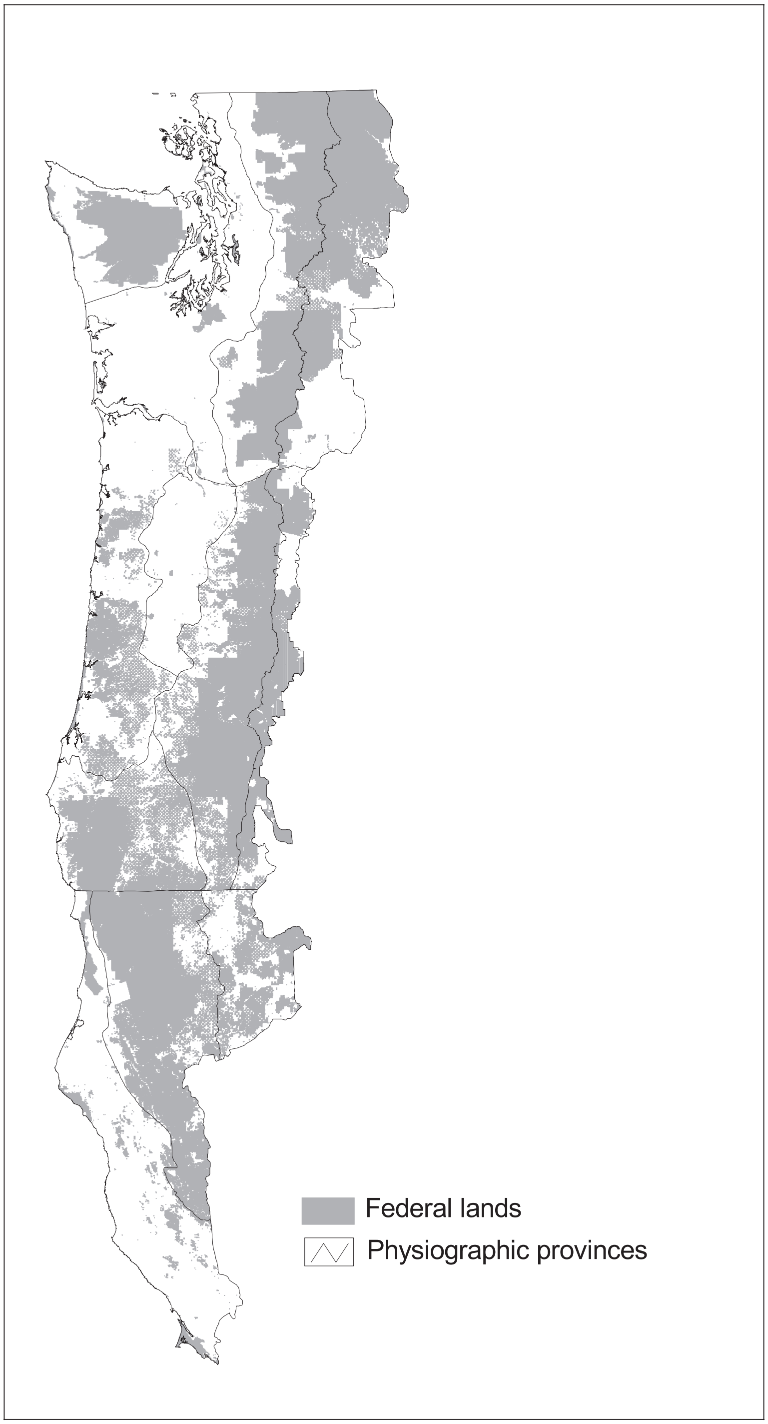

Figure 1—Range of the northern spotted owl in western Washington and Oregon and northern California.

Table 1—Criteria guiding development of the effectiveness monitoring program for the Northwest Forest Plan

Points	Criteria
1	Respond to the information needs for assessing goals and objectives of the Forest Plan
2	Follow an incremental approach to constructing a large-scale monitoring program
3	Focus on status and trend monitoring
4	Address questions at the regional or ecosystem scale
5	Apply to Forest Plan activities on Federal lands (Forest Service and BLM)
6	Consider options that are cost-effective
7	Provide a sound science-based framework for monitoring

Monitoring is required by the ROD (USDA and USDI 1994b), is mandated under applicable laws and regulations (for example, National Forest Management Act of 1976 [NFMA]; Federal Land Policy and Management Act of 1976 [FLPMA]; Endangered Species Act of 1973, as amended [ESA]), and also is an action expected by the public and interest groups (Dwyer 1994). The ROD explicitly states the need to develop a monitoring strategy for key components of the Forest Plan as part of the adaptive management process. The Forest Plan describes three types of monitoring: implementation, effectiveness, and validation. Federal agencies have taken a multi-phased approach to building a comprehensive monitoring program to evaluate the Forest Plan (Mulder et al. 1995, Tolle et al. 1994): implementation monitoring is already underway (Alverts et al. 1997, Tolle et al. 1995). This and the reports for specific resources issues, noted below, describe the strategy for effectiveness monitoring, and a future report will address validation monitoring.

The purpose of this report is to provide guidance for designing and implementing an effectiveness monitoring program for the Forest Plan. The initial resources assigned by the Federal agencies for monitoring are late-successional and old-growth forests (LSOG), the northern spotted owl (*Strix occidentalis caurina*), the marbled murrelet (*Brachyramphus marmoratus*), and aquatic and riparian ecosystems. Table 1 summarizes the general criteria that guided the planning effort of the Effectiveness Monitoring Team (EMT) for these issues (see appendix A for team membership and summary of the process).

This report describes a program that, if implemented, will generate the information needed to address whether the regional ecological objectives of the Forest Plan are being met on Federal lands in the three-State area. Ultimately, we believe that full implementation of the monitoring program will provide insights to management effectiveness for the whole Forest Plan and associated resources.

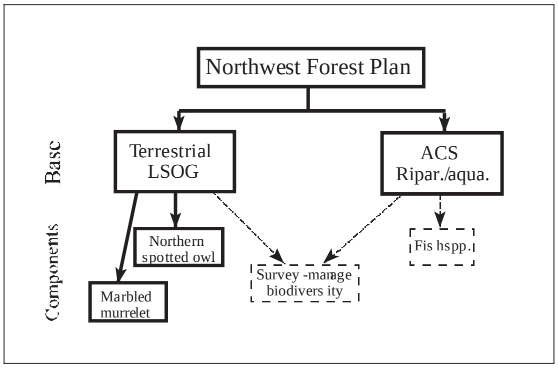

Figure 2—Forest plan conservation strategies and subcomponents that form the basis for the ecological part of the effectiveness monitoring program (note that some LSOG and ACS [aquatic conservation strategy] data are also pertinent to the socioeconomic strategy); dashed lines indicate potential monitoring issues (Mulder et al. 1995).

Role of Monitoring in the Northwest Forest Plan

The primary goals and objectives for the Forest Plan were both ecological and socioeconomic (FEMAT 1993). A regional-scale monitoring program is needed to evaluate these goals. Monitoring is intended to ascertain whether current resource conditions match an expected outcome or lie within some acceptable confidence region around that outcome. Because monitoring usually is justified by an explicit goal or mandate, any planning effort starts with determining the goals and objectives to be evaluated (NRC 1990, Noss 1990). For the Forest Plan these goals—as articulated by President Clinton at the beginning of the forest planning process in 1993—are to:

- Maintain and restore biological diversity
- Maintain long-term site productivity of forest ecosystems
- Maintain late-successional and old-growth forest ecosystems
- Maintain sustainable levels of renewable resources
- Maintain rural economies and communities

These goals were embodied in the Forest Plan under three conservation strategies (FEMAT 1993, USDA and USDI 1994b): terrestrial, aquatic, and social (see Mulder et al. 1995 for discussion of relations between these strategies; fig. 2). The primary goal for the terrestrial strategy is “to protect and enhance habitat for late-successional and old-growth forest related species.” The primary goal for the aquatic conservation strategy is “to restore and maintain the ecological integrity of watersheds and aquatic ecosystems.” The goals for the social strategy are “to provide a predictable, sustainable commodity and resource production, maximize the social and economic benefits, and assist long-term economic development and diversification.” Because the initial focus was to follow an incremental approach (table 1) in developing an effectiveness monitoring program for ecological issues, only the terrestrial and aquatic strategies have been addressed, but the approach to designing a monitoring program would be the same for any resource issue.

These conservation strategies assume successful outcomes. As such, the standards and guidelines (USDA and USDI 1994b) needed to realize them are the primary focus or the treatment being evaluated through the monitoring program. The Forest Plan assumes that if the strategies are successfully implemented, then the goals will be met. Compliance with standards and guidelines is evaluated through implementation monitoring; validation monitoring will determine the link between cause (standards and guidelines) and effect (trend). Effectiveness monitoring will establish the status and trends for selected resources under these strategies. Therefore, there is a strong link between these monitoring programs.

The goals form the basis for the questions that the monitoring program is designed to answer. These goals are redefined as general monitoring questions that provide the basis for developing more specific questions that can be addressed with monitoring data for the Forest Plan and for each individual resource (see Mulder et al. 1995 for further discussion). For example, the primary question for effectiveness monitoring to address the success of the terrestrial and aquatic strategies is, "What are the status and trends of the ecologically important habitat features and processes, and populations of key species on Federal lands[1] within the Forest Plan area?"

The general approach for developing monitoring questions for each resource follows from the primary monitoring question above and focuses on the status and trends of the resource being monitored. For example, for the northern spotted owl, the general owl question would be, "What is the status and trend of the spotted owl population and its habitat over the Forest Plan area?" This question is then subsequently subdivided into more specific questions. These more specific questions refine the monitoring goals, and suggest variables (or indicators) for measurement, based on the components of the resource assumed to be responsive to Forest Plan standards and guidelines (see monitoring modules for LSOG, northern spotted owl, marbled murrelet, and aquatic and riparian[2] for the specific monitoring questions and candidate indicators). These variables then provide the basis for developing specific monitoring tasks. Identifying quantifiable questions, measurable indicators, and the subsequent monitoring design and field protocols, along with an appropriate supporting infrastructure, are key to designing an implementable monitoring program that meets agency information needs (for example, Davis 1993, MacDonald et al. 1991, NRC 1995, Vora 1997). Providing the guidelines for designing the monitoring program and its operational components is the purpose of this document.

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[1] Although not a focus of this exercise, we note that many species overlap other ownerships; information from these lands that has a bearing on the resources being monitored is important to interpreting monitoring results on Federal lands.

[2] The effectiveness monitoring program will consist of a number of modules, referred to in this report as LSOG monitoring module (Hemstrom et al., in press), northern spotted owl module (Lint et al., in press), the marbled murrelet module (Madsen et al., in press), and draft annotated outline for aquatic and riparian monitoring (Furniss et al. 1997). Future modules on other subjects will be added to this program.

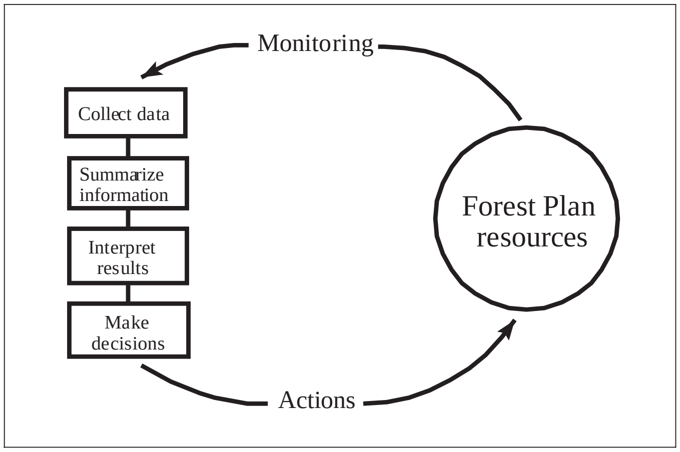

Figure 3—Adaptive management cycle where monitoring plays a major role by taking measurements and making observations of key resources (adapted from: Keune and Mandry 1996).

Considerations in Developing the Effectiveness Monitoring Program

Monitoring is expected to play a major role in implementing and managing the Forest Plan (Dwyer 1994; FEMAT 1993; USDA and USDI 1994a, 1994b). Credible and accurate data are needed for future resource planning (U.S. GAO 1994), particularly given these legal and political expectations. Monitoring is at the core of adaptive management (fig. 3) and essentially synonymous with effective decisionmaking. In other words, the more information available, the greater the flexibility to manage. Monitoring is, however, more complex than we realize, and the Forest Plan adds a new level of complexity to ecosystem and adaptive management. Our focus therefore must be on identifying information that is needed and usable to address key issues; that knowledge must build from information appropriate to the question (Persson and Janz 1997, Vora 1997). As such, monitoring is more than taking measurements or making observations; it also includes data management, assessment, and decisionmaking. Thus, decisionmakers should be involved in the planning as well as the application of a monitoring program (CENR 1997, Noble and Norton 1991).

In the field of natural resources, adaptive management is still somewhat conceptual, and we are beginning to realize that agencies are having difficulties in applying its objectives. Although considerable literature exists about both adaptive management (for example, Bormann et al., in press; Brunner and Clark 1997; Everett et al. 1993; Gunderson et al. 1995; Holling 1978; Morrison et al., in press; Walters 1986), and ecosystem management (for example, CENR 1997; Christensen et al. 1996; Duffus 1994; Franklin 1996; Grumbine 1994, 1997; papers in Haeuber and Franklin 1996), these articles give little explanation or description about monitoring other than to note that it is part of the management planning process. We believe that this has led to a lack of appreciation of the complexity and difficulties in carrying out a monitoring program and in using monitoring information in decisionmaking.

Monitoring is particularly difficult when large geographic areas are being managed. To be successful, it needs to be a routine and integrated component of land management planning and be managed at a scale directly addressing the policies that affect land management (CENR 1997, Marcot 1994, Olsen and Schreuder 1997). The ability to successfully institutionalize monitoring into our day-to-day operations not only will improve decisions but also will support management actions, make planning more efficient and responsive, and help focus future expectations (CENR 1997, Olsen and Schreuder 1997, Schreuder and Czaplewski 1992, Vora 1997). As Persson and Janz (1997) note, however, it is not really worth carrying out the program, if an infrastructure to support all components is absent. Historically, monitoring has not been effectively integrated into agency operations, and Federal agencies do not have a good track record in using or applying monitoring programs (for example, Bella 1997; Grumbine 1997; Hilbran 1992; Lee 1993; Morrison and Marcot 1995; NRC 1990; U.S. GAO 1988, 1994). A formal approach to improve the use of monitoring information in the adaptive management process is needed (Morrison et al., in press).

Although considerable information exists in the monitoring literature, it is largely conceptual, particularly at the scale of the Forest Plan (Chapter 2 has numerous references). In addition, Federal resource agencies have some experience with monitoring but mostly at a scale not really useful to the design of a large, regional-scale, multidimensional program (CENR 1997). The EMT therefore sought to apply knowledge gained from a relatively few large-scale programs. Most concepts in ecological monitoring have been generated by the Environmental Monitoring and Assessment Program (EMAP) (for example, Stevens 1994; Thornton et al. 1993, 1994), and we relied heavily on the planning done for that program. Additional insight was gained from EMAP's Forest Health Monitoring (FHM) program (FHM 1994, Lewis and Conkling 1994) and the U.S. Fish and Wildlife Service's (FWS) North American Waterfowl Monitoring Program (Nichols et al. 1995), among others (for example, International Geosphere-Biosphere Programme 1990, Programme Center 1989, Ringold 1994).

As a result, we have identified several critical issues that must be considered as the agencies decide on an optimal approach to monitoring for the Forest Plan. Trend monitoring is a long-term effort, so we need to consider how to reduce the response time in obtaining useful information. Trend monitoring is usually retrospective: thus, we need to consider how to anticipate or predict trends so that it is not too late for management to respond. In addition, the scope and magnitude of this program, covering parts of 3 states, 18 National Forests, and 7 BLM districts, will require considering how to collect and manage a large amount of information among several local and regional administrative units within and among a variety of agencies. Monitoring at this (regional) scale also raises critical questions about links from local to international issues, or with nonmonitoring activities (for example, inventories) that also may use or provide important data. Addressing status and trend questions about the Forest Plan also will require considering how to link findings with their causal mechanisms, specifically as they relate to the standards and guidelines and implementation monitoring.

Ultimately, plans to monitor at this scale and over such a long time must address the total cost of the program, especially in times of declining agency budgets. We need to monitor, though, to know if our management actions are successful; the more certainty we want, the higher the cost. This is a question of risk, in knowing that the methods proposed provide sufficient data to meet our information needs for status and trend monitoring. Key questions then are whether we can use or increase the usefulness of existing programs (for example, vegetation surveys), make their data more accessible, and integrate related data gathering and assessment efforts in a way that meets local, regional, and larger scale monitoring needs. Because we know little about monitoring at these large scales, many of these questions lead to assumptions that need to be tested as we improve and adapt the monitoring program over time.

Because regional scale monitoring is complex, especially at the scale of the Forest Plan, the program needs to be dynamic, iterative, and capable of continual modification over time (Olsen and Schreuder 1997, Vora 1997). Monitoring programs, particularly of this size, cannot remain static; they need to adapt to meet emerging or changing needs. This “adaptive monitoring” process (Ringold et al. 1996; Ringold et al., in press) is intended to result in improvements to the program and data that will increase the value of the monitoring results over time, thus leading to more efficiency and increasingly responsive decisions.

Links to Individual Forest Management Units

To assess the success of the Forest Plan, the effectiveness monitoring program addresses regional-scale monitoring requirements. Individual forest management units also conduct monitoring, but at a more local scale. Many questions have arisen regarding the relation between the programs at these two scales: How can the regional program assist with local-scale monitoring needs? Does the regional program address all local information interests? What should be the role of individual forest management units in the regional program? How can an individual management unit benefit from participating in the regional program? and Why is it important for an individual management unit to support the implementation of the regional program? These questions can best be answered by understanding the links from the regional program to individual management units.

This monitoring program needed to build on and improve ongoing monitoring activities such as the Forest Service’s current vegetation survey (CVS; Max et al. 1996). It thus will rely significantly on data obtained through the assistance of local forest management units. The expertise of local specialists is also extremely important in assisting the regional program with interpreting these data. Local specialists are familiar with their data and may be able to provide information to assist with calibrating models or establishing thresholds of concern.

The regional program, on the other hand, can provide assistance and guidance for improving local monitoring efforts. The scientific approaches developed for the regional program—such as the monitoring design, indicator selection, or data interpretation methods—also apply to local-scale monitoring. Many of the effectiveness monitoring questions apply directly to individual forest management units (for example, Pagel et al. 1997); only the scale of the question has changed. Although the regional program cannot respond to all local information needs, regional-scale monitoring results can assist with local-scale interpretations by providing a regionwide

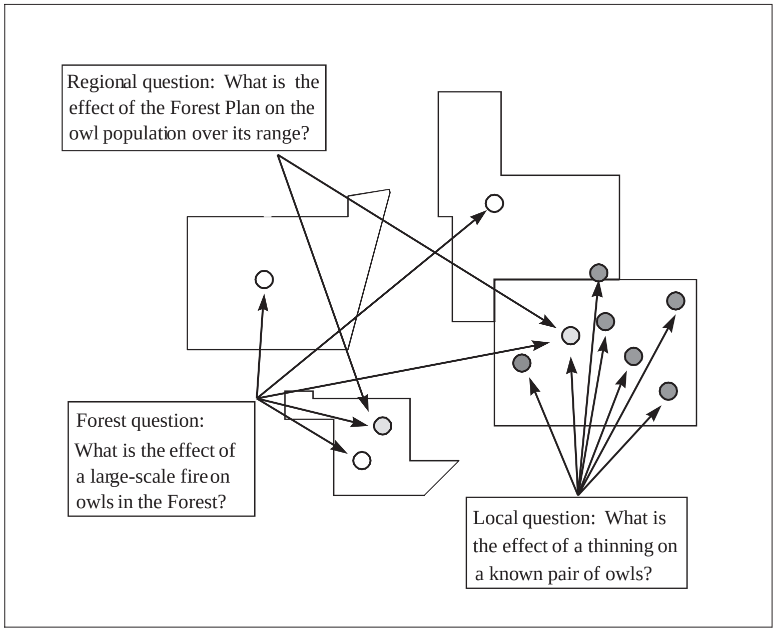

Figure 4—Comparison of monitoring questions at different scales illustrating relations and differences among monitoring questions.

context for those interpretations (CENR 1997; also see fig. 4). This context should be particularly useful in regulatory (for example, ESA) and planning assessments in helping to meet resource goals (for example, for species and commodities).

The importance of regional monitoring to making decisions at individual forest management units, however, is indirect rather than direct. The regional program is directed to the regional land management policies and decisions that govern local direction. As such, monitoring information is not needed from every local management unit. Results may be used to establish new regional goals and objectives, modify standards and guides, or focus management on emerging issues. Changes to the Forest Plan would then be passed along to the individual forest management units to assist them in refining their own goals and objectives, standards and guides, or monitoring requirements through amendments to their forest management plans. Although resources directed to the regional effort may result in diminished availability of resources for local monitoring, regional efforts can provide important feedback to the individual forest management units that replace or complement remaining local monitoring efforts.

Relation to Emerging National and International Monitoring Requirements

Monitoring is needed to evaluate the success of management practices on public lands in the Pacific Northwest. Requests for monitoring information also arise at other geographic scales, including national and international; for example, questions are being asked about forest trends in the United States, North America, and the world at large. Considering how effectiveness monitoring in the Northwest fits into the picture of forest monitoring requirements for the Federal land management agencies at national and international scales is important.

Two significant issues are emerging as a common requirement for monitoring at national and international scales: conservation of biodiversity and sustainable management of forests. President Clinton's Committee on Environment and Natural Resources recently issued their report (CENR 1997) calling for a strategy and framework for environmental monitoring and research that will enable comprehensive assessments of the Nation's natural resources. The strategy emphasizes the need to increase understanding, improve information links, focus on status and trends, be predictive, improve methodologies, increase efforts to integrate programs and activities, and make better use of existing information.

Considerable international effort also has been focused in recent years on criteria for assessing forest issues. The United States signed the Santiago Agreement (Anonymous 1995) defining criteria and indicators for conserving and sustainably managing temperate and boreal forests. Other efforts in Europe (Helsinki Process), tropical countries (Tarapoto Proposal), and Africa (Dry Zone Africa Initiative) are helping to develop a worldwide consensus on these topics. These criteria are now being used to develop the Global Forest Resource Assessment 2000 by the United Nations, and they served as the program theme for the 1997 World Forestry Congress in Antalya, Turkey (World Forestry Congress 1997). The Santiago Agreement identifies seven criteria for assessing sustainable forest management:

1. Conservation of biological diversity

2. Maintenance of productive capacity of forest ecosystems

3. Maintenance of forest ecosystem health and vitality

4. Conservation and maintenance of soil and water resources

5. Maintenance of forest contribution to global carbon cycles

6. Maintenance and enhancement of long-term multiple, socioeconomic benefits to meet the needs of societies

7. Legal, institutional, and economic framework for forest conservation and sustainable management

The goals for effectiveness monitoring are consistent with this emerging national and international framework for monitoring. For example, the first criterion above is the primary focus of current efforts in effectiveness monitoring that also should address some aspects of criteria 2 and 3 (see footnote 2). Planning is currently underway with the riparian and aquatic issue (see footnote 2) and the socioeconomic resource areas in effectiveness monitoring, and these efforts should address some aspects of criteria 4 and 6. Although effectiveness monitoring is not being designed to address all the criteria and indicators proposed in the Santiago Agreement, it does provide a means for conducting regional assessments that could be expanded to address additional emerging monitoring requirements, as recommended by CENR (1997). These efforts will be extremely useful to agency staff at the national level as they attempt to develop a national picture or contribute to the international perspective on forest status and trends.

Key Aspects of the Effectiveness Monitoring Program

The challenge the EMT faced was to construct an approach to effectiveness monitoring that met the goal of providing useful information (see table 1) to managers at the local, regional, and national scales and was organized and timely. Development of this monitoring program has been difficult, and the difficulty little understood. We have gained considerable knowledge about the complexity of these issues, however, as investigations have proceeded. The result has been an evolution in thought about monitoring, what it will take to successfully monitor, and what this will mean to Federal (and other) agencies (see appendices A and E for a summary of the process).

We realized from our experience that the approaches for monitoring that have been followed in the past were not appropriate for the Forest Plan, but that we needed to create a more structured and effective monitoring design and operational approach. The implications led to a realization that for adaptive management to work, a fundamental change would be needed in how agencies monitor, which will inevitably lead to a change in institutions. A number of barriers will need to be overcome, including technical, institutional, and philosophical. If we had started with this knowledge, our approach could have been focused more on helping agencies understand the need for change, which may have made it easier to interpret and understand the proposals for Forest Plan monitoring. We recognize that time is needed to gain this understanding before agencies can fully implement a long-term, functional program meeting their needs. As such, the transition from the current way of doing business to a more organized and consistent approach will not be easy and cannot be done overnight. A concerted and coordinated effort by all participating agencies will be needed to fully fund, implement, and institutionalize the process into our operational culture—a national as well as a regional question. The approach, described in this report and summarized below, is intended to provide the framework for accomplishing this goal.

The basic scientific premise underlying the proposed program is to implement a predictive and integrated habitat-based approach to monitoring (fig. 5) that will produce useful and timely results more efficiently and cost-effectively than past programs have. Developing an approach to monitoring at any scale requires careful planning; thus, we began with emphasis on the scientific foundation for monitoring design (see Chapter 2), based on the use of conceptual models supported by ecological theory and empiricism. This approach is critical to selecting the focal point or points for monitoring, thus leading to opportunities for integrating programs and reducing costs. It allows us to construct a program that builds from a base information set; for example, by using the LSOG database to evaluate questions about spotted owl habitat. The approach also helps identify problem areas where pilot studies or research to test underlying assumptions or develop new methodologies will be critical to the long-term success of the program; concurrent research is a necessary part of a monitoring program (CENR 1997, Olsen and Schreuder 1997).

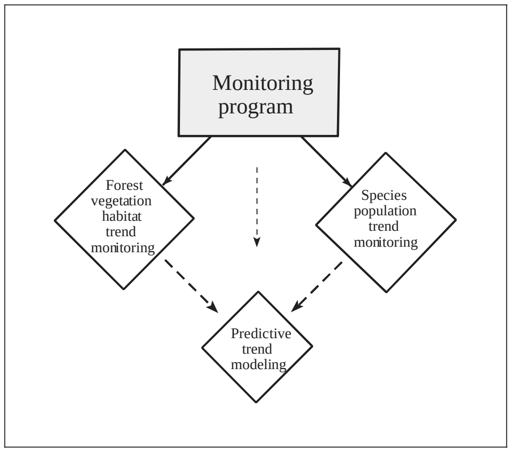

Figure 5—Basic components for effectiveness monitoring of ecological resources.

Given the great diversity of species—plant and animal, vertebrate and invertebrate—monitoring all biotic components of managed ecosystems is clearly impossible. It also would be prohibitively expensive. As such, the foundation of our approach to effectiveness monitoring for the Forest Plan is to initiate a gradual transition from an intensive, individual species-resource focus to a more extensive, ecosystems approach (Chapter 3). This transition assumes identification and measurement of surrogate variables to allow reliable inferences about the integrity of the primary resources of the Forest Plan. Conceptual models were used to construct approaches for collecting and managing monitoring information meeting the information needs of the Forest Plan about specific resources, such as LSOG, northern spotted owl, marbled murrelet, and aquatic and riparian (see footnote 2).

The focal point for measuring success of the monitoring program will be on periodically producing interpretive reports that respond to questions about the status and trends of selected resources, beginning with the initial monitoring modules (see footnote 2). The EMT realized that the complexity of the design, and the scope and magnitude of the program needed to produce these reports required an operational context for data collection and management, and assessment and reporting to meet land management and regulatory agency information needs for adaptive management (see Chapter 4). Although the modules for monitoring specific resources emphasize data collection, the focus is on developing an organized, institutionalized approach to managing and assessing information to enhance the ability of managers to make effective and efficient decisions locally (that is, for a Forest or province) and regionally. Data management, assessment, reporting, and the supporting infrastructure are as important to the success of a monitoring program as the underlying science and the design for collecting data (Persson and Janz 1997).

Moving toward implementing an effectiveness monitoring program requires decisions to establish, implement, and manage a large-scale, multifaceted, and interagency monitoring program (see Chapter 5). The decisions begin with an understanding of the goals of the program, the implications of implementing a program of this scale and magnitude, and the structure and organization needed to manage a comprehensive program. Answering questions about establishing monitoring as a formal resource program within the participating agencies with long-term base funding are essential to the success of the program. Necessary steps include developing annual work plans, multiyear budget allocations, and staffing assignments to operate the program. Institutionalizing monitoring into agency operations is critical (CENR 1997, Olsen and Schreuder 1997, Schreuder and Czaplewski 1992, Vora 1997).

The resulting program will provide greater benefits than do existing activities because it is constructed as a fully integrated process to provide reliable information more efficiently and cost-effectively; that is, it is designed to yield results. The approach to monitoring design that we describe also provides the basis for future modules that may address other important resources (for example, socioeconomic, tribal, survey-and-manage species,[3] or other species associated with late-successional or aquatic ecosystems), and it is intended to be a template for managers in directing future monitoring, whether for effectiveness monitoring or other objectives. Because of the comprehensive approach to design and application described here, the program also will make a contribution to experience in the application of monitoring, and thus should have long-term benefits to future monitoring and associated resource management activities in this region and elsewhere.

Many steps will be needed to carry out the monitoring program and achieve long-term success; these additional steps, which include research, are identified in this report. The approach allows opportunities to ensure that an appropriate and scientifically based program is rigorously tested at each step. Although this statement may give the impression that significant questions about monitoring at this scale may warrant delay or smaller scale testing as a first step, following up on these issues is a long-term, but necessary exercise (Olsen and Schreuder 1997). As such, the program is structured to respond to emerging needs and improvements adaptively, so that we can be pragmatic and move ahead to implement a program of this complexity with minimal concerns.

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[3] The ROD (USDA and USDI 1994b) identifies a large group of organisms, referred to as "survey-and-manage species," that require special management. Concern has been expressed about the high cost of monitoring these species as well as other aspects of biodiversity. We believe that monitoring resources, such as survey-and-manage species, as a biodiversity component of the LSOG and aquatic and riparian monitoring programs should be possible by tracking trends in forest and riparian habitats and evaluating the link to species-habitat requirements through research or validation monitoring.

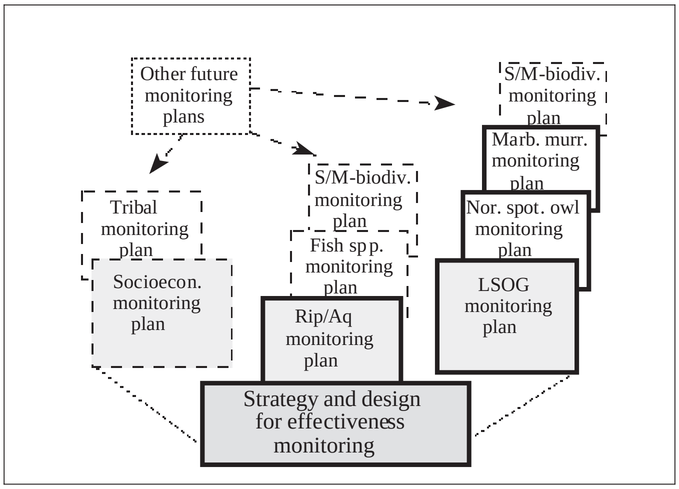

Figure 6—Current and potential future modules of the effectiveness monitoring program for the Northwest Forest Plan (dashed lines indicate potential modules; S/M (survey-and manage species) and biodiversity includes terrestrial and aquatic and riparian species.

Focus of This Report

The intent of this report is to explain the strategy for effectiveness monitoring, describe the scientific framework underlying the strategy, and establish the guidelines for monitoring design and program implementation and management (fig. 6). The purpose of Chapter 1 has been to provide background and summary information on the need for an effectiveness monitoring program for the Forest Plan. Chapter 2 provides a technical description of the underlying science to be considered when establishing the monitoring program. The intent is to clearly define the scientific approach for a monitoring program. This approach, as applied to effectiveness monitoring, is presented in Chapter 3, which focuses on the use of habitat as a surrogate for measuring biotic populations. This foundation, as described in Chapters 2 and 3, is essential to obtaining usable and credible information for adaptive management under the Forest Plan. Chapter 4 describes the structural components of an operational program. The intent is to provide a context for implementing and managing a resource program of this magnitude and importance so that the collected information can be readily and efficiently used. Chapter 5 identifies the strategy or steps needed to implement, manage, and fund the program.

This report is provided to help people understand and to give context to the specific monitoring plans for each resource monitored under the Forest Plan. The full set of documents, including subsequent implementation plans, field manuals, and annual work plans, are intended to function as integrated guidance to Forest Plan monitoring.

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Chapter 2: Conceptual Basis for Designing an Effectiveness Monitoring Program

Barry R. Noon, Thomas A. Spies, and Martin G. Raphael

Scientific Basis for Monitoring

What Is Monitoring?

Monitoring is the “measurement of environmental characteristics over an extended period of time to determine status or trends in some aspect of environmental quality” (Suter 1993:505). The challenge in this definition, and the topic of this chapter, is to clearly understand why monitoring is an important activity, to decide which characteristics of the environment to measure, to determine what information these characteristics indicate about environmental quality, and to use that information to make better management decisions about the Forest Plan.

Monitoring is purpose oriented (Goldsmith 1991). In general, monitoring data are intended to detect long-term environmental change, provide insights to the ecological consequences of these changes, and to help decisionmakers determine if the observed changes dictate a correction to management practices. Monitoring is conducted at regular intervals to assess the current status and the time trend in various environmental attributes. By its very nature, monitoring is a dynamic exercise; that is, it is a continuing activity and its temporal span may be indefinite. The time frames for monitoring programs are frequently unspecified, because human behavior and continuing human population growth lead to ongoing environmental change with unexpected ecological events as unavoidable consequences.

In the following discussion, environmental attributes are broadly defined to include any biotic or abiotic feature of the environment that can be measured or estimated. The convention is to refer to the measured attributes as “indicators,” under the assumption that their values are somehow indicative of the quality, health, or integrity of the larger system to which they belong (refer to definitions in EMAP 1993, Hunsaker and Carpenter 1990).

The most common reason to monitor a specific indicator is to detect differences in its value among locations at a given moment (status), or changes in value across time at a given location (trend). Changes in the value of an indicator are useful and relevant to the extent that they provide an early warning of adverse changes to an ecosystem before unacceptable loss has occurred. Trend, viewed as the estimated time trajectory of a state variable (a variable that describes some fundamental attribute of the system), is particularly relevant because even if the value of an indicator is currently acceptable, a declining (or increasing) trend may indicate a trajectory towards system degradation, or an undesired state.

The task of detecting and recognizing meaningful change is complex because natural systems are inherently dynamic and spatially heterogeneous. Further, many changes in space and time are not a consequence of human-induced effects, and many are not amenable to management intervention. For example, at least three kinds of change are intrinsic to natural systems: stochastic variation, successional trends after natural disturbance, and cyclic variation. Assuming that sustained ecosystems maintain these dynamic variations with predictable bounds of variation (Chapin et al. 1996), management intervention may be appropriate even when change is not human induced. For example, developing an underlying structural model that predicts the expected magnitude of change in state variables arising from natural variation may be possible. Values of indicators could then be viewed in the context of deviations from expectations based on the structural models. Repeated observations of indicator variables whose values appeared “out of range” could trigger a management response.

Extrinsically driven changes to biological indicators that arise as a consequence of some human action are of most interest to environmental monitoring programs. Concern arises when extrinsic factors, acting singly or in combination with intrinsic factors, drive ecosystems outside the bounds of sustainable variation. Thus, one key goal of a monitoring program is to discriminate between extrinsic and intrinsic drivers of change; that is, a mechanism is needed to filter out the effects of expected intrinsic variation or cycles (noise) from the effects of additive, human-induced patterns of change (signal).

Intrinsic and extrinsic drivers of change can, for the most part, be collectively referred to as “disturbances events.” Disturbances alter processes or act as physiological disruptors that elicit a response from the biota; they generate a change in the value of the state variables that characterize an organism or an ecosystem. The term “stressor” is used to refer to disturbance events that result in significant ecological effects. These effects can be either positive or negative; however, our focus is usually on those resulting in undesired outcomes. In this context, stressors are considered as the proximate causes of adverse effects on an organism or system. This terminology is consistent with the literature on monitoring (for example, Suter 1993). The focus is on stressors arising from human activities because they are amenable to management intervention and changes in policy. Further, we focus on stressors that cannot be incorporated within the natural disturbance dynamics of a system, exceed the resilience of the system, and drive an ecosystem to new state.

Stressor effects are evaluated in the context of induced changes in one or more indicators. The magnitude of indicator change that could generate a management response, however, is difficult to determine *a priori*. This uncertainty arises primarily from an incomplete understanding of the dynamics of ecosystems and the bounds of variation to which they are resilient. Interpretation of the significance of changes in the value of an indicator is also complicated by nonlinear, cause-effect relations between the indicator and its stressor(s). The assumption of linearity implies that marginal increases in the magnitude of the stressor generate fixed, marginal changes in the value of the indicator. Such assumptions fail to recognize the fundamental nonlinearity of most ecological systems (see Jones and Lawton 1994 for examples).

The real danger for monitoring programs, however, is that assumptions of linearity fail to acknowledge the possible existence of thresholds. Thresholds are regions of change in the value of a stressor that generate precipitous declines in the value of the indicator or, more seriously, the larger ecosystem. A familiar analogy is an acid-base titration in analytical chemistry. Increasing acidity (the stressor) is indicated by changes in color (the indicator) of the liquid, but the change in color is not uniform with marginal increases in acidity; rather, the change is precipitous when the buffering capacity (threshold) of the liquid has been surpassed.

A lesser known, but extremely relevant example in public land management, considers the effects of habitat loss and fragmentation on the extinction process. Loss of some area from relatively continuous habitat may have no effect for some time. But, at some point, landscape connectivity is lost, and populations become isolated and vulnerable to stochastic processes (Opdam et al. 1993). Computer simulations of these scenarios suggest that critical threshold amounts and distribution of habitat exist, below which species populations rapidly decline (Lamberson et al. 1992, Lande 1987).

Why Monitor?

The ultimate rationale for monitoring arises from the fact that long-term human welfare and environmental integrity are inseparable. Monitoring is usually justified in the context of a more immediate goal or mandate; however, on multiple-use public lands, management actions are subject to many environmental standards. The public demands information about whether these standards are being realized and resources sustained; for example, monitoring is mandated on National Forest lands to ascertain the degree of compliance with the population viability requirement of National Forest Management Act (NFMA) and with minimum water quality standards of the Clean Water Act of 1972, as amended. Even for lands reserved from resource extraction and multiple use, such as the National Parks, compliance with the broad mandate to sustain “wild” resources for the enjoyment of future human generations must be assessed. In this document, we are developing a monitoring program for the Forest Plan to determine whether the goals and objectives of that plan are being met.

Determining compliance with a monitoring goal requires a predetermined standard or norm for comparison. The degree of deviation of the indicator from its desired value serves as a signal of noncompliance or a measure of environmental degradation. Standard or benchmark values for indicators are particularly important when monitoring is part of a large restoration project. In highly degraded ecosystems (for example, coastal watersheds in the Pacific Northwest [Bisson et al. 1997, Reeves et al. 1995]), some time may elapse before indicator values begin to approach the standard, but evidence that the indicator is changing in the direction of the benchmark value is evidence that the restoration effort is working.

One way to establish the benchmark value of an environmental indicator is to refer to documented historical values or to conduct preliminary, baseline monitoring of a nonaffected ("pristine") system. Given the scarcity of truly pristine systems, however, benchmarks may have to be based on some concept of a "desired condition" (see discussion of this concept in Bisson et al. 1997). Therefore, in the absence of reference systems, some other method must be used to generate expected values or time trajectories of indicator variables.

In addition to assessing compliance, environmental monitoring programs have great value as early warning systems. By providing measures, in the early stages of decline, of those attributes indicative of ecological change, monitoring can result in prompt intervention before unacceptable environmental losses occur. Note, however, that compliance monitoring and early warning monitoring can lead to selection of very different indicators. A simple example will demonstrate this difference. On a parcel of public land, the ESA may require compliance monitoring for a top-level, vertebrate predator, such as the northern spotted owl. The life history of this species (long lived, high survival rate, low fecundity, high site fidelity) may introduce lags in its response to environmental change, however, and thus make it a particularly poor choice as an early warning indicator of all but large-scale changes in old-growth ecosystems.

Thus monitoring, whether for compliance or early warning, is undertaken to ascertain whether the current state of the system matches the expected norm or lies within some acceptable confidence region about the norm. If monitoring results indicate that conditions lie outside the acceptance region, then some specific attribute of land management practice or resource policy should be changed. Alternatively, the information from monitoring can be used to investigate the response of the system to specific management actions. This information will allow the question, "Is the system responding as predicted?" to be addressed.

What Can a Monitoring Program Tell Us?

Before a monitoring program can be developed for the Forest Plan or any given management unit (for example, National Wildlife Refuge, state park, National Forest), understanding and agreement on what environmental monitoring is must be reached. What are realistic goals for a monitoring program? What biological insights can and cannot be inferred from a monitoring program. How are the costs of a monitoring program justified?

To determine if a monitoring program is, by itself, adequate to assess attainment of management objectives, what can and cannot be legitimately inferred from the results of monitoring must be understood. A logical first step, often referred to as "implementation monitoring," is to determine if the management guidelines or environmental regulations have been implemented. Given implementation, a monitoring program can help to evaluate the effectiveness of current management practices, develop a predictive understanding (in the form of one or more testable hypotheses) of why an environmental indicator is changing, and decide when more active management or intervention is required.

If the purpose of the monitoring program is to provide an early warning of ecosystem decline (or signs of improvement), then its success depends on having selected an appropriate indicator or indicators, and knowledge of how much change in the value of the indicator signals a significant biological change. By itself, however, a monitoring program cannot unambiguously determine the cause of a change; help decide on how much change is acceptable—that is, whether the observed change is still within the range of acceptable variation; decide on threshold values of the indicator that trigger specific management actions; or avoid false alarms—that is, concluding the state of the system has changed significantly when no meaningful change has occurred.

Because changes in the status of an indicator are of limited value without evidence of causation, cause-effect relations are best established by concurrent assessment of suspected ecosystem stressors. The second and third limitations are largely research problems; minimizing these deficiencies clearly demonstrates the complementary nature of research and monitoring programs. The last limitation is, to varying degrees, unavoidable. For a fixed sampling effort, limiting false positives (type I errors) occurs at the cost of increasing the likelihood of type II errors (that is, failing to detect a significant biological effect). The tradeoff between these risks is determined by which error is considered most important to avoid.

The Legacy of Environmental Monitoring Programs

Monitoring to estimate the viability of an individual species or a group of related species is more straightforward than assessing the integrity of an entire ecosystem. Therefore, it is not surprising that the few examples of successful, long-term monitoring programs that exist have a narrow focus on specific taxa. Arguably, the best example of such a program is the North American waterfowl monitoring program administered by the U.S. Fish and Wildlife Service (Nichols et al. 1995).

Despite the obvious value of holistic environmental monitoring, few examples exist of successful monitoring programs at the ecosystem scale. Unfortunately, little evidence supports the idea that such programs have contributed to informed management decisions, or proved valuable in averting biological crises (NRC 1990, U.S. GAO 1988). In fact, the most ambitious (and expensive) monitoring program to date, EMAP, has little tangible evidence of success and has been heavily criticized both scientifically and technically (NRC 1990, 1994a, 1994b, 1995). Given the obvious importance of knowledge of the status and trends of the Nation's natural resources, and the integrity of the ecosystems that provide these resources, why have monitoring programs contributed so little to environmental decisions or policy formulation at the ecosystem scale?

One fundamental reason for consistent failure is that monitoring costs are perceived by managers and the public to be prohibitively high, so there is reluctance to commit to implementation. In addition, environmental monitoring programs often are discussed in abstract terms, have little theoretical foundation, try to measure too many attributes, have vague objectives, and have no institutionalized connections to the decision process. The result has been a shallow comprehension of the need for, and components of, an effective monitoring program. Further, almost all previous programs have been given low priority, seldom have been fully implemented, and have been insufficiently funded. In times of budget reductions, monitoring programs often are the first to be eliminated.

The limited investment in environmental monitoring by most public land management agencies demonstrates its low priority and lack of appreciation. One example is in the U.S. Department of Agriculture. To assess whether resource management practices are maintaining biological diversity on National Forest lands, environmental monitoring is required under NFMA; however, a review of existing Forest Service monitoring programs indicates that they often exist in name only and are funded at a fraction of programs for resource extraction. And what monitoring has been done is often ad hoc, has little foundation in ecological theory, or fails to follow the fundamental statistical principles of sampling and estimation. Those few National Forests that have implemented scientifically defensible monitoring programs have not developed a formal mechanism to link the results of monitoring to management decisions (Morrison and Marcot 1995). The primary reasons for the failure of monitoring programs are:

- Minimal foundation in ecological theory or knowledge
- Little logic to support selection of indicators
- No necessary understanding of causation
- Trigger points not identified
- No connection to decisionmaking

To gain institutional support, the concept of environmental monitoring must become less abstract, its purposes more relevant, and its contributions more apparent. At a minimum, a defensible monitoring program should do the following:

1. Clearly state management goals and objectives, emphasizing how periodic information about the status of the resources is needed for informed management decisions.

2. Provide a clear statement of why the monitoring program has value, what information it will provide, and how the interpretation of that information will lead to a more responsible management response.

3. Establish the relation between those factors that may compromise the management goals and their ecological expression. This action is best accomplished by developing a conceptual model of how the system works and how it will be affected by external stresses.

4. Provide a clear exposition of the logic and rationale underlying the selection of the environmental attributes (indicators) to be measured. Recognizing that every species or physical or biological process of interest cannot (and need not) be measured, on what basis should attributes to be monitored be selected from among all possible candidates? Inherent in this step is the need to select indicators that can be measured simply and cost-effectively.

5. Outline the sampling design and methods of measurement to estimate the value of the indicator variable. This element includes, but should not be limited to, the sampling and measurement protocols.

6. Ensure statistical precision of the measurement protocols. For example, the sampling design must address the necessary precision of indicator estimation to detect a given magnitude of change, and the likelihood of detecting this change should it occur (for a good example, see Zielinski and Stauffer 1996).

7. Include those procedures that connect the monitoring results to the decision process. For example, determine what magnitude of change in a given indicator should trigger a management response, and what the response or responses should be?

Most existing monitoring programs frequently omit the first, second, third, sixth, and seventh elements or address them only superficially. Most attention has been given to the fifth element, and even here, the focus has been narrow, often restricted to an exhaustive discussion of the sampling and measurement protocols. It is not unusual to discover that great thought and deliberation have gone into how, when, and where to measure a given indicator, but little discussion of why that particular attribute is being measured or what magnitude of change needs to be detected (that is, issues of monitoring design and management decisionmaking).

Prospective (Predictive) or Retrospective Monitoring?

To be most meaningful, a monitoring program should provide insights into cause-and-effect relations between environmental stressors and anticipated ecosystem responses; that is, prior scientific knowledge and an understanding of the factors likely to stress ecosystem functions should be incorporated into the selection of variables to measure and the sampling design (NRC 1995). Indicators should be chosen based on a conceptual model clearly linking stressors and indicators with pathways that lead to effects on ecosystem structure and function (NRC 1995). This process enables the monitoring program to investigate the relations between anticipated stressors and environmental consequences and provides the opportunity to develop predictive models.

Prospective and retrospective studies focus on determining if a cause-and-effect relation exists as postulated. In epidemiology, a prospective study begins by selecting cases with and without a suspected antecedent cause and following cases to determine if the anticipated effect is associated with the antecedent cause. Conversely, a retrospective study begins by selecting cases with and without an effect and tracing back the cases to determine whether the effect is associated with the suspected antecedent cause. Both approaches have their foundation in identifying a supposed causal relation between an antecedent cause and its expected effect. The two perspectives differ only about whether the study begins with a set of cases with or without a suspected antecedent (stressor) or with a set of cases with or without an anticipated effect.

The NRC report (1995) states that "retrospective or effects-oriented monitoring is monitoring that seeks to find effects by detecting changes in status or condition of some organism, population, or community," and "predictive or stress-oriented monitoring is monitoring that seeks to detect the known or suspected cause of an undesirable effect (a stressor) before the effect has had a chance to occur or to become serious." Effects-oriented monitoring does not require knowing a cause-effect relation, but if stressors and effects are *both* included in the monitoring, then the program permits analyses directed at establishing cause-effect relations. Stress-oriented monitoring assumes that a cause-effect relation is known. See Thornton et al. (1994) and Suter (1993) for additional discussions. A specific effort must be made to gather cause-effect data; this effort was not part of the current assignment for effectiveness monitoring of the Forest Plan (FEMAT 1993, USDA and USDI 1994) but rather left for future research.

The emphases chosen for effectiveness monitoring of the Forest Plan may best be described as anticipatory monitoring and predictive effects monitoring. Each incorporates supposed causal relations between effects and stressors through the judicious selection of indicators. Anticipatory monitoring starts with a characterization of threats (stressors) to the ecological integrity and ecosystem functioning (effects) of the management unit. A conceptual model then outlines the pathways from the stressor(s) to the supposed ecological effects. Attributes that indicate the anticipated changes in specific ecological conditions are then selected for measurement. The ultimate success of this approach depends on the validity of the assumed cause-effect relations among the stressor(s), their ecological effects, and the selected indicators of stress. Anticipatory monitoring does not require monitoring ecological condition or assessment endpoints of interest. It attempts to detect effects as they are occurring by measuring anticipatory indicators, rather than describing effects after they have occurred. An advantage of this approach at the local and regional scales is that the emphasis on anticipated cause-effect relations allows an earlier and more focused management response to environmental change. Given that all potential stressors cannot be identified, complete reliance on this approach is not without some risk. A possibility exists of failing to detect the ecological effects of significant but unanticipated stressors.

Predictive effects monitoring incorporates the basis of anticipatory monitoring and extends it to predicting ecological effects. Not only does this extension require the assumption of an assumed cause-effect relation but it also requires developing a predictive model for the relation. As an example, an anticipatory monitoring program could be established to measure the vegetation characteristics necessary to support northern spotted owls. Based on these characteristics, a model is developed to predict the probable distribution or population status of spotted owls. The model may assume the vegetation characteristics remain as measured, hence predicting presence under steady-state conditions, or it may predict future vegetation characteristics under natural growth or harvest assumptions to allow a prediction of population trend. In this case, predictive monitoring focuses on estimating the future effects of changes in habitat. Initial phases of a predictive monitoring program would include additional monitoring of the effect of interest (that is, population response) to construct the predictive models and establish their reliability. Subsequently, the direct monitoring of owl populations would be conducted periodically as required for model validation and model refinement.

Challenges of Monitoring Ecological Systems

Ecosystems are poorly understood, complex systems subject to stochastic variation and unpredictable behaviors. In addition, the process of ecosystem adaptation and accommodation to stress is not well explored scientifically (Rapport and Reiger 1995). Given this reality, it is not surprising that the task of monitoring ecosystems, and drawing reliable inferences to system integrity before irreversible degradation, has proved such a daunting task. Incomplete understanding of ecosystem process and function, and limited ability to predict system response to stress will remain for the foreseeable future. As a consequence, research and monitoring are inextricably entwined and mutually dependent; a successful monitoring program will require a parallel research program.

Despite the complexity of ecosystems and the limited knowledge of their functions, to begin monitoring, we must first simplify our view of the system. The usual method has been to take a species-centric approach, focusing on a few high-profile species; that is, those of economic, social, or legal interest. Because of the current wide (and justified) interest in all components of biological diversity, however, the species-centric approach is no longer sufficient. This wide interest creates a conundrum; we acknowledge the need to simplify our view of ecosystems to begin the process of monitoring, and at the same time we recognize that monitoring needs to be broadened beyond its usual focus to consider additional ecosystem components.

To address this dilemma, we need information about a small number of surrogate variables whose status and trend provide insights to the integrity of the larger system. This is the logical basis for the indicator variable concept. But, no body of ecological theory or empiricism that will unambiguously tell us what to measure currently exists. To develop a step-down process to move towards a solution requires that we begin to build on experience and existing ecological knowledge and theory.

One step toward a comprehensive but simplified approach to ecosystem monitoring is to focus on the structural and composition elements of the landscape that express underlying process and function (fig. 7). Applying this logic to managing public lands, such as through the Forest Plan, suggests an emphasis on living and nonliving elements that collectively define the habitat of a species. Thus, an assessment of the status and trend of habitat types and key habitat elements may be a useful surrogate set of variables to substitute for the direct monitoring of numerous biotic populations. Indicators may vary, however, depending on the class or classes of organisms being addressed.

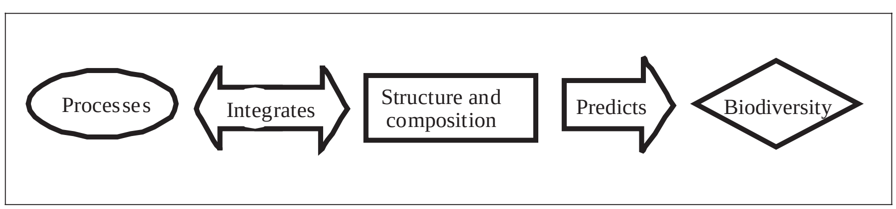


Figure 7—The conceptual model that is the basis for identifying indicators from structural and compositional landscape elements. We assumed that these elements reflect underlying ecological processes and allow predictions of the biodiversity response.

Table 2—A sequential list of key issues to address in the design of a prospective monitoring program

Steps	Design topics
1	Specify goals and objectives
2	Characterize stressors and disturbances
3	Develop conceptual models—outlines the pathways from stressors to the ecological effects on one or more resources
4	Select indicators—detects stressors acting on resources
5	Determine detection limits for indicators—to guide sampling design
6	Establish "trigger points" for management intervention
7	Establish clear connections to the management decision process

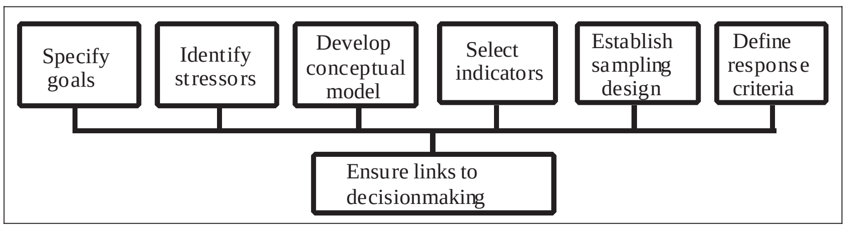


Figure 8—Steps in the design of a monitoring program.

Key Steps in Designing the Monitoring Program

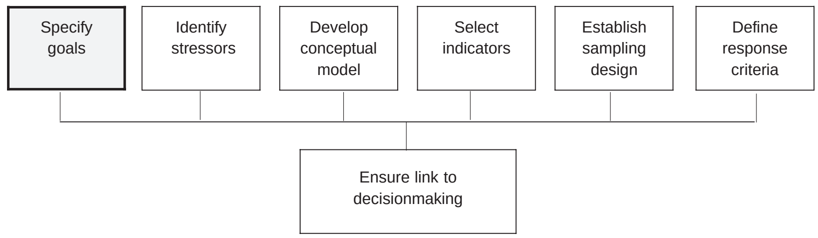
A key premise of our effort is that improving the framework for monitoring, specifically grounding the process in ecological theory and empiricism, will result in a defensible and useful monitoring program for the Forest Plan. The value of monitoring will become more apparent because the process will become less abstract and better focused; the relevance of the indicators to the integrity of the larger system will be more obvious; and a better theoretical framework should prove to be more cost-effective. We therefore sought to apply the concepts presented here by following a logical process to creating a monitoring program. The steps we followed are summarized in table 2.

These represent, in a step-down fashion, the key components in the design of the effectiveness monitoring program for the Forest Plan. Figure 8 is a model to guide the reader through each step discussed in the following sections.

The principles and concepts discussed in this chapter are general, and they can be applied to environmental monitoring programs regardless of spatial scale: local, regional, or national. The process and recommendations expressed here, however, are targeted to regional-scale monitoring programs, as required for the Forest Plan. Monitoring programs to evaluate the effects of specific local projects are more amenable to the experimental designs of environmental impact studies (see Schmitt and Osenberg 1996).

Our intent here is to provide a brief overview of the scientific basis underlying development of the monitoring proposals by the team; a more thorough understanding can be gained from the literature we applied to this effort. Because monitoring is an ongoing, active process, however, implementing these components will never be completely finished. These components must constantly be revisited and revised as scientific knowledge is acquired and as the threats to the integrity of ecosystem functions change.

State the Goals of the Monitoring Program



No universal set of goals characterizes a “quality” environment, assures the maintenance of biological diversity, and applies to all ecosystems experiencing a diversity of stresses. No single benchmark condition applies to all ecosystems. The concept of ecological integrity (Karr 1991), however, serves as a broad unifying concept and provides a universal set of goals for ecosystem management. Ecological integrity has been defined as the capacity to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitats of the region (Karr 1987, 1991, 1996). The key aspect of this definition is that it ties ecological integrity to evolution—the ability of the biota to persist by way of adaptive responses to environmental variation. In this broad context, the goal of monitoring of the Forest Plan is to provide the information needed to answer the question, “Are current management practices maintaining the ecological integrity of the ecosystem, including human uses of these resources for needed goods and services?”

A relevant example of a human-induced disturbance leading to a loss of biological integrity is silviculture as practiced in the forests of the Pacific Northwest from 1950 to 1990. The conversion of old-growth coniferous forests to intensively managed forests has resulted in significant changes in forest structure, decreased biological diversity, and a loss of resilience to natural disturbance events such as fire and windthrow (Spies 1991; Spies and Franklin 1991, 1995). The ecological integrity of these forests has been compromised.

Invoking the concept of ecological integrity puts the problem in the context of an ecological system composed of integrated biological components (individual organisms, populations, species, and communities) connected by exchanges of matter and energy. This model represents the traditional notion of an ecological hierarchy, and it will be a comfortable starting point for most ecologists, though it may not be a good starting point for decisionmakers responsive to societal, not necessarily biological, values. A connection, therefore, must be made between measured biological and physical attributes and what society values. This link requires a conceptual framework identifying the relations between societal values (the ultimate assessment endpoints for an environmental monitoring program) and biotic integrity.

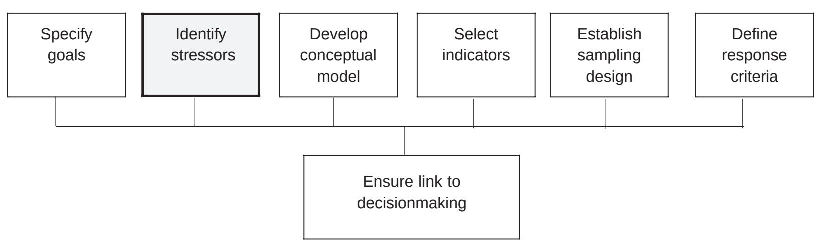
The Forest Plan (FEMAT 1993, USDA and USDI 1994) provides general direction for management in the form of standards and guidelines, and makes qualitative predictions of anticipated changes in the forest ecosystem, given their implementation. To develop a monitoring program for the Forest Plan, the general management objectives and predictions of the Forest Plan must first be refined into a set of specific monitoring questions. The monitoring program is designed to answer these questions, restated as parameters to be estimated or formal hypotheses to be tested with monitoring data.

A key ecological resource identified in the Forest Plan, and mandated for monitoring in subsequent legal decisions (USDA and USDI 1994), is late-successional and old-growth forests (Hemstrom et al., in press [see footnote 2, Chapter 1]). Monitoring goals, stated in the form of questions that can be addressed with monitoring data from late-successional forests, include:

- What are the amounts and distribution of forest age classes (including LSOG) at the landscape scale?
- What are the patch size distribution, patch interior area distribution, and interpatch distance distribution for LSOG at the landscape scale?
- Based on stand sample data, what changes have been produced by stressors in the amount and distribution of forest age classes, beginning with data collected for the 1993 FEMAT analysis?
- What are the effects of silvicultural treatment and salvage logging on LSOG structure and composition at the stand scale?
- Are the standards and guidelines leading to an increase in the amount and distribution of late-successional forest?

These questions refine the monitoring goals and suggest attributes (indicators) to measure. Measured attributes are those components of late-successional forests assumed to be indicative of the successful implementation of the standards and guidelines of the Forest Plan.

Identify Stressors Relating to Management Goals



This step usually will take the form of identifying the anticipated extrinsic environmental stressors that may compromise the integrity of the ecosystem and its component species and resources. From previous studies of disturbed ecosystems (for example, Delcourt et al. 1983), we know if the effects of an extrinsic stressor exceed the resilience or adaptational limits of the ecosystem, change occurs, the ecosystem moves to a new state, and the management goal may be compromised. Stressors, as envisioned here, can be both human-induced and "natural." Examples include (see Barber 1994):

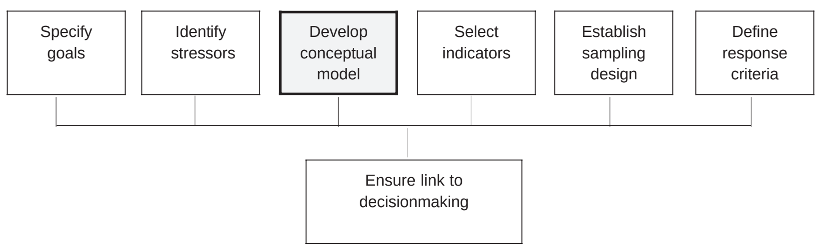
- Loss of late-successional habitat by fire
- Alterations of hydrologic cycles because of dams or water diversions
- Reduction, loss, or fragmentation of critical habitat
- Increased sediment loads to streams after storm events

- Overharvest of game species
- Changes in the transport of minerals and nutrients resulting from road construction
- Increased pollution from point sources or diffuse input of toxins

To retain the possibility of establishing cause-effect relations from the monitoring program, the status of the stressor also must be periodically estimated; that is, to infer causation from an observed change in the value of an indicator requires concurrent estimates of the status of the indicator and the magnitude of the supposed stressor.

To aid the process of indicator selection, identifying the ecological resource(s) likely to be affected by a given stressor, is important. A resource is broadly defined as an ecological entity subject to stressor effects. In practice, a resource is usually a key component of the larger ecosystem or management unit. Examples include freshwater lakes and montane meadows in National Forests. A resource can be either discrete or extensive (EMAP 1993). Examples from the Forest Plan of extensive resources include late-successional forests and aquatic-riparian ecosystems; discrete resources include the northern spotted owl and marbled murrelet. Establishing the functional relations between stressors (natural or human-induced) and resources is an essential first step in developing the conceptual model.

Develop a Conceptual Model Linking Relevant Ecosystem Components



To select indicators that reflect underlying ecological structure and function requires well-developed conceptual models of the resources of concern (Barber 1994; NRC 1990, 1995). The conceptual model outlines the interconnections among ecosystem resources (key system components), the strength and direction of those links, and the attributes that characterize the state of the resources. The model should demonstrate how the system works, with particular emphasis on anticipated system responses to stressor input. The model also should indicate the pathways by which the system accommodates natural disturbances and how the system may acquire resilience to disturbance. These processes could be portrayed by illustrating the acceptable bounds of variation of system components, and normal patterns of variation in input and output among the model elements.

As a general goal, management will strive to maintain ecological processes. These functions, however, are often difficult or impossible to measure directly. Conceptual models should identify structural and compositional elements of the resources affected by, and affecting, the underlying processes. A heuristic device to guide the model development would link process and function to measurable aspects of structure and composition. These elements, in turn, can be used to make predictions of expected biological response (see fig. 7).

Ecological hierarchy; components	Biotic consequence	Measurable attributes	Scale of measurement	Sampling methods
Landscape: Function-process Structure-composition				
Community-ecosystem: Function-process Structure-composition				
Population-species: Function-process Structure-composition				
Genetic: Function-process Structure-composition				

Figure 9—The stressor-specific worksheet used to identify the biotic consequences of stressor action at several scales of the ecological hierarchy. The attributes that reflect the biotic consequence (that is, indicators) and their measurement also are listed.

Measurements and inferences from biological systems are affected by the scale of observation. Therefore, to determine the appropriate scale for measuring an indicator, the temporal and spatial scales at which processes operate and resources respond must be estimated (at least to a first approximation) and clearly identified in the conceptual model. As a result, the most useful conceptual models will have a hierarchial structure; that is, a given structural-compositional resource in the model will reflect processes operative at smaller temporal and spatial scales, and indicate the constraints operating at larger scales (Allen and Hoekstra 1992, Allen and Starr 1982).

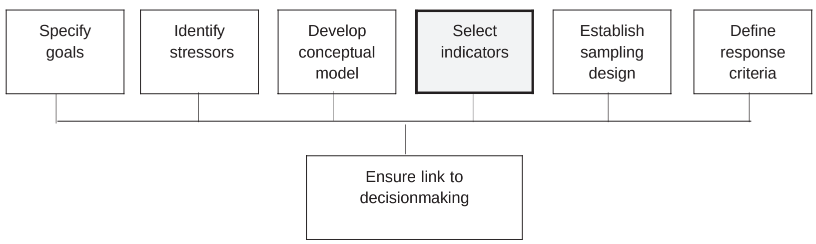
To make the process of scale an explicit component of the conceptual models developed for the Forest Plan, we developed a worksheet to characterize stressors and their anticipated effects on the ecosystem and its components (fig. 9). The purpose of this exercise is to assist with the development of the conceptual models leading to the selection of indicators for measurement. Scale was considered by allocating the effects of specific stressors to various levels in the ecological hierarchy: landscape, community-ecosystem, population-species, or genetic (see Noss 1990). Formalizing of the conceptual model required identifying the scale associated with each model component (fig. 9). As a result, insights to both the resolution and the range of the measured indicators become apparent in the conceptual model.

To illustrate the use of the worksheet in developing a model, consider the addition of roads as a stressor. The biotic consequences at the landscape scale for road building could be a disruption of landscape connectivity for plants and animals (function-process) leading to the isolation of habitats or species (structure-composition). A consequence at the community-ecosystem level could be changes in the dynamics of predator-prey systems resulting in changes to the species abundance distribution. At the population-species scale, a decrease in connectivity among individuals within a population may result in inbreeding depression. At the genetic scale, gene flow is altered via the barriers to dispersal and migration, thereby resulting in a change to the distribution of genotypes.

Developing the conceptual model should highlight that the links between stressors and biotic responses may be indirect. The building of roads, for example, may lead to an increase in erosion resulting in excess fine particle sedimentation in streams and associated biotic responses. The preliminary effects of stressors on the physical-chemical components of the ecosystem also should be considered hierarchically during development of the conceptual models (Ulrich 1994).

The indicators arising from the conceptual model are the attributes that characterize structural and compositional resources of the system. Their values indicate the current state of those resources. The indicators subsequently selected for measurement are those best reflecting known or suspected cause-effect relations among system components as identified in the model. Resources occupying central positions in the model should receive increased weight when the indicators are selected. As a result, in terms of contemporary ecological principles and theory, the model justifies the indicator or indicators selected for monitoring, and demonstrates how knowledge of the status and trend of the indicator reflects underlying process and function and will meet the goal of the monitoring program. Usually, modeling a restricted, but relevant component of the system will be sufficient. Thus, a complete model of an ecosystem is seldom necessary before proceeding with a reliable monitoring program.

Identify Candidate Indicators Responsive to Environmental Stressors



On the basis of the conceptual model and characterization of its central components, indicators are proposed for monitoring and subsequent field testing. At this point, the primary criteria for selecting indicators are that they reflect underlying ecological processes **and** changes in stressor levels, represent the larger resource of which they are a structural or compositional component, and are measurable. We begin with candidate indicators because our knowledge of the stressors affecting the system is limited. Thus, we identify a set of indicators that, based on our current knowledge, best meets our needs, but with the understanding that these may change as the program is implemented and new knowledge is gained.

Before field or simulation testing, the list of candidate indicators can be narrowed by focusing on those with the following properties:

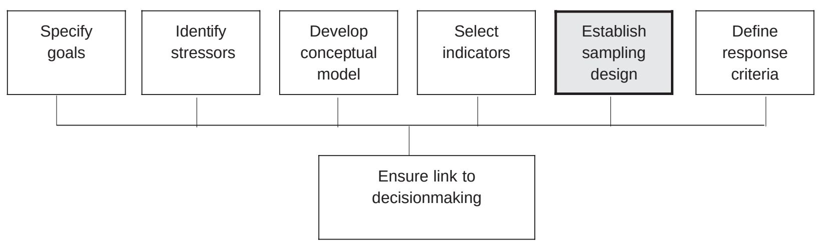
- Their dynamics parallel those of the larger environmental component or system of ultimate interest.
- They each show a short-term but persistent response to change in the status of the environment.
- They can be accurately and precisely estimated (that is, a high signal-to-noise ratio).
- The likelihood of detecting a change in their magnitude is high, given a change in the status of the system being monitored.
- Each demonstrates low natural variability, or additive variation, and changes in their values can readily be distinguished from background variation.
- The costs of measurement are not prohibitive.

Additional evaluative criteria for screening candidate indicators are in NRC (1990) and Barber (1994).

Even if a monitoring program is fully funded and implemented for many years, it will fail if the wrong indicators were selected. Thus, *the ultimate success or failure of the program may be determined by this one step*. The likelihood of choosing appropriate indicators is greatly improved if the conceptual model thoroughly characterizes the dynamics of the system, and accurately reflects stressor inputs. (A review of the effort by EPA to produce a strategy for developing indicators for EMAP [for example, Barber 1994] and subsequent criticism [NRC 1995] clearly shows the difficulty of this task.)

We find the following a useful analogy for the process of indicator selection. Imagine a funnel-shaped filter into which are poured all possible attributes of an ecological system that can possibly be measured. The fabric of filter is composed of scientific, political, and social threads. Our goal is to design the scientific fibers of the filter so that only those attributes that allow the most comprehensive and reliable inferences to the status of the ecosystem, constrained by cost functions, remain in the filter. Those attributes retained by the filter become the indicators.

Estimate the Status and Trend of the Indicator



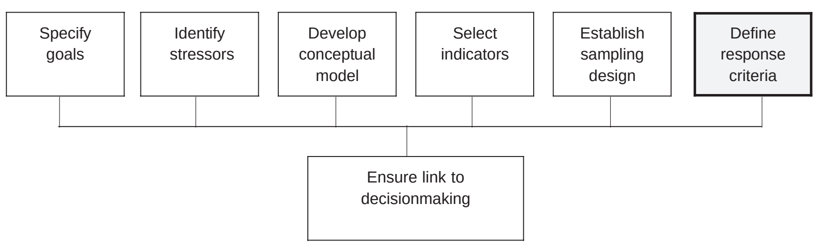
In general, determining the status of an indicator is a problem in estimating the value of an unknown parameter (that is, state variable) within some specified bounds of precision. Estimates of trend address the pattern of change over time in the status of the indicator. These problems are to be addressed by statisticians using the tools of survey and sample design (for example, Cochran 1977). As indicators change, the sampling design may change, so continual effort is needed to ensure that the design meets our monitoring needs. This topic is broad, and proper design requires substantial statistical expertise. Fortunately, a large body of statistical literature exists on parameter estimation, hypothesis testing, and trend estimation that is relevant to this problem (for example, Larsen et al. 1994, Overton and Stehman 1995, Sauer and Droege 1990, Stevens 1994).

Debate exists over the correct statistical framework for monitoring: parameter estimation or hypothesis testing (for example, Stewart-Oaten 1996). For the moment, we frame the monitoring question in terms of a statistical null hypothesis of no difference between the estimated value of the indicator and its hypothesized baseline value. The choice of significance level (α) for tests of the null hypothesis of no difference in the status of an indicator must be balanced against the likelihood of failing to detect a significant biological difference. Determining the α risk-level is a burden borne by decisionmakers. The β risk-level, in contrast, is a burden borne by those charged with maintaining ecological integrity.

The managers' responsibility is to implement an environmental monitoring program with sufficient statistical power (that is, an acceptable value of 1-β) to detect meaningful changes in the values of the indicators. For the monitoring design and analyses to be meaningful, statistical power must be considered *a priori* when determining sample sizes, and post hoc to interpret the result of statistical tests that failed to reject the null hypothesis (Skalski 1995, Zielinski and Stauffer 1996). In practice, to address questions of statistical power requires that the minimal magnitude of change in the indicator variable that is of biological significance be stated (this critical value must be estimated by some defensible process). Given this information, practical sampling issues, such as number of samples and resampling interval, can be addressed.

One of the most difficult challenges is to determine the value of an indicator, or the magnitude of change in its value over some interval, that indicates a significant biological effect. In statistical terms, this amount is referred to as the effect size (Δ) or magnitude of change in the value of the indicator that the monitoring program should be able to detect. Initial estimates of an appropriate effect size can be based on the spatial or temporal variation in the indicator (σ^2) under baseline or reference conditions (Skalski 1995). In sum, specification of acceptable levels for type I and II errors (α and β), natural variability of the indicator (σ), and the sensitivity of the test (Δ), determine the sampling effort for a given effect size. A comprehensive discussion of statistical power, and its relevance to decisionmaking in the context of responsible management of natural resources, is found in Peterman (1990).

Expected Values and Trends



An essential component of a monitoring program is the generation of expected values or expected time trends of the indicator variables; that is, the system is observed at time *i* and its state projected at time $i + \Delta$ given some management action. Only by comparing observed with expected values or trends can a determination be made about the effectiveness of management practices. The close approach to, or the passing of, an expected value is the threshold point that triggers a change in management practices. Estimating expected values (that is, benchmark conditions), however, is difficult and imprecise for five reasons: (1) the limited availability of pristine, undisturbed ecosystems to provide insights to benchmark conditions; (2) an incomplete understanding of the relation between the value of an indicator and the desired ecosystem state(s); (3) inadequate knowledge of the expected variability, over time and space, of the indicator of ecosystem state (or species status); (4) the nonlinear relations between indicator values and ecosystem processes (including the existence of sharp threshold regions); and (5) the fact that indicator benchmarks may be best represented by probability distributions rather than single target values.

Expected values and thresholds implicitly assume that an ecosystem will evolve to (or was historically at) a steady state of ecosystem integrity. This concept, often referred to as “the balance of nature,” has been replaced by one that recognizes the dynamic nature of ecosystems (Pickett et al. 1992). Therefore, when evaluated for periods ranging from decades to hundreds of years, the assumption of a steady state is clearly false. The dynamic nature of ecosystems argues for specifying a probability distribution of values rather than an expected value at a single moment. A second aspect of the nonequilibrium paradigm concerns the predicted time trajectory for an indicator (by trajectory, we mean how the value of the state variables change through time). Given the long delay between management actions and the response of the ecosystem to those actions, a monitoring program needs to be designed to predict the future, expected trajectory of the indicator. This prediction will require developing a mechanistic model that simulates the system response to management and whose state variables reflect both current and future ecological conditions.

Determining threshold values first requires the selection of a spatial scale to observe the ecosystem. If the spatial scale is a point in space, for example, when stream temperature is measured at a single location, an indicator threshold may be specified as a single value. An example would be a maximum water temperature beyond which conditions become lethal for cutthroat trout (temperature >22 ^{O}C). If the spatial scale includes a complete watershed, or the range of the species, however, then expecting the water temperature of all stream reaches within this area to be ≤ 22 ^{O}C may be unreasonable. Specifying an expected distribution of temperature values over the area would be more appropriate. Thus, two different categories of indicators may be described: those that lend themselves to threshold values (for example, water temperature for some fish and amphibians), and those best categorized by a target distribution (for example, number of snags and logs per acre). In practice, few indicators will be characterized by a single target value.

In addition, because the physical and biological processes and structural-compositional elements that characterize ecosystems differ in space and time, most indicators are best considered random variables; that is, when integrated across space, at a given moment, a specific process or landscape element is characterized by a dynamic distribution. To illustrate, assume that we have selected “forest stand age” as our measured indicator. We know that under a natural disturbance regime a dynamic distribution of stand ages would differ according to the spatial scale of aggregation of forest stands. If the goal of management is to mimic natural disturbance processes, then the scientific challenge is to estimate the benchmark distribution of stand ages that management should aspire to achieve. This distribution, however, depends on spatial scale. The age distribution would change as it is estimated for different-sized areas. As a consequence, a threshold value or an objective distribution cannot be specified without having some idea of the “correct” spatial and temporal scale for measuring the indicator, and the “correct” spatial scale for aggregating the measurements.

Once the scale of observation has been determined, indicator values can be aggregated into a frequency distribution. For a given moment, the observed distribution of indicator values would be compared to the expected distribution to detect both the magnitude and pattern of deviation from desired conditions. The concept of a spatial distribution of indicator values as the appropriate evaluative statistic is critical to the monitoring of ecological systems.

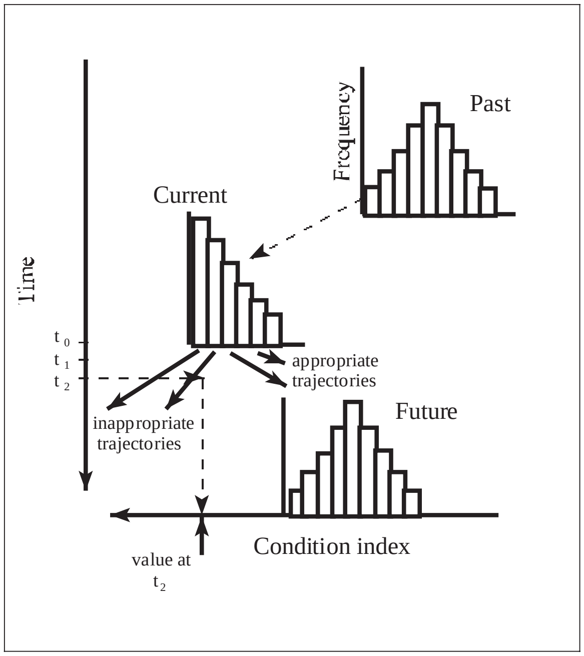


Figure 10—Frequency distribution of indicator values showing environmental condition at various points on the landscape. The past benchmark distribution, current distribution, and future, desired distribution are shown as they change through time. Current-to-figure changes are a consequence of management intervention.

Given the inherent dynamic nature of ecosystems, the value of a given ecosystem component (for example, process or landscape element) will follow a probability distribution. Based on this understanding, a monitoring program must address two distinct questions: Is the observed value of the process (or its indicator) at a specific area on the landscape, or at some moment in a time series, within acceptable bounds of the expected probability distribution? and When the observed value of the indicator, at a given time and space, is considered in the context of neighboring locations on the landscape, or in the context of a longer time series, does the expected distribution of indicator values result? For a given resource on the landscape (for example, a segment of stream, a forest stand, a riparian corridor), establishing a target value for a given indicator may be appropriate. When deviation from the desired ecosystem state at the landscape scale is evaluated, however, inferences drawn from the indicator's value at a site are of limited use without considering that signal in the broader context of values from neighboring landscape sites.

The concept of the distribution of indicator values as a collective index of ecosystem state at the landscape scale is illustrated in figure 10. This figure shows a historical distribution used as a benchmark, the current distribution of indicator values, and the future targeted distribution. In recognition of the impossibility of returning to preindustrial, pristine conditions, the target distribution is not identical to the historical distribution. Despite the need to establish benchmark distributions, the process of establishing such benchmarks is subject to some degree of arbitrariness. For example, the

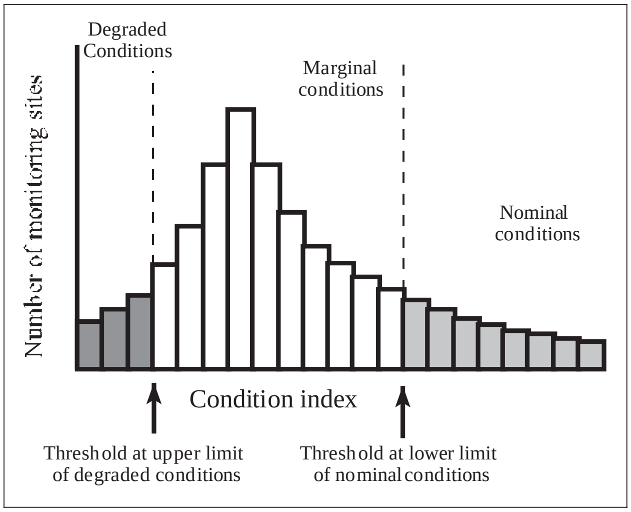


Figure 11—The distribution of indicator scores showing ecological condition at various points on the landscape. Index values relate to ecological conditions considered degraded, marginal, and nominal.

appropriate temporal reference point and uncertainty on how benchmark conditions are to be estimated from historical data are being debated. No clear guidance has been given on how far back in time to go to find an appropriate point of reference. Finally, how the concept of benchmarks can be reconciled with the dynamic nature of landscapes is unclear, especially when viewed over long time scales. For the time being, any evaluation of the ecological consequences of human activity will inescapably depend on value judgments.

In the interim, benchmark distributions, and the critical values that separate degraded from nominal conditions (fig. 11), will be based on best available information. Evaluating local conditions relative to these threshold points will be the basis of management decisions even though the location of threshold points is subject to change as ecological understanding increases. In the absence of decision thresholds or explicit objectives that management seeks to achieve, monitoring will be disconnected from management and policy formulation. Because of the complexity of this issue, the EMT did not believe this could be adequately addressed in this planning effort. This is an area that needs further work to improve sampling designs and make the program more responsive as we implement the program (see Chapter 4, "Research Support").

Most natural systems and resources recover slowly and will be slow to respond to changes in management practices. In the interim, while ecological resources are moving in the direction of a more desired ecosystem state, it is useful to identify appropriate trajectories of change in indicator values that, if continued, would lead to the target distribution (fig. 10). Thus, periodic estimates of the direction and magnitude of indicator change provide an ongoing evaluation of the appropriateness of the management strategy.

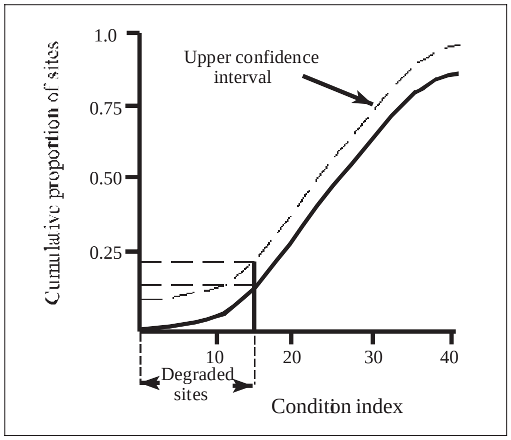
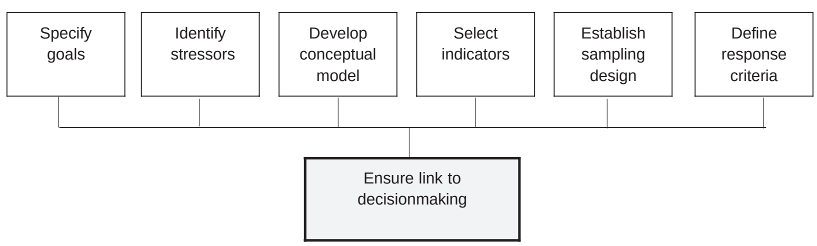


Figure 12—Cumulative distribution of indicator scores showing the collective ecological condition of many locations on the landscape. The figure illustrates that about 20 percent of the sample locations show degraded conditions.

A useful way to evaluate the integrity of a given ecological resource, concurrently across many locations, is to compute the cumulative distribution of indicator scores (fig. 12; Barber 1994). This distribution allows computing the proportion of sites below (or above) a given indicator value (that is, the lower or upper acceptable value of the indicator). In addition, the observed and expected distributions can be compared by using statistical tests (that is, Kolmogorov-Smirnov goodness-of-fit test; Zar 1984) to evaluate the deviation of the current distribution from the target distribution. Unacceptable test statistics for accepting goodness-of-fit, for example, can be used as pseudo-threshold points to trigger a change in management policy.

Linking Monitoring Results to Decisionmaking



Monitoring programs do not end with the collection of data, its analysis and synthesis, or even with summary reports. The results of monitoring programs are of value to the extent that they provide information for management decisions, and provide early warnings of ecosystem degradation. *The link between monitoring and decisionmaking begins with the formulation of and agreement on the monitoring questions*. The “correct” questions allow monitoring to be directed at areas where management requires information to adjust activities to mitigate unplanned and undesirable outcomes. Because the behaviors of complex systems are frequently unpredictable (Smith 1997), the link between decisionmaking and monitoring is essential.

Table 3—A sequential list of the steps to follow to make an optimal decision in the context of uncertainty and incomplete information

Steps	Decisions
1	Determine the bounds of the management decision space
2	Provide a range of possible management responses to the monitoring data
3	Estimate the probabilities associated with each possible interpretation of the monitoring data
4	Estimate the utilities associated with each possible combination of decision and monitoring data interpretation (that is, the costs of wrong decisions and misinterpretation of the monitoring signal)
5	Determine the decision that maximizes utility

Decisionmakers begin by asking questions such as, “Is the Forest Plan achieving its objectives for late-successional and old-growth forests?” A simple yes or no answer is not necessarily useful. A process must be instituted to connect the decisionmakers’ questions to the analysis and summary of the monitoring data. One formalization uses principles of statistical decision theory (Lindley 1985).

Statistical decision theory involves determining the potential alternative ecological outcomes, assessing the probability each of these outcomes is valid, describing the management decisions under consideration, and associating a “utility” with each combination of decision and outcome (table 3). A few examples applying decision theory to the management of natural resources exist: Maguire and Boiney (1994) used decision analysis in conjunction with dispute-resolution techniques to resolve a public policy dispute in Zaire over the best policy for managing an endangered species; and Conroy and Noon (1996) applied decision theory to the question of reserve selection and species conservation.

A simple, but nonetheless relevant, example illustrates the value of monitoring data and how it is integrated with decision analysis to improve decisionmaking under the Forest Plan. Assume the plan is responsible for conserving a species listed as threatened under the ESA. In their simplest form, the possible management decisions are to take no action at all (the status quo decision) or to institute conservation measures. Based on available data, particularly the monitoring data relevant to status and trend, we estimate some probability that the species is stable or increasing ($p(\theta_1)$), or in decline ($p(\theta_2)$). (Note: Because of the impossibility of knowing the “true” status of a population, all we can do is to estimate the likelihood of the different status categories based on the best available data. The combination of alternative decisions by possible states of the population are presented in a two-way decision table [fig. 13].)

Decision (d_i)	Population status - likelihood (θ): θ_1: increasing/stable	θ_2: declining
No action (d_1)	1.0	0.0
Conservation (d_2)	0.5	0.75
Probabilities	$p(\theta_1)$	$p(\theta_2)$

Figure 13—Hypothetical utility table illustrating the likelihood of different population states, the possible management decisions, and the utilities associated with the combinations of states and decisions.

The task now is to assign values to each combination of decisions and population states (fig. 13). These values are the utilities, $u(d_i, \theta_j)$, associated with the various outcomes. Utilities are scaled to the unit interval, with $u = 1$ "best" and $u = 0$ worst; $u(d_i)$ is the expected utility for decision i, over the probability space of the possible outcomes (Conroy and Noon 1996). Although utility is arguably subjective in many instances, certain outcomes (for example, the species goes extinct) are unequivocally the worst possible [$u(d_1, \theta_2) = 0$], and others (for example, the species persists with no economic costs) are the best [$u(d_1, \theta_1) = 1$]. The other outcomes have intermediate utilities. In this example, taking conservation action when none was needed (that is, the population was not declining) was assigned a lower utility because of the economic costs (for example, opportunity costs) that accompany most conservation actions.

Once the elements of the table are complete (d_i, θ_j, and $u_{i,\,j}$; fig. 13), the management decision is chosen that maximizes the expected (average) utility:

$$\bar{u}(d_i) = \sum_{i=1}^{u} (d_{i,}\theta_j)p(\theta_j)$$

That is, the decision (d_i) with the largest $u(d_i)$ is chosen.

As new data become available (for example, through monitoring the behavior of the ecosystem) the probabilities associated with the possible states of the system (the $p(\theta_i)$ values) are recomputed. The decision process is then revisited to determine if a different decision now maximizes overall utility. This iterative process is the substance of adaptive management.

In summary, application of decision analysis under uncertainty involves specifying management objectives and criteria for measuring success in achieving them; identifying alternatives to achieving the objectives; describing the uncertain events in the ecological and sociopolitical environment that influence the outcome of actions taken; assessing the outcome of each combination of management alternative and uncertain events in terms of the decision criteria; estimating the likelihood, or probability, of each uncertain event; calculating the expected values of the decision criteria for each alternative; resolving any tradeoffs among conflicting criteria; and reexamining the "optimal" decision by analyzing its sensitivity to changes in input parameters (Maguire et al. 1988). This is an area of current research and one not carried out by the EMT. We expect this to be addressed as we gather monitoring information for each resource issue and begin to study how to make the results useful to management (see Chapter 4, "Research Support").

Summary of Key Points

The purpose of this chapter has been to explain our scientific framework for effectiveness monitoring. The definition and purpose of monitoring were presented along with an attempt to address the challenges and experiences encountered by others when developing monitoring programs for complex ecological systems. The concepts of prospective and retrospective monitoring were introduced and the reason for our selection of the former approach was given. Seven steps for developing a prospective monitoring program were explained, including specifying goals or monitoring questions, identifying stressors, developing conceptual models relating stressors to ecological responses, selecting indicators, establishing sample designs, defining response criteria, and linking monitoring results to decisionmaking. These seven steps have been used as guidance for developing the modules for each of the resources to be monitored under the Forest Plan. They are intended to be used as the template for developing future modules.

Acknowledgments

This chapter includes contributions from Anthony Olsen and Hart Welsh.

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Chapter 3: Scientific Framework for Effectiveness Monitoring of the Northwest Forest Plan

Barry R. Noon

Habitat as a Surrogate for Biotic Populations

Logical Foundation—A Habitat-Based Approach

The foundation of our approach to effectiveness monitoring for the Northwest Forest Plan is to initiate a gradual transition from an intensive, individual species-resource focus to a more extensive, ecosystems approach. This transition assumes identifying and measuring surrogate variables that allow reliable inferences about the integrity of the primary resources. Such a fundamental shift means a movement away from the current crisis response to individual endangered species-resource issues, to a prospective evaluation of management decisions in an ecosystem context. For agency requirements, this change in focus means an eventual shift away from directly monitoring species to a habitat-based (primarily vegetation) monitoring program. Implicit in this approach is the validity of the assumption that inferences to species viability, biodiversity, and ecological integrity can be reliably drawn from assessments of the status and trends in attributes of habitat structure and composition. The assumption underlying this is that we have a solid base of information from which to address questions about a range of related resources.

A simple conceptual model describes our approach: *process* ↔ *structure-composition* → *biodiversity* (see fig. 7, Chapter 2). For forested ecosystems in the Pacific Northwest, we propose that measurable, biotic and abiotic structure and composition reflect underlying driving forces. In turn, knowledge of habitat structure and composition (amount and distribution) allows reliable predictions of biological diversity and the integrity of the ecosystem.

We recognize that knowledge of the status and trends of a small set of habitat attributes will not provide comprehensive insight into species viability, biodiversity, and ecological integrity; that is, monitoring the change in habitat structure from management actions is simply a surrogate for directly measuring biodiversity and ecological integrity. As such, it is accompanied by uncertainty. To reduce this uncertainty, regular, local-scale validations of assumed relations between habitat (primarily vegetation structure and composition) and species viability and fundamental ecological processes will be required. Despite this important caveat, accurate and timely monitoring of changes in the status and trends of habitat should provide a reliable early warning system of changes in biological diversity and ecological processes.

The transition to a habitat-based monitoring program has several advantages:

- Monitoring vegetation change will be more cost-effective than directly monitoring populations of all the possible species for which agencies are responsible. Costs savings may be greatest if much of the monitoring can be based on remotely sensed data.
- Existing forest inventory programs can be the foundation for habitat-based monitoring programs.
- A habitat focus is more in line with the agencies' mission to manage vegetation communities (habitat), not species populations directly.
- Estimating the trends in habitat structure and composition represents an anticipatory approach to ecological monitoring, and allows alternative management strategies to be evaluated through predictive models.

Some important limitations to a strictly habitat-based approach to monitoring also must be addressed in the design of a monitoring program:

- Some unknown proportion of the variation in species' population dynamics is not driven by changes in habitat amount and distribution.
- Changes in habitat will not predict population responses to other stressors, for example, environmental toxins and climate change.
- On the basis of the first two limitations, a strictly habitat-based monitoring program may have limited ability to predict changes in the viability of some species and prove unreliable for some ecosystem processes.
- Most existing vegetation inventories (for example, Forest Inventory and Analysis [FIA] data) do not measure the complete complement of attributes relevant to the status and trends of species populations.
- Model validation efforts are required to ensure the continued validity of the habitat-based predictive models.

Given the possible limitations of defaulting to just habitat measures, several precautions are needed. The most important is that models predicting population status on the basis of habitat predictors must be subject to frequent validation. If validation tests are unsatisfactory, the structure of these models may need to be expanded to include additional predictors. Unfortunately, this addition would increase the scope of the monitoring program to include measuring additional indicators. Finally, the prudent course is to not devote the entire program to monitoring surrogate variables. Some effort needs to be devoted to direct measurement of the resources of interest.

Toward a Theory of Habitat

Given the great diversity of species—plant and animal, vertebrate and invertebrate—monitoring all biotic components of managed ecosystems clearly is impossible. Based solely on pragmatic considerations, only a few surrogate measures can be used that allow indirect (but reliable) inference to the integrity of the larger set of biological processes and components. A possible surrogate for the biota is to measure the pattern and dynamics of habitat structure, defined as the physical arrangement of objects in space (Bell et al. 1991). These objects, tangible and with discrete boundaries, can be either biotic or abiotic in origin. They have defining attributes including type, size (length by width by height), volume, mass, form (geometry), and if biotic, characteristic renewal rates. Most relevant to dynamic ecosystems are objects that create and modify environments, differ in their effects, and can be affected by human-induced and natural disturbance processes. These objects include dominant geologic features (for example, mountains, rivers) or biotic, structure-producing organisms (for example, coral reefs, trees, kelp forests) that create environments favorable to structure-using organisms. Over time scales relevant to management, the geologic features are assumed to be static. Thus, our focus is primarily on the biotic components, particularly plants, as the dominant objects in the space of landscapes that modify the environment and are affected by human activities.

A theoretical framework for organizing the effects of living objects on ecosystems is beginning to develop (for example, Brown 1995, Jones and Lawton 1994, Jones et al. 1994); that is, ecologists have begun to recognize that organisms cause physical and chemical changes in their environments, altering the flows of matter and energy, and thereby create environments favorable to other organisms. Jones and his colleagues focused primarily on animals that perform mechanical engineering resulting in such things as gopher-mound disturbances, bison wallows, and beaver dams. Our focus in the Forest Plan is more on vegetation that, through autogenic processes, controls flows of matter and energy in ecosystems and creates environments favorable to other species.

Given this framework, we return to our heuristic model (see fig. 7, Chapter 2), where underlying processes are reflected in and affected by structural and compositional elements of the biota. Focusing on the biotic components, some small subset of the vegetation or aspects of plant community structure and pattern would be directly monitored. Most plant species would not be directly monitored, however. Rather, those aspects of the vegetation that are measured would be chosen, at least in part, on their ability to provide surrogate information back to the integrity of the larger plant community and provide predictive insights into animal responses. These structural and compositional components would be biotic elements that are persistent, change or ameliorate the local environment, and create microenvironments favorable to many other species (plant and animal).

Justification—The justification for using habitat structure as a surrogate variable for predicting wildlife populations is based on both pragmatic and theoretical arguments. Habitat loss and fragmentation were the primary drivers or stressors behind creation of the Forest Plan. The theoretical argument is based on the belief that animals respond to habitat adaptively (Noon 1986); that is, where an animal selects to live is believed to be an evolved behavioral response stimulated by structural and compositional features of the landscape. The fitness gain accrued by making the "correct" decision is an increase in lifetime reproductive success. According to the conceptual model of Southwood (1977, 1988), by the processes of discrimination and eventual selection, habitat acts as the templet that guides the evolution of ecological strategies. Many behavioral studies support the understanding that animals evaluate a habitat's "quality" on the basis of proximal cues received from the environment. Habitat selection therefore would evolve if different decisions were associated with different probabilities of survival and reproduction.

Casting the theory of animal-habitat relations in an evolutionary framework serves two key purposes. First, it establishes a theoretical justification for attempting to model the relations between animals and habitat structure. Second, it suggests that predictive models relating patterns of a species' distribution to components of habitat structure are likely to be useful. Given such models, management-induced change in specific structural or distributional components of the landscape can be simulated and the likely biotic response estimated (see fig. 7, Chapter 2). Such tools would allow management alternatives to be evaluated in an anticipatory context.

Spatial Scales of Habitat Evaluation

Traditionally, most studies of habitat suitability have been conducted at the within-site scale; that is, ecologists have focused on the relations between individual patterns of occurrence on the landscape and features of the environment within the immediate neighborhood. We are now aware, however, that the distribution and abundance of most plants and animals also are strongly influenced by the spatial arrangement of suitable habitats across the landscape (for example, Flather et al. 1992, Lamberson et al. 1992, Short and Turner 1994). The spatial arrangement of habitats, however, is dynamic and subject to a variety of stressors; one of the primary causes of declines in biodiversity and in individual species has been a consequence of human-induced habitat fragmentation (reviewed in Noss and Csuti 1994). Thus, conservation efforts for any species must include analyses at multiple scales.

Species respond to environmental patterns at different scales—no single correct scale for habitat evaluation exists. In addition, the "correct" spatial arrangement of habitat elements is a function of the degree of population organization; what may be a fragmented habitat at the scale of the individual home range may not be fragmented at the scale of the population of the same species (Wiens 1996). Thus, habitat quality must be evaluated at a minimum of two spatial scales: the scale of the individual and the population scale. A third scale of assessment becomes important when long-term persistence of populations is considered in the context of environmental variation. Given this consideration, what is needed are many distinct populations, widely distributed across the landscape, with fluctuations spatially asynchronous (Den Boer 1981).

Developing predictive habitat suitability models requires consideration of the relations between landscape pattern and life history characteristics of individual species and population-scale dynamics (Rickers et al. 1995). These needs will require monitoring changes in the status and trend of habitat quality at the scale of the individual, the local population, and the metapopulation (see example for spotted owls in Noon and McKelvey 1996). Thus, managers and policymakers also will need to consider the effects of their decisions (that is, land use) at all three scales; decisions affecting habitat quality and species persistence can no longer be assessed just locally. The assessment strategy for northern spotted owls and marbled murrelets, which uses both remotely sensed and ground-plot habitat data, should allow inferences to habitat quality at all three spatial scales.

Developing Predictive Habitat-Relations Models for Animals

Two general types of models are possible: heuristic and mechanistic (Pielou 1981). Those that simply fit a statistical model to the observed data (that is, correlational approaches) often have no obvious biological interpretation; their coefficients do not necessarily reflect fundamental biological processes or elements. In contrast, mechanistic models attempt to simulate key biological process. As a result, mechanistic models go beyond forecasting to explain the behavior of the system.

In practice, developing models for selected components of the biota will be an iterative process moving from relatively crude to more refined models. A logical first step would be to explore the spatial relations between remotely sensed vegetation (habitat) data and existing data on patterns of species distributions. These relations could be integrated with higher resolution wildlife habitat relations models that already exist (for example, Morrison et al. 1994, Verner et al. 1986). This synthesis will allow the development of initial models to forecast changes in animal species distributions based on possible future changes in vegetation structure and composition. These models are largely heuristic.

Predictive models that reflect biological mechanisms, however, will need to explicitly incorporate demographic processes affected by habitat change at the individual, local population, and metapopulation scales. Such models directly evaluate changes in habitat quality as they affect key demographic processes: birth, death, and dispersal rates. This type of model has been developed for the northern spotted owl and used to investigate the response of the subspecies to landscape change on the Olympic Peninsula, Washington (Holthausen et al. 1995).

Population processes are affected by habitat factors operating at several spatial scales; for example, the survival and fecundity of a pair of spotted owls is a function of habitat quality at the scale of the home range. The likelihood of their offspring finding a suitable site and a mate are a function of the distribution of suitable territories at the population scale. And, the persistence likelihood of a regional population is a function of the number and distribution of local populations across the landscape. Therefore, to invoke habitat as an appropriate surrogate for anticipatory monitoring will require a multiscaled approach to modeling the relations between population dynamics and habitat. Only when population dynamics is considered in this holistic context will the monitoring program be sufficient.

Model validation—Predictive models lend themselves readily to validation. When habitat changes, as a result of management or natural disturbance, for example, field survey data can be used to test whether the species responds as predicted by the model. (Note the absence of a 1:1 mapping of habitat to population status requires that other drivers of change be treated as covariates and be controlled for statistically.) If little correspondence is found between the observed and predicted response, then the model is revised to incorporate new understandings, and validation begins again. Model validation and revision are ongoing and iterative processes.

Species populations are affected by many factors other than their immediate habitat; for example, disturbance history, availability of source populations, and current or past weather greatly affect observed population abundance and distribution. The correspondence between observed and predicted states therefore is seldom going to be 1:1. The challenge is to estimate the contribution of habitat structure; that is, What component of the variation in a species population is due to habitat variation? This question requires that the influence of habitat structure on organisms (and processes) be separated from all other environmental influences; that the majority of the structural components of habitats affecting organisms be identified; and that habitat structure be examined at all spatial scales relevant to the organism of interest. All these factors must be considered as habitat-based models are constructed, validated, and revised.

Tradeoffs Between Habitat and Population Monitoring

By choosing to measure a surrogate, instead of a direct measure of the variable of interest, inference to status and trend of the resource becomes indirect. The step back from direct inference inescapably introduces additional uncertainty to estimates of "true" status and trend of the population. The uncertainty associated with surrogate measures can be so large that no substitute exists for directly measuring the population. The results of attempts to predict population status from habitat predictors suggest that surrogate measures should be viewed with skepticism (see for example, papers in Verner et al. 1986).

Reasons can be cited for why inferences from habitat state to population status are uncertain: the realized habitat distribution of a species is affected by more than just habitat quality; and actual habitat use is affected by the species' density, the density and competitive interactions with other species, the abundance and distribution of biotic resources not directly related to vegetation, history of the population, and abiotic drivers such as climatic variation (Block and Brennan 1993). As a consequence, a species' pattern of habitat use is dynamic in both space and time. This realization has an important consequence for the use of habitat as a surrogate indicator of population status. To some degree, habitat attributes, particularly those components assessed by vegetation measures, will not be sufficient predictors of population status. Some component of population variation (that is, variation in distribution or abundance) will be unrelated to the current value of habitat attributes.

Focal Species as Ecological Indicators

An often-asked question concerns the degree to which the population status of a few selected species reflects the state of the larger ecosystems to which they belong. This is a reasonable question. Even if the species-based metrics are not selected as the most appropriate measures during indicator development, often legal mandates (for listed species under the ESA) or social mandates (for economically valuable species) exist for directly monitoring the population status of some species. The answer to the question, however, is not clear; for example, the interpretation and usefulness of "indicator species" have been widely debated. Most of the criticism has been directed at the reliability of drawing inferences to the status of unmonitored species from the status of a monitored species (Landres 1992, Landres et al. 1988). For the most part, criticism has not been directed at the use of species as sentinels of system change, as early warning of the action of one or more stressors, or as indicators of ecosystem state.

Current research has revived interest in the value of measuring aspects of species populations as useful indicators of ecological integrity; for example, multispecies conservation issues in Africa have been addressed by concentrating on "focal species" (Davis 1996). Often these species are simply those with large area requirements in habitats experiencing loss and fragmentation. Recently, simple models have been used to compare and rank species with similar life histories in terms of their sensitivities to habitat loss and fragmentation (Noon et al. 1997). This work represents a first step in moving from single to multispecies conservation planning. Of most interest to ecological monitoring, however, may be the recent quantitative formulation of the keystone species concept into an expression that formally links species dynamics to ecological processes (Power et al. 1996). An extended discussion of this paper is in order because it develops a framework for the selection of focal species as indicators of ecosystem state.

The most abundant species are well known for playing major roles in controlling the rates of ecosystem processes simply because of their numeric dominance. In contrast, keystone species differ from dominant species in that their effects are much greater than would be predicted from their abundance (Power et al. 1996). To make the concept more operational, Power et al. measure the impact of a species by its community importance (*CI*)—the change in a community or ecosystem trait per unit change in the abundance of a given species, which is expressed mathematically as:

$$CI = \frac{[d(trait)]}{dp} \bullet \left[\frac{1}{(trait)}\right]$$

where the right side of the equation represents the per capita rate of change in the ecosystem trait given a change, *dp,* in the proportional abundance (or biomass) of a given species. For example, the ecological trait of interest might be total carbon storage capacity in a forest ecosystem. We are interested in the per capita rate of change in carbon storage capacity with a reduction in the abundance of large-diameter pine trees. Deleting this species from the forest and recomputing carbon storage capacity provides an estimate of the *CI* of pine trees. In this example, our focus has been on species; however, the arguments about *CI* values could be computed for landscape elements as well as for species (for example, the *CI* of all trees > 30 inches in diameter at breast height).

Estimating the *CI* of a species or landscape element is difficult, but management "experiments" are often inadvertently performed that eliminate, or greatly reduce, a species (or element) from a community. Then, a measure of the species' importance (*CI*), given as the change in an ecosystem trait before and after its deletion, can be computed as:

$$CI = \frac{\left[\left(t_n - t_p\right)\right]}{t_n} \bullet \left[\frac{1}{p_i}\right]$$

where t_n is a quantitative measure of an ecosystem trait (that is, primary productivity) before deletion, t_p is a measure of the trait after species *i* has been deleted, and p_i is the species proportional abundance (or biomass) before deletion (Power et al. 1996). Despite the practical difficulties in estimating *CI* values for a community of species, this formalization offers a worthwhile perspective when contemplating which species to monitor.

The current understanding of the relative importance of species in communities and ecosystems does not allow a listing of life history traits that unambiguously characterize keystone species. Most known examples include species at high trophic levels (that is, top of the food chain) with high rates of prey consumption relative to prey production (Power et al. 1996). Given the criterion of disproportionate per capita effects relative to abundance or biomass, however, keystone species may occur at any trophic level. Perhaps the quickest way to gain insight into which species act as keystones is to better exploit management actions as ecological experiments (Walters 1986). Management actions on public forest lands cause changes in the abundance and occurrence of species in the management unit. By viewing these as "deletion experiments" relative to some ecosystem trait, we can more rapidly gain an understanding of which species most contribute to ecological integrity.

In the Pacific Northwest, one of the best examples of keystone species may be the anadromous fishes (Willson and Halupka 1995). Before their current population reductions because of habitat destruction, dams, and over-fishing (Stouder et al. 1997), salmon and steelhead made significant contributions to the base of the terrestrial food chain. In addition, they represented a significant vector of nutrient and biomass transmission from the marine to the terrestrial environment (Willson and Halupka 1995). Their contribution to the terrestrial food web and their role in nutrient transport into riverine and riparian ecosystems greatly exceeds their numerical abundance, qualifying them as a keystone species group.

In addition to the idea of keystone species, the "umbrella species" concept also may be useful when selecting indicator species for the Forest Plan. The umbrella species concept rests on the simple principle of animals with large area requirements, as Murphy and Wilcox (1986) stated, by protecting the minimum areas needed for a viable population of a single, large-bodied species, sufficient space should also be maintained for the viability of smaller and more numerically abundant species in the area. Implicit in this concept is that both the area and habitat requirements of the umbrella species encompass those needed for viable populations of other sympatric species and that the umbrella species' population is itself viable. A recent application involves the black rhinoceros in South Africa, and its role as an umbrella for the conservation of other large-bodied herbivorous species with which it is sympatric (Berger 1997).

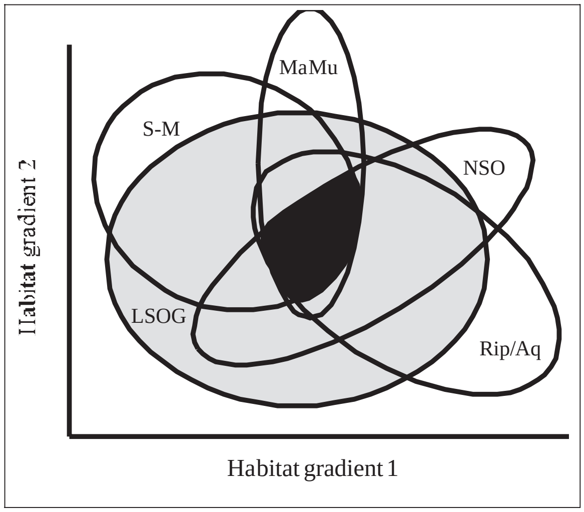

Figure 14—Hypothetical relation between important habitat elements in the Forest Plan. LSOG = late-successional old growth; S-M = survey-and-manage; MaMu = marbled murrelet; NSO = northern spotted owl; and Rip/Aq = riparian and aquatic.

For umbrella species, a preliminary list of ecological attributes could be compiled. Other than large area requirements, these species should generally be year-round residents (that is, nonmigratory), have low vagility, and select habitat elements that also limit the population sizes of sympatric species. Compelling arguments could be made that, in the Pacific Northwest, the northern spotted owl serves as a strong candidate umbrella species for much of the late-seral forest community (for example, Noon 1997).

Application to the Northwest Forest Plan

Key ecological resources are identified in the ROD (USDA and USDI 1994), among them the northern spotted owl and marbled murrelet populations, late-successional and old-growth forest, aquatic and riparian habitats and their associated species, and other associated late-successional organisms, including survey-and-manage species. To move toward a habitat-based approach to monitoring, each resource category is assumed to be represented by several specific, but surrogate, habitat elements expressed as quantifiable attributes of habitat structure and composition. This concept is illustrated in a model showing the ordination of each resource category along a pair of habitat gradients (fig. 14). Based on the current understanding of these resource categories, we believe that considerable overlap exists among the sets of habitat attributes that characterize the vegetation components of their ecological niches (fig. 14). Habitat attributes in the area of overlap should receive top priority for quantification. These concepts guided our application of the design principles (see table 2, Chapter 2) for each of the modules for the resource issues, as summarized in the following sections (see also “Research Support” in Chapter 4).

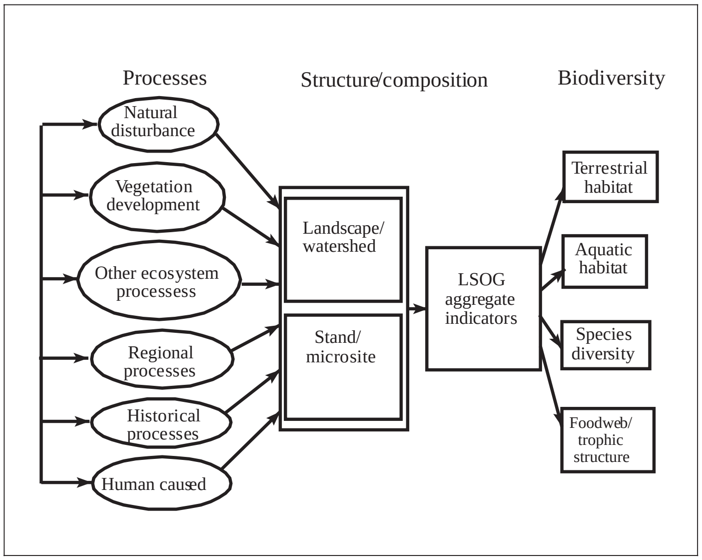

Figure 15—Conceptual model for late-successional and old-growth forest. LSOG = late-successional old growth.

Late-Successional and Old-Growth Forests

The core ecological resource of the Forest Plan, and the one about which we are most concerned, is late-successional and old-growth forest. To differing extents, providing for the vegetation elements that characterize such habitats will meet many of the requirements of other resources (fig. 15). Given this understanding, the first task is to develop a conceptual model for these habitats that retains our concept: biotic and abiotic processes are reflected in vegetation structure and composition, which in turn can be used to predict biological diversity and ecological integrity (see fig. 7, Chapter 2). Following the procedure outlined in Chapter 2, we have made an initial attempt to develop the late-successional and old-growth conceptual model by elucidating key processes, specifying the spatial scales at which vegetation structure and composition are evaluated, and listing the main components of biodiversity (fig. 15; Hemstrom et al., in press [see footnote 2, Chapter 1]).

We elaborate further on this conceptual model by resolving the components of the model into measurable attributes (fig. 16). For example, we list the key disturbance processes (stressors) likely to affect Pacific Northwest forests. These include wind throw, insect outbreaks, fire, logging, and road construction (fig. 16). Importantly, disturbance processes arising from human behavior are distinguished from those disturbances that would occur in the absence of people.

The most important task at this step, however, is to exhaustively list measurable attributes that describe vegetation structure and composition at various spatial scales. Because our focus is on measuring the key elements of vegetation structure and composition through time, these attributes constitute the list of candidate indicator variables for measurement by the monitoring program. The final selection of indicator variables at this step is done in the context of our underlying paradigm: *process* $\leftrightarrow$ *structure-composition* $\rightarrow$ *biodiversity*. That is, we must select for measurement

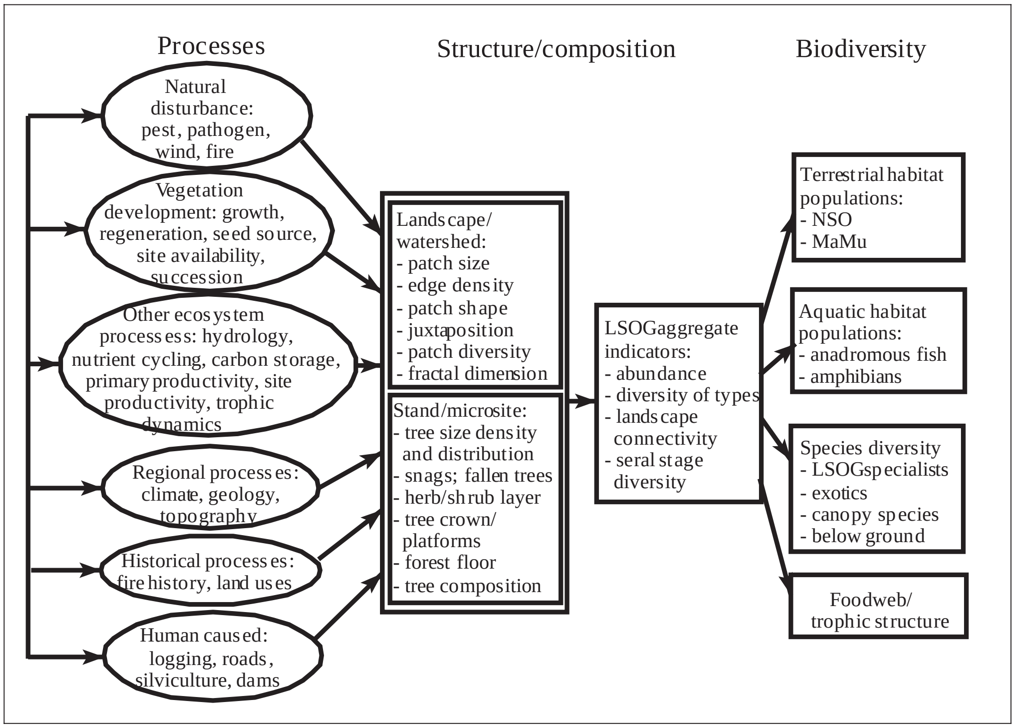

Figure 16—Expanded conceptual model for late-successional and old-growth forests showing measurable attributes that represent candidate indicator variables (Hemstrom et al., in press [see footnote 2, Chapter 1]). LSOG = late-successional and old growth; NSO = northern spotted owl; and MaMu = marbled murrelet.

those attributes that best reflect underlying ecological processes, and at the same time serve as the best predictors of biological diversity and ecosystem integrity. This process must be scientifically credible: based on the most current data, analyses, and understandings of Pacific Northwest ecosystems, and on the most applicable ecological theory.

Northern Spotted Owl

Given the Forest Plan's concentration on late-successional and old-growth forests, the task for monitoring individual species is to identify those components of the resource that overlap with critical components of the species' habitats. For the northern spotted owl (Lint et al., in press [see footnote 2, Chapter 1]), we are initially most interested in those elements of vegetation structure and function that simultaneously characterize the forests and spotted owl habitat (see fig. 14). Some spotted owl habitat requirements may lie outside the vegetation space that defines these forests (fig. 14). To the extent this is true, and to feel confident that the measured habitat attributes serve as a reliable surrogate for owl population status, we may need to expand the monitoring program. In this case, we would then elect to measure vegetation attributes beyond those required solely to monitor changes in the late-successional forests.

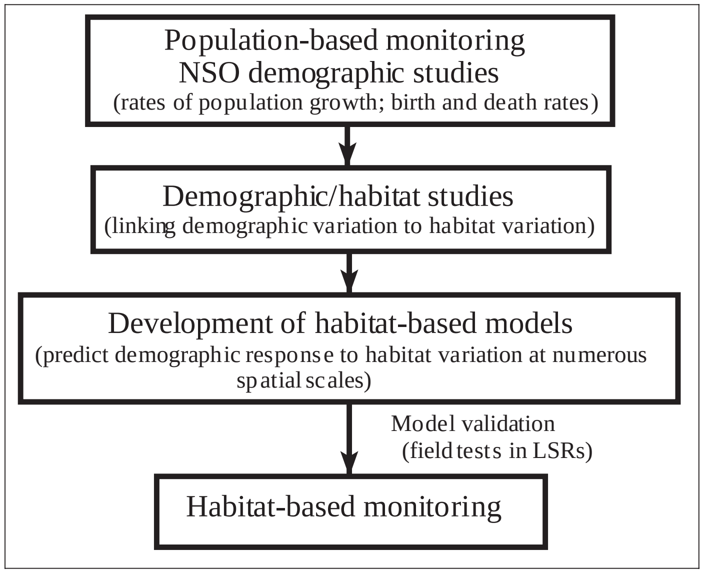

Figure 17—Key steps in the predictive modeling of species-habitat relations (Lint et al., in press [see footnote 2, Chapter 1]). NSO = northern spotted owl; and LSR = late-successional reserve.

To make the transition from the current demographic-based monitoring program for spotted owls to a habitat-based program requires an active period of habitat modeling (fig. 17). We must identify those aspects of vegetation structure and composition that have the greatest power to predict the distribution of owls on the landscape, as well as to explain the observed variation in demographic rates (owl birth and death rates) at a local scale. To accomplish this task will require an active research program characterizing vegetation at a variety of spatial scales based on data from the existing demographic study areas. The intersection of spatially referenced data from both the owl demographic studies and vegetation samples provides the fundamental data for the model-building phase. The degree to which these models explain the observed variation in owl distribution and population performance shows the certainty with which habitat variation predicts population variation. Explained variation is thus a direct measure of the confidence we have in habitat as an appropriate monitoring surrogate for population attributes.

We are aware that not all observed, population-scale variation will be explained by habitat predictors. Many factors, in addition to habitat quality, affect population size and demographics. The first task will be to estimate the expected proportion of population variance explained by habitat. To the extent the variance explained by habitat falls below expectation, the models will need to be refined to increase their predictive ability. Validating model predictions by independent field surveys also is essential; that is, the models will be used to predict an owl population response that must then be verified by direct field measurement from one or more owl populations (fig. 17). Finally, a period of concurrent monitoring of owl populations and habitat may provide additional insights into how they covary and accelerate the process of model development.

Marbled Murrelet

We take a similar approach with the marbled murrelet as for the northern spotted owl. We first identify those components of late-successional and old-growth forests that overlap with critical components of its habitat. A key difference, however, is that the murrelet spends most of its life at sea and uses forest habitat primarily for nesting. Our interest relative to the Forest Plan therefore is in the elements of vegetation structure and function that simultaneously characterize late-successional forests and murrelet nesting habitat (fig. 14; also see Madsen et al., in press [see footnote 2, Chapter 1]). Certain important murrelet habitat requirements, however, may not be included in the broad vegetation definition of the forests (fig. 14); therefore, we need to measure vegetation attributes beyond those required solely to monitor changes in the late-successional resource. At the initial stage of the monitoring program, analyses will be conducted to refine identification of definitions of these habitat attributes.

An active period of habitat modeling will be required to identify those aspects of vegetation structure and composition that have the greatest power to explain the distribution of murrelets on the landscape, as well as to explain the observed variation in population and demographic rates from the marine environment. To accomplish this task will require an active research program characterizing vegetation at a variety of spatial scales in known murrelet nesting habitat. As for the spotted owl, initial models may be heuristic (that is, correlational), but the ultimate goal is to develop mechanistic models.

In contrast to the spotted owl, the most appropriate place for evaluating population status and trends of murrelets, and to estimate demographic parameters, is in the marine environment. Murrelet status and trends will be evaluated through at-sea surveys to estimate population size and compute age ratios (young of the year to adults) as estimates of breeding success. If the terrestrial habitat management plan is appropriate, and at-sea conditions suitable, then an effective Forest Plan should result in a stable or increasing number of murrelets in at-sea counts, as well as stable or increasing age ratios.

Development of predictive models will focus on nesting habitat. The intersection of spatially referenced data from terrestrial surveys and corresponding vegetation samples provides the fundamental data for the model-building phase. As with the spotted owl, the degree to which these models explain the observed variation in murrelet distribution and population performance estimates the certainty with which habitat variation predicts population variation. Explained variation is thus a direct measure of the confidence we have in nesting habitat as an appropriate monitoring surrogate for population attributes. We know that not all observed, population-scale variation will be explained by forest habitat predictors, particularly for the murrelet, because of its reliance on the marine environment and because a large percentage of its nesting habitat is on non-Federal lands. To the extent the explained variation falls below that expected on the basis of habitat predictors, the models will be refined to increase their predictive ability. Validating model predictions by independent field surveys also is essential in both terrestrial and marine environments.

Aquatic and Riparian Ecosystems

The objective of the aquatic and riparian monitoring program is to assess the degree to which the goals of the aquatic conservation strategy (ACS; FEMAT 1993:V30-V31) are attained. In general, the ACS seeks to preserve or return ecological integrity to these systems by maintaining and restoring physical and biological processes, water quality, and the structural and compositional diversity of biologic (plant and animal) and geologic (shorelines, banks, and bottom configurations) elements that characterize "healthy" watersheds. Focusing on these key elements help form a basis for monitoring other aquatic and riparian resources—similar to the stepdown approach from LSOG to the spotted owl and marbled murrelet—such as fish and survey-and-manage species or other aquatic and riparian-associated species.

Following the approach outlined previously in this chapter, we begin the planning effort by identifying the human-caused stressors that may compromise attainment of the ACS goals (Furniss et al. 1997 [see footnote 2, Chapter 1]). The effects of these stressors on specific processes (biotic and abiotic) will be assessed at the site, reach, and watershed scales. The interactions among natural processes, human-caused disturbances, the structural and compositional elements of the watershed, and the response of the biota are characterized in a multiscale conceptual model. The model relies on an integrated indicator called watershed condition that combines the range of crucial processes necessary to sustain populations in specific watersheds. The multiscale model provides candidate indicator variables for both structural-compositional elements and direct measures of biological indicators. Finally, the approach is to use the conceptual model to aid developing empirical models linking land management to aquatic-riparian habitat conditions, and then to aquatic and riparian species.

When completed, the monitoring plan for aquatic and riparian resources will be formed around key components consistent with the overall design for effectiveness monitoring:

- An evaluation of current watershed condition based on available data and expert opinion, aggregated to basin, province, and regional scales
- Design and implementation of a statistically based survey to provide estimates of temporal trend for selected indicators of watershed condition
- Development of empirical models that characterize the relations between upslope disturbances and watershed condition

Evaluation of watershed condition would occur on a 5- to 10-year cycle. This would include evaluation of the effectiveness of forest practices (that is, standards and guidelines) and of the ongoing watershed analysis process relative to its intended role in scaling the ACS objectives to specific watersheds, and in providing the ecological context of watersheds at larger scales. These components will provide a foundation for developing modules of other aquatic and riparian resources and species.

Other Forest Plan Resources

We believe the step-down process that we developed for prospective, habitat-based monitoring (see table 2, Chapter 2) should apply to most ecological resources of concern in the forest planning area; for example, the concepts described above for monitoring spotted owl and marbled murrelet populations should apply to the survey-and-manage species group. Given the many species included in that list (USDA and USDI 1994), however, a focal-species approach may be essential. For system-based resources, such as old-growth forests and watersheds, we encourage the development of conceptual models first to facilitate indicator selection.

The approach we have outlined in this and the preceding chapters (see table 2 and subsequent discussion) provides only general guidance to the prospective monitoring process. To appreciate the full details required of a monitoring program, the reader is referred to the reports for each monitoring module (Hemstrom et al., in press; Lint et al., in press; Madsen et al., in press; also see Furniss et al. 1997 [see footnote 2, Chapter 1]).

Essential Data Requirements for Forest Plan Monitoring

In a habitat-based approach to environmental monitoring, the initial data requirements are estimates of the amount and distribution of vegetation communities (habitats), their defining attributes, and landscape features in the entire planning area. These baseline data—combining remotely sensed (aerial photographs, LANDSAT imagery) and plot data (current vegetation survey data; CVS)—will provide a preliminary characterization of habitat structure and composition in a spatially explicit format (that is, a map) across a range of related resource issues. Remeasurement at regular intervals will estimate the magnitude and pattern of change in major landscape features. Given these patterns of change, including information on changes in habitat amount and geometry, the expected biotic response can be predicted (see fig. 7, Chapter 2).

Minimal Components for Baseline Monitoring of the Forest Plan

The minimal data requirements to begin effectiveness monitoring under the Forest Plan are spatially referenced data drawn from surveys of the entire planning area; that is, a map of the structural and compositional features of the landscape, including information drawn from both public and private lands. The map will be based on data collected from plot surveys and remote imagery (Hemstrom et al., in press [see footnote 2, Chapter 1]). Standardized methods of change detection will need to be devised and applied at two spatial scales: local and landscape. Before the mapping exercise can begin, consensus on a standardized vegetation classification system and the minimum spatial resolution of the data is required (Vegetation Strike Team 1996).

Guidelines for the base map include:

- Use a spatially explicit framework that allows for easy and rapid updating. Create an “electronic map” via geographic information system (GIS) technology. Attributes to include as data layers should be carefully considered before data collection begins, and emphasis should be strong on data reliability.
- Monitor trends in several response variables: for example, the area of each vegetation type; the patch-size distribution of vegetation types; statistics of spatial pattern (for example, degree of contagion of late-successional stage communities; contrast between vegetation types; degree of connectivity within various vegetation communities). Trend should be estimated at a variety of spatial scales (local to regional).

- Manipulate the electronic maps, in the context of GIS, to simulate various stressor effects (for example, timber harvest or road construction). These simulations can be used to project changes in the response variables through time under various stressor regimes, and to explore the extent to which they could be mitigated by management actions.
- Select landscape elements that integrate disturbances across time and space (for example, watersheds or provinces) as a basic unit for spatial monitoring. Change statistics would be estimated at this scale and accumulated for provincial and regional summary statistics.

The primary function of the map, and its regular updating, would be to provide a straightforward tool for change detection at the landscape scale. Although a 10-year cycle may be realistic, we propose the above list as a minimum set of analyses to be conducted on no longer than a 5-year cycle, assuming annual updates to the map. We also suggest that the remotely sensed data be cross-referenced with CVS plot data (Max et al. 1996) to allow accuracy assessment for validation of the map classification and to provide estimates of classification error. Such a cross-reference also should allow inferences to habitat change at the stand scale.

To be useful for modeling and to reliably forecast the effects of changes in land use practices on ecological processes, the map, at the landscape scale, must be wall-to-wall to include attribute information on non-Federal as well as Federal lands.

Attributes of the Habitat Map

The attributes of the habitat map will determine the initial set of variables available for predictive modeling for owls and murrelets at the landscape scale. The key variables for inclusion in the map will be determined by the intersection between the habitat attributes that can be estimated from remotely sensed data and the attributes relevant to owl and murrelet ecology. This map will be produced as part of the monitoring program for late-successional and old-growth forest resources.

The effectiveness monitoring program uses two perspectives of habitat, one from remotely sensed attributes and the other from ground plot data collected at the stand scale. Habitat is estimated at two distinct scales: landscape and forest stand. These scales are appropriate to owls and murrelets and correspond to population processes operative at the scales of the individual animal and the population. By some process (to be determined by future research), stand-scale habitat quality metrics can be accumulated upward to draw inferences to habitat quality at the population scale. Consequently, inference to habitat status and trend for owls and murrelets can be made at two independent scales of assessment.

Maps will be developed at two spatial scales, with preference given to landscape-scale mapping. The minimal attributes to include are listed below:

Landscape scale—maps and analyses:

- Forest class (potentially forested; seedling and sapling forest; small, single-storied stands; medium to large single-storied stands; large multistoried stands)
- Forest land class type (coniferous, mixed, deciduous)
- Vegetation unit (combination of forest class and land class type, resulting in 16 possible mapping units)
- Acreage by forest land class type

- Spatial distribution of land class types
- Distribution of patch interior areas by land class type
- Distribution of interpatch distances

Stand scale—data tables and analyses:

- Acreage by forest class and land class
- Tree-diameter distribution by species
- Canopy structure and height-class distribution by species
- Snag height and diameter distribution by species
- Down woody debris

The development of a reliable landscape-scale map of forest types, accompanied by annual updating for change analyses, is an essential landscape habitat component of an effectiveness monitoring program for the Forest Plan. Another essential site-scale habitat component is the existing CVS survey information; additional measurements are required for CVS to obtain site-scale habitat measures for the spotted owl and marbled murrelet. Because these data have utility beyond the monitoring program, a consolidated ecological classification, inventory, and mapping program crossing agency and program lines would be most effective and useful.

Summary of Key Points

The application of the scientific approach presented in Chapter 2 to effectiveness monitoring for the Forest Plan is presented in this chapter. The scientific justification for a gradual transition to a habitat-based approach is discussed along with the basis for the selection of focal species. The dependence of this approach on the development of reliable habitat-relation models is presented, and the application of these concepts to late-successional and old-growth forests, northern spotted owls, marbled murrelets, and aquatic-riparian resources is discussed. The data requirements for these modules are reviewed, emphasizing the importance of both remote sensing and ground-plot surveys of vegetation to all aspects of the monitoring program.

Acknowledgments

This chapter includes contributions from Thomas Spies and Martin Raphael.

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Chapter 4: Components of the Effectiveness Monitoring Program

Craig J. Palmer and Barry S. Mulder

A Structured Approach to Monitoring

The monitoring program for the Forest Plan will produce considerable information throughout the life of the program, including a wide variety of data tables, maps, and reports. Numerous individuals and groups will participate in this effort at many localities across Washington, Oregon, and northern California. The mechanics of how this information is collected and managed will dictate how successful the monitoring program will be in the adaptive management process.

Efforts to plan monitoring programs almost always focus on the technical aspects of design, with little consideration given to the specifics of who will actually do the work and, even more important, how that information will be maintained and used. The basic problem in implementing a monitoring program is that the full process of monitoring—including data collection, management, analysis, and reporting—has not been well organized and usually not institutionalized in existing agency cultures (Bella 1997, CENR 1997, Grumbine 1997, Morrison and Marcot 1995, NRC 1990, Noble and Norton 1991, Schreuder and Czaplewski 1992, U.S. GAO 1988). Structured, periodic reporting is critical (Vora 1997), but people often take for granted that information will appear when it is needed, without much thought about how it actually gets there. In addition, few models at this scale are available to illustrate what will be needed to adequately support an ecosystem-based monitoring program (Persson and Janz 1997).

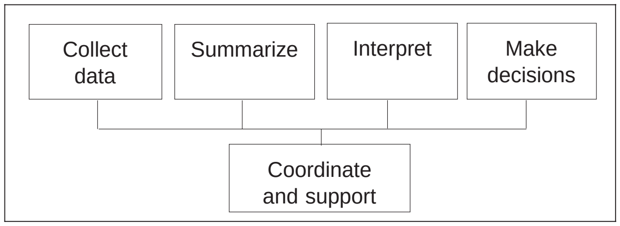


Figure 18—Conceptual model of the components for implementing an operational monitoring program.

To respond to this concern, we have attempted in this chapter to answer the question, What is a monitoring program? Although not a major part of the assigned task, our experience made us realize that the scope, complexity, and magnitude of the proposed monitoring designs for the combined resources required an operational context. A monitoring program is more than data collection, and more than a source of information in the adaptive management cycle. In developing and implementing a monitoring program, equal consideration must be given to collecting, managing, and reporting information (Persson and Janz 1997). The program resulting from these considerations for the Forest Plan will be different, however, from how we have traditionally handled monitoring activities and will require giving thought to the operational components of a monitoring program. Close collaboration during all phases of planning is required between decisionmakers and those designing a monitoring program (CENR 1997; Morrison et al., in press; Noble and Norton 1991; Vora 1997).

To understand the myriad decisions that managers must make to implement the monitoring program for the Forest Plan, we offer a conceptual model (fig. 18). The model focuses on the five operational components of a structured and organized monitoring system and illustrates the relations among these components. Each box represents people, assignments, and products, and the model helps illustrate how decisions need to be made to manage the different elements successfully. It can help to identify needed actions and documentation. By referring to this model, staff can be assigned specific tasks, for specific purposes, and essential collaborators can be identified. Although not emphasized in this diagram, feedback occurs among each of the components to encourage continual improvement and ensure ongoing utility in the program.

The model also can clarify how staff responsible for the different components contribute to the adaptive management process. Each box in figure 18 identifies a process or activity. Data collection results in developing databases that must be maintained. Databases, especially large ones, are most valuable when they have been summarized into useful information. This information must then be interpreted in the context of other information (such as recent scientific research) to improve the understanding and knowledge of the systems we are evaluating (U.S. GAO 1994). This knowledge can then become an important component in contributing to wise management decisions (Keune and Mandry 1996, Roots 1992, Thow-Yick 1994). A representation of these concepts is presented in figure 19 (see also fig. 2, Chapter 1). This chapter will describe each of the critical components that are part of a monitoring system.

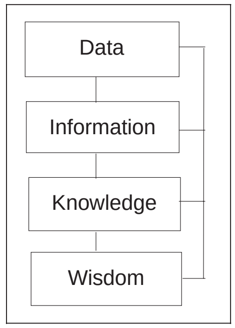
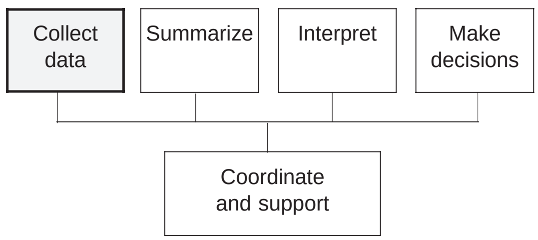


Figure 19—Conceptualized feedback between data and decision for adaptive management.

Data Collection



Data collection represents the largest component of a monitoring program, usually employs the most staff, and is the most costly part. To ensure that collected data meet our needs, the monitoring design is critical (see Chapter 2, "Key Steps in Designing the Monitoring Program"). Agencies often are data rich because of the myriad programs involved in collecting information (CENR 1997, Olsen and Schreuder 1997), so part of the exercise is to determine if existing activities can contribute to the monitoring effort. An objective of this section is to identify the role of existing projects in the region of the Forest Plan that may provide critical data needed for effectiveness monitoring. A second objective is to provide a strategy to address important monitoring-data needs not currently being met by ongoing projects. Because these projects will need to be integrated into effectiveness monitoring, an approach also is presented for coordinating these efforts and improving data collection over time.

Review of Ongoing Data-Collection Activities

Many existing agency inventory, research, and monitoring activities are collecting data of value to effectiveness monitoring in the region of the Forest Plan. For example, current data collection in the region of the Forest Plan can be arranged into four categories as illustrated in figure 20. This figure shows the relations between these four categories and how they may contribute to the effectiveness monitoring program. Although some data collection activities may be initiated solely for the effectiveness program (type A), there will be many other data collection activities that may contribute only partially (type B or C) or may not contribute to this program (for example, type D).

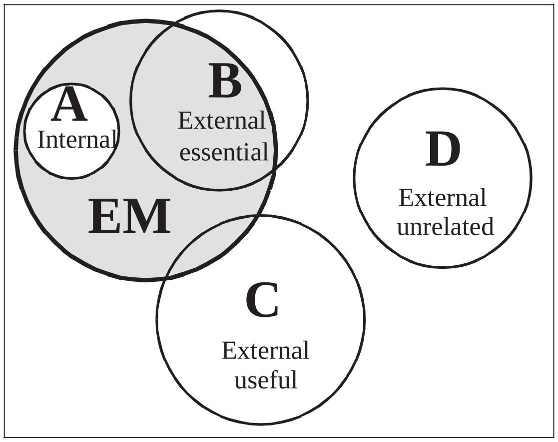


Figure 20—How data-collection projects are related to effectiveness monitoring. EM = data collection needs of effectiveness monitoring; type A = monitoring activity initiated solely for the effectiveness program and internal to it; type B = external activity, initiated for other purposes, that makes a significant contribution to the data requirements of effectiveness monitoring; type C = external program that provides useful but not critical data; and type D = external activity with no apparent connection to effectiveness monitoring.

Rather than duplicate projects that may contribute needed information, the monitoring modules (Hemstrom et al., in press; Lint et al., in press; and Madsen et al., in press [see footnote 2, Chapter 1]) build as much as possible on ongoing activities, which—in a real sense—makes this a "value added" program to enhance the usefulness of results from other programs. It also reduces or avoids new monitoring costs. Programs should be evaluated to determine whether they could provide needed information.

To meet the needs of the monitoring program, however, a project must meet certain standards. General criteria to assist in placing data collecting activities into one of the four categories given in figure 20 are presented in table 4. The purpose is to evaluate the utility and importance of a project to effectiveness monitoring. These criteria should be considered individually and then combined to develop a rating for a specific activity. The criteria also can be used to identify changes to improve the utility of a project for the monitoring program.

Because of the potential to adapt existing activities[1] to meet the needs of the monitoring program, no type A activities have been proposed at this time. Examples of existing Federal activities considered essential (type B) to effectiveness monitoring include (also see appendix D, table 12):

- Forest Service and BLM's current vegetation surveys (CVS)
- Forest Service and BLM remote sensing programs

[1] Most existing activities proposed as essential sources of data for effectiveness monitoring are not permanent resource programs with base funding, but instead have been funded and staffed as short-term projects (see Chapter 5 for funding needs).

Table 4—General criteria for evaluating utility of existing or new projects for effectiveness monitoring (EM)

Criteria	Internal to EM (type A)	External essential (type B)	External useful (type C)	External unrelated (type D)
Objectives	Focus on EM objectives	Addresses one or more EM objectives	Related to EM objectives	Not related to EM objectives
Monitoring questions	Answers specific EM question(s)	Contributes to or answers one or more EM questions	Useful to EM questions	Not related to EM questions
Geographic coverage or scale	Rangewide on Federal lands—Forest Plan	Rangewide on Federal Lands—Forest Plan area—or when combined with other components, becomes a rangewide program	Single province or partial coverage	Local or limited coverage
Indicators and measurements	Focus on EM indicators	Includes EM indicators within regular project indicators	Other useful data (e.g., stressor data)	Not related or unknown value
Sampling design	Statistically valid for EM objectives	Statistically valid for EM objectives in addition to original project objectives	Statistically valid for other objectives	Not statistically valid design or no design
Project duration	New	Ongoing	Likely to end	Has ended
Historical record	New	Long term	Short term	Minimal
Quality assurance	Under EM quality-assurance program	Rangewide comparability	Inconsistent quality assurance	No quality assurance
Database management	Designed for EM	Well designed, efficient, and maintained	Inconsistent	No database management
Database access	Accessible electronically through the EM program	Accessible electronically with project permission	Accessible but not in electronic format	Database not accessible
Project reports available	To be available annually	Available on annual or other planned period	Occasional	None available
Ability to adapt to changing EM needs	Intended to be improved over time	Can be improved	Low flexibility	No flexibility
Uses (for planning, budgets, reporting)	Intended for these uses	Contributes to these uses	Occasional use	Not of use
Costs; availability of base funding	New	Currently funded	Uncertain	None or unknown
Costs; additional base funding needed to address EM objectives	New	Small to none	Medium	Large

- Northern spotted owl demographic studies (Federal research agencies)
- Watershed analyses as required under the ROD (USDA and USDI 1994)

Several projects in this category, such as CVS (Max et al. 1996), have recently been established with a major purpose of meeting the needs of programs such as effectiveness monitoring. As the Forest Plan monitoring program is established, these projects may move to the type A category.

Type C activities collect data that are of value but not essential to the success of the program. One method of evaluating whether a program is type B or C is to decide how the utility of the monitoring program would be affected by terminating these activities. If the monitoring program could not meet some of its objectives because a type C project was discontinued, then it probably belongs in type B. If the program could continue to meet its goals even though the analyses might be diminished through loss of type C activities, then the activities fall in the C category. Examples of existing projects that provide information of value (type C) to effectiveness monitoring include FHM, FIA, and murrelet marine surveys (also see appendix D, table 13). Additional projects that collect useful information likely will be identified as monitoring plans are developed and implemented. If these activities are consistent (see table 4) in protocol and design required for monitoring (for example, see the murrelet module [Madsen et al., in press] for discussion on marine surveys), the data would be essential (type B) to effectiveness monitoring. Of particular interest will be how the large number of projects currently involved in gathering information on aquatic and riparian resources will meet the goals of the effectiveness monitoring program (Furniss et al. 1997 [see footnote 2, Chapter 1]).

Addressing New Data-Collection Needs

We anticipate that some data requirements for effectiveness monitoring may not be met by ongoing data-collection activities. Two approaches should be considered to address these additional needs. First is to enhance or adapt existing efforts by adding to them the new measurement variables required for effectiveness monitoring. The additional expenses from adding a new variable to an existing survey are much less than starting a completely new program. The CVS program, for example, is testing the possibilities of adding measures for murrelet nesting habitat to ongoing surveys (Madsen et al., in press [see footnote 2, Chapter 1]). Although minimizing the cost of collecting these data, this strategy also will improve the use of data from existing survey efforts in the monitoring program. But before new measurement variables are added to existing projects, they need to be tested. In addition, existing projects should have appropriate spatial and temporal coverages to meet the needs of effectiveness monitoring (see table 4).

The second approach is to develop entirely new data-collection projects for the montoring program (type A). Each project would follow the design criteria described in Chapter 2 ("Key Steps in Designing the Monitoring Program"), have a detailed project plan, obtain funding, and be fully integrated into the monitoring program.

Coordination Among Data-Collection Activities

Numerous projects will contribute data to the monitoring program. Coordinating the integration of these activities into the effectiveness monitoring program will have multiple benefits, such as improving the ability to use data for multiple resources, thus reducing costs (see "Integration," below, this chapter). Any data-collection activities that fall into the type A category would be directly managed as an integrated part of the program. Type D data-collection activities would not need to be integrated unless data of particular interest to the program are collected, which then moves them into another category. What requires thought, however, is how to integrate information from the B and C categories into the program.

Type B monitoring projects collect data critical to the success of the effectiveness monitoring program. Many of these projects (for example, CVS and spotted owl demographic studies) are funded by various Federal agencies and would need to be continued to be useful to effectiveness monitoring. A decision by an agency to alter or terminate a type B program could have profound implications to the success of the monitoring program. In other words, information provided by these projects is so critical that close coordination and integration with the monitoring program are essential.

Although type C activities may not be essential to the effectiveness program, we recommend that some coordination with the monitoring program be considered for these activities. Monitoring staff should keep informed about results coming from these activities by periodically reviewing project reports and attending program reviews. Emerging needs of monitoring should be communicated to managers as well. Significant changes in these projects should be identified, in case data from the projects become essential for effectiveness monitoring.

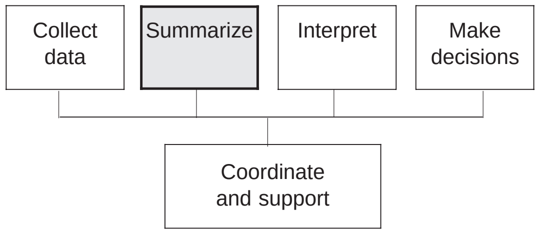
Coordinating and integrating the data collected through all these independent efforts is critical to the success of the monitoring program. The following steps would contribute to achieving this integration:

- **Direct staff links**. Monitoring staff would be responsible for coordinating mutual activities. Direct staff links will foster awareness of any changes contemplated for these projects that could affect the monitoring program.
- **Direct data links**. A direct link to data from type B activities by effectiveness monitoring staff is essential. Monitoring staff and managers will require rapid and consistent access to these data and associated information about the data (metadata) to complete the required monitoring reports.
- **Quality-assurance (QA) systems**. All data used in monitoring must be of documented quality to be legally defensible (see "Quality Assurance," below, this chapter). Assessments of data originating from many sources are most useful when data are comparable, compatible, and verifiable (Burke 1996, Schroder et al. 1996). Because most current monitoring projects do not have established QA systems, the monitoring program will need such oversight for its activities. Oversight would include implementing QA project plans, QA management reviews, and QA reports.

Strategy for Continual Improvement

A major goal of the monitoring program is to continually improve the quality and utility of data. Because many of the essential data-collection activities are external (type B and some type C), the program will need to provide feedback to the managers of those activities about the utility and quality of the data to keep them informed or reminded of the requirements of the effectiveness monitoring program. Internal (type A) data collection can be improved through annual debriefings of field crews, review of the quality of data, reports from data analysts about the utility of the collected data, and feedback from policymakers (see "Management Decisions," below, this chapter).

Data Summaries



The reporting of information has been a major problem in environmental monitoring (CENR 1997). To facilitate this process, two essential types of reports are described: data summaries and interpretive reports. Each has an important role in making data collected for effectiveness monitoring available to decisionmakers; interpretive reports are covered in the next section.

Data summaries are brief, comprehensive reports of essential data collected for the monitoring program by internal (type A) or external (type B) data-collection projects. The primary intent of a summary is to present data in an organized and useful manner. Some evaluations of the significance of the results also may be presented, if readily apparent. Data summaries should be prepared for each module each year, or as appropriate to the resource being monitored (for example, some activities may not collect data every year); therefore they can be preplanned.

The routine preparation of data summaries will provide several important benefits to the program. If prepared on a predictable and recurring basis, the summaries can foster program support by establishing a client base for the reports (Ember 1995). Preparing them also serves to motivate data collectors to process their data in a timely manner so that assessment and reporting needs can be met. These reports provide a tangible product for which staff and agencies can be held accountable each year. Most important, data summaries are essential building blocks for preparing interpretive reports and provide intermediate progress reports for assessing Forest Plan objectives. In this section, we discuss the steps required to summarize data and prepare these reports (fig. 21). Two options will be considered for the spatial coverage of individual reports, and a strategy for continually improving these reports is included.

Summarizing Data

The first step in summarizing and evaluating ecological data is to conduct a quality check of the data to be used in preparing the report. The process—called data validation—results in the acceptance, rejection, correction, or qualification of data. Although this step often is overlooked, it is essential to producing credible and valid results (see “Quality Assurance,” below, this chapter).

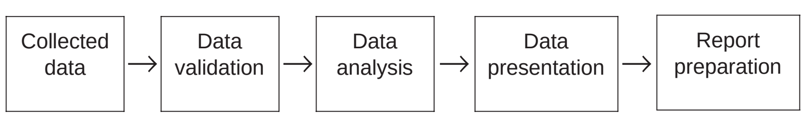


Figure 21—Data summarization process.

Once data have been accepted or corrected through validation, the summary process begins. An important first step may be to consider combining many measurements into simple indices useful for interpretation (see Chapter 2, "Expected Values and Trends"). Examples of some useful indices might be adult female survival rate, biotic integrity, species diversity, down woody debris per acre, or connectivity between old-growth patches on the landscape (for example, see Hemstrom et al., in press; Lint et al., in press; Madsen et al., in press; also see Furniss et al. 1997 [see footnote 2, Chapter 1]). Regional standards should be developed for how these indices are calculated (Thomas 1996); the indices can then be presented in the summary reports as statistical tables, bar charts, cumulative distribution functions, figures, or maps. Trends also can be calculated by comparing results with those reported in previous data summaries.

Staff members responsible for collecting or working with the monitoring data would be expected to play the major role in preparing data summaries. These individuals would be responsible for obtaining data from external monitoring projects, validating these data, synthesizing them into useful indices, evaluating them, and preparing the summary reports.

Content of Data Summary Reports

The data summaries would include monitoring results for each of the resource issues (that is, late-successional and old-growth forests, spotted owl, marbled murrelet, and aquatic and riparian). Monitoring questions for which data have been collected should be addressed in the data summary, and results should be reported as quickly as possible to avoid a delay in the evaluation if major issues arise. Data can be presented in many forms including statistical tables, charts, figures, and maps. We recommend developing standardized formats for each resource report so that new data can be readily substituted each year into subsequent reports.

The first data summaries prepared by the monitoring program will be important milestones because they will be the model for future summaries. These first reports must undergo extensive review to evaluate their utility and the accuracy of the assessments. This review also should include a detailed examination of the data-assessment algorithms, because they will be used for future reports. This examination should check whether the appropriate calculations have been made and if they have been correctly programmed for computer or other use.

Options for Data Summaries

A unique challenge for the monitoring program will be to prepare summary reports with data from many different monitoring efforts. Each effort may cover different areas and have different remeasurement cycles, and complete data sets may not be available each year from every monitoring activity. Note that a monitoring program for a specific resource may consist of more than one field project; for example, in the eight demographic studies for the spotted owl, data are collected every year, managed, and reported separately by project. On the other hand, in any one year, data are collected for only part of the range of the Forest Plan for the Forest Service CVS project. Regardless, the information from these different projects needs to be combined for use in the regional summary reports.

Several options exist for developing data summaries. One is to report all monitoring data collected during any given year from across the Forest Plan region for all resource issues. This approach would tend to encourage timely evaluation of all data. An implication of this approach is that monitoring would need to be active in all parts of the region every year, which would allow frequent regionwide analyses or interpretations of monitoring data.

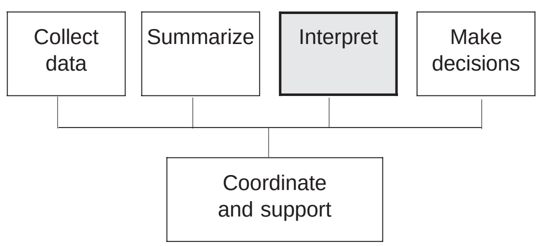
A second approach is to select a subregion (such as two or three provinces) or a specific resource, and complete a summary report for those on a rotating basis. The report could include all data from the most recent remeasurement cycle that may have taken a monitoring group several years to collect. Over a period of 4 or 5 years, all areas could be covered. This approach would mean that the synthesis or interpretation of results for the Forest Plan could be done only after analyses for all areas had been completed. The region could be divided by political or ecological boundaries. The choice of political boundaries would foster cooperation among management units, and the choice of meaningful ecological units would foster the ecological interpretation and presentation of data. Focusing on a specific resource issue may help address emerging questions that arise unexpectedly (for example, under the ESA).

Strategy for Continual Improvement

One goal for the staff preparing data summaries should be to continually improve them over time to make them more useful and responsive. Obtaining feedback about the quality and utility of the data summaries through peer reviews, management reviews, or client surveys is important. These surveys can be included with each report, and feedback from the surveys and reviews can be used to improve subsequent reports.

Publishing monitoring data as well as reports also would be useful, for example; by providing access through the Internet. This strategy offers external reviewers an opportunity to look at the data and verify or identify trends. Some may not want their data published, but the program could provide a link to data users by listing data sources in summary reports. The goal is to improve methods for evaluating data by encouraging as many people as possible to use monitoring results.

Interpretive Reports



The primary product of the effectiveness monitoring program will be a periodic region-wide interpretive report. The purpose of the interpretive process is to evaluate the ecological significance of status and trends emerging in the monitoring data, as identified in data summaries (fig. 22). The role of interpretive reports is to present a synthesis of monitoring results and statements of their implications to management for each resource being monitored, and how those results may relate to continuing implementation of the Forest Plan. This information is critical to the adaptive management process mandated in the Forest Plan; it will be used to change plans, direction, or policies and contribute to budgetary and other decisions.

Interpretive reports differ from data summaries in several key features. Interpretive reports are more analytical and comprehensive than data summaries. Considerable effort and planning are required to develop successful interpretive reports, and they will require significant participation by knowledgeable agency scientists. This section describes a process for preparing interpretive reports, including options for staffing, the reporting frequency, and a strategy for future improvement.

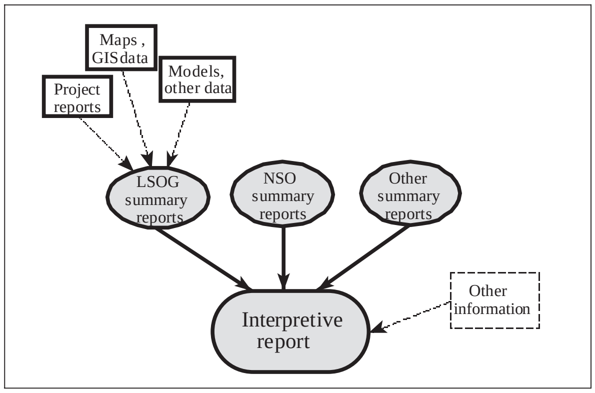


Figure 22—General flow of information from projects to annual data summaries to periodic interpretive reports using LSOG as an example. LSOG = late-successional old growth, and NSO = northern spotted owl.

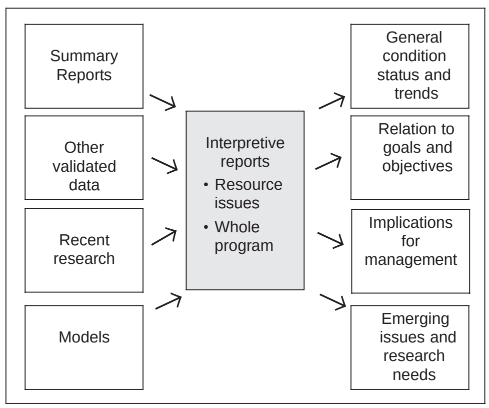


Figure 23—Information sources and topics addressed in effectiveness monitoring.

Preparing Interpretive Reports

The key task of interpretive reporting is to address the effectiveness monitoring questions by using all available data (fig. 23). The focus will be on analyzing and interpreting trend data. Analyses should emphasize past trends, current status, and projected future trends. These trends should be explained in terms of their ecological context and their implications to management (for example, Southern Appalachian Man and the Biosphere Cooperative 1996).

Sources of data include all monitoring activities producing types A and B data and useful type C data. Summary reports provide an important starting point for additional data analyses, as do relevant research findings, especially new ones. In addition, other information that may have a bearing on the monitoring questions should be considered and addressed, as appropriate, such as information from other lands (for example, National Park Service or non-Federal lands) or from other related programs (for example, FHM, FIA, or local databases). All data used in preparing interpretive reports need to be validated, although much of this validation will have been completed in preparing data summaries.

Content of Interpretive Reports

The ultimate goal from an ecosystem perspective is to address status and trend questions about the Forest Plan, as gained through knowledge of the status and trends for the resources being monitored. As a starting point, all effectiveness monitoring questions outlined in the modules for each resource (Hemstrom et al., in press; Lint et al., in press; Madsen et al., in press; also see Furniss et al. 1997 [see footnote 2, Chapter 1]) would be evaluated in the interpretive reports. Questions may be prioritized or additional questions may be added depending on current information needs. The report may be organized to address specific resources, such as spotted owls, or it may be organized to foster a synthesis of results across resources that would facilitate conclusions about the status of the Forest Plan relative to these resources. As with summary reports, a standardized format should be developed.

These reports would interpret monitoring signals in the context of all relevant data and contemporary ecological theory, and a range of possible management responses to the monitoring results should be suggested for each resource. Discrimination among possible management responses to the monitoring data should be made in a formal decision-theoretic framework (Marcot 1994; also see Chapter 2, "Linking Monitoring Results to Decisionmaking"). That is, the possible decisions should be listed, the likelihoods associated with each possible interpretation of the monitoring data estimated, and the costs and benefits associated with each possible combination of decision and likelihood should be thoroughly discussed. By this process, the monitoring data fully contribute to the decision process. Each step should be fully documented in the interpretive report.

Options for Frequency and Staffing of Interpretive Reports

Given the long time frame of monitoring, interpretive reports would not be needed every year, but should be prepared at periodic intervals (for example, see monitoring modules [Hemstrom et al., in press; Lint et al., in press; Madsen et al., in press]). Reporting would be regional, although a more focused report addressing a specific question or resource may sometimes be needed. Options can range from intervals of 1, 2, 5, or 10 years, although a 5-year interval may be the most practical. One- or two-year intervals would be too frequent, given the intensity of effort required to prepare the reports and because of the time required for significant trends in data to emerge. Because agency planning occurs on about a 10-year cycle, a 5-year reporting interval offers land management agencies the benefit of two interpretive reports on which to base changes to management plans in the normal planning cycle, or to make adjustments between cycles if the results so warrant (see Chapter 5 for milestones). More frequent reports could be provided if necessary or requested.

A significant amount of preparatory work is associated with developing these reports, and several options exist for preparing them. One would be to assign specific agency staff who would be dedicated to preparing the report. The problem with this approach is that a 5-year cycle may be too infrequent to justify hiring staff solely for this task. Staff responsible for collecting monitoring data may participate, but a range of other disciplines including both staff and managers needs to be involved. Specific expertise would include data managers, statisticians, subject-area specialists, ecological modelers, and remote-sensing and GIS specialists. The regional monitoring staff would be most logical to manage this task with specialists assigned as needed. The number would differ depending on the nature and size of the expected report (see "Infrastructure Requirements: Institutionalizing the Program" in Chapter 5).

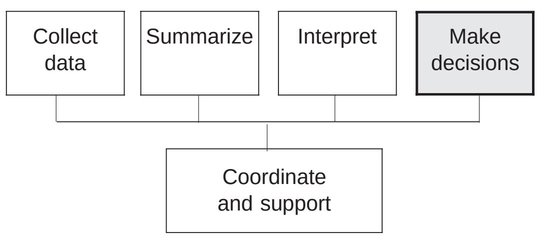
A second option would be to select a consulting panel of experts to assist in-house monitoring staff. The panel would be composed of agency scientists with expertise to address the monitoring questions. Program staff responsible for preparing data summaries would provide technical support to the panel of experts. The panel would have responsibility to evaluate the implications of answers to the monitoring questions and identify important followup actions. For the panel of experts to be most effective, they would need to be assigned 2 years before an interpretive report is to be completed. This timing would allow them to organize data, evaluate the summary reports, identify other relevant external data, and prepare the reports. This approach also would allow the participating agencies to budget for this periodic activity and allow research agencies to adjust assignments of key research staff needed to participate.

A third option would be to contract the preparation of the interpretive reports to a separate panel of scientists or consultants. An example could be a contract with the National Research Council to prepare an interpretive report on monitoring questions for a specific resource issue; other supporting factors noted under the second option above would be applicable.

Strategy for Continual Improvement

As with the data summary reports, obtaining feedback through peer reviews and client surveys on the quality of the interpretive reports is vitally important. An additional method of feedback could be from encouraging involved scientists to publish key results of data analyses in peer-reviewed journals and using the results to improve the process.

Management Decisions



Readers may wonder why a step for making decisions has been included as a separate component of the effectiveness monitoring program. As Noble and Norton (1991) concluded “Many monitoring programs fail not because of poor design or measurement but due to a lack of appreciation or understanding by managers of the purposes of the exercise.” The monitoring program is set up to generate a continual output of information and reports. A major problem for the adaptive management process will be knowing how and when to use this information. This section discusses how to integrate this information into the planning and decision processes, and it identifies ways of making monitoring more useful to those making decisions; the latter area, particularly the emphasis on use of decision theory and risk analysis, needs further investigation (see “Research Support,” below, this chapter).

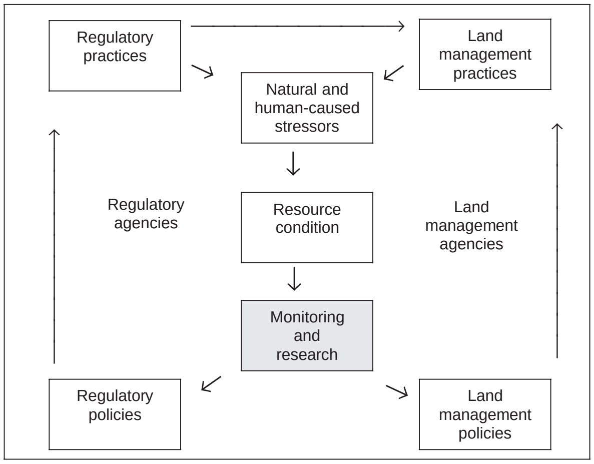


Figure 24—Conceptual model of how monitoring is related to management.

Conceptual Model

A general schematic of the relation of monitoring to agency policies is presented in figure 24. Changes in resource condition result from a combination of natural stressors, land management practices, and regulatory practices. The role of monitoring is to provide feedback about status and trends in resource condition that will be useful in evaluating the effects of land management or regulatory practices. If undesired effects are encountered, agency administrators can consider changing policies, or delaying implementation of policies until the full consequences are better understood. Implementing a change in policy affects land management and regulatory practices, which in turn would affect resource conditions over time. Subsequent monitoring can then provide feedback to management on the effectiveness of these new practices.

Roles of Monitoring in Land Management Decisions

Monitoring data and the resulting reports are important to administrators because they are sources of feedback about results of past and current practices and help identify need for change to future practices (Morrison et al., in press; Vora 1997). Although adaptive management is proposed as an ongoing, iterative process that implies flexibility, it is not easy to do in an agency environment (Bella 1997; Hilbran 1992; Lee 1993; Morrison and Marcot 1995; NRC 1990; U.S. GAO 1988, 1994). A formalized process of evaluating and responding to new information is needed that makes routine the interactions of monitoring staff and decisionmakers (Marcot 1994; Morrison et al., in press); to our knowledge this process does not exist.

The program will be monitoring, for example, status and trends in spotted owl habitat across the region of the Forest Plan, in terms of areal extent, connectivity, fragmentation, and other indicators (see northern spotted owl monitoring module [Lint et al., in press]). The implications of these trends would be described in the interpretive report and provided to the appropriate administrators who would then consider the conclusions, including their reliability, and make a decision relative to current policies

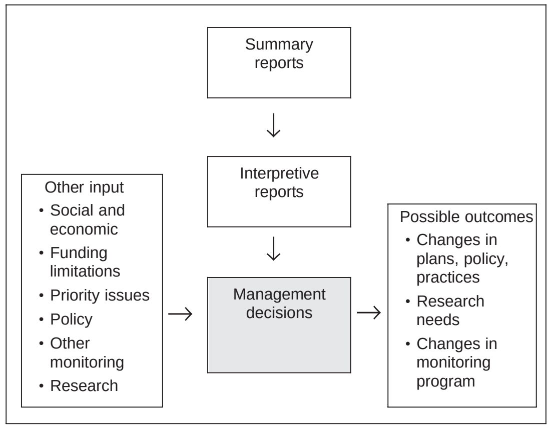


Figure 25—Factors affecting decisionmaking.

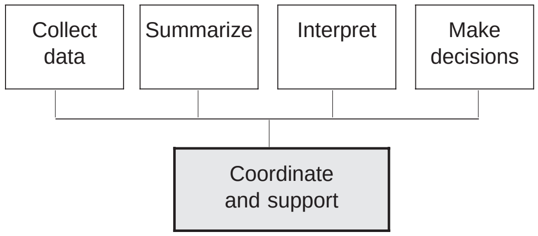
(fig. 25). Policymakers also would consider several other factors, such as politics, economics, and availability of resources. Decisions could include improving Forest Plan implementation, continuing on the same path, reformulating implementation, changing the standards and guides, altering monitoring strategies, requesting assistance from research agencies, or other actions. Any change in the Forest Plan, of course, would require National Environmental Policy Act (NEPA) consideration and would be handled on an interagency basis.

Strategy for Continual Improvement

Given our experience with past monitoring efforts, a significant need exists to improve the monitoring process so that relevant feedback is provided to managers that will be useful in making timely decisions. This effort is collaborative, and land management, research, and regulatory agencies involved with the Forest Plan can benefit from participating in and supporting monitoring. Monitoring staff and managers should take several steps to ensure that monitoring continually improves.

The first step is to make sure that the questions most relevant to management are being addressed in monitoring reports; feedback should be solicited from managers before and after these reports are prepared (Vora 1997). The feedback should come from land management, research, and regulatory agencies. A second step is to assure that the data in monitoring reports are presented in ways useful to management (Marcot 1994; Morrison et al., in press). Periodic meetings should be held among key monitoring agency staff, researchers, and managers to discuss the implications of data summary and interpretive reports (see Chapter 2, “Linking Monitoring Results to Decisionmaking”). Important findings should be highlighted rather than simply presented to managers as many multicolumned tables and complicated charts. A third step is to assure the data are sufficiently accurate to meet the needs of management and reduce uncertainty (see “Quality Assurance,” below, this chapter). If uncertainty in interpreting monitoring results is high, managers may have difficulty making reliable decisions (U.S. GAO 1994, Williams et al. 1996). Considerable dialogue will be needed between management and program participants to identify requirements for the quality of results.

Program Coordination and Support



The monitoring system component, called program coordination and support, spans all aspects of monitoring from data collection through reporting to decisionmaking. This section describes critical support functions underlying the program, focusing on integration, research, pilot and testing projects, information management, and quality assurance.

Integration

A goal of the monitoring program is to integrate all the critical components, including data collection, information management, and assessment and reporting, by using common databases to answer monitoring questions across a range of resource issues; linking monitoring efforts with research, implementation monitoring, or monitoring programs of state or other agencies; or integrating assessments and methods to evaluate trends. The outcome will maximize use of collected data, increase cost effectiveness of the program, and improve the ability to evaluate data from an ecosystem rather than an issue-by-issue perspective. Integration is becoming a major theme in recent literature (CENR 1997, Marcot 1994, Olsen and Schreuder 1997, U.S. GAO 1994). This task is challenging, given the diversity of cooperating agencies, the number of resources being monitored, and the variety of different monitoring groups.

A primary concern has been developing a strategy to integrate the monitoring components of the different resources (for example, late-successional and old-growth forests, spotted owls, marbled murrelets, and aquatic and riparian resources), so that the program to facilitate evaluation of the Forest Plan is unified. This will not be easy. Our approach has been to develop a scientific and management framework that fosters integration. The monitoring plans for each resource follow a common monitoring approach, conceptual framework, indicator-selection strategy and monitoring design, and data-assessment and reporting process. Similarly, strategies to address research needs, pilot studies, data management, and quality assurance are part of each plan. Developing these strategies has already fostered integration in the program by identifying common areas, such as using regional vegetation maps to assess LSOG and spotted owl and murrelet habitat. Further efforts are needed to improve methods of integrating appropriate activities.

Research Support

The scientific development of the effectiveness monitoring program has presented many challenges, particularly in attempting to apply the concepts and theory in the literature to this program. As the program develops, these challenges will expand because of the complexity of the issues being monitored. Given the conceptual nature and complexity of the program, drawing a clear distinction between research and monitoring is difficult; rather it is becoming clear that they are meant to be companion programs (CENR 1997, Marcot 1994, Olsen and Schreuder 1997). At the present time, research agencies are highly involved in ongoing monitoring projects, such as the owl demographic studies, and they will have a major role in fostering development of the conceptual approach and framework for additional monitoring through the interagency strategic research plan (Benson and Owston 1997) for the Forest Plan. Research will be needed to address emerging needs, such as selecting new indicators, establishing associated sampling designs, and estimating thresholds for assessing monitoring trends. Research expertise also is needed to assist managers in interpreting monitoring data (Marcot 1994), particularly with integrated data sets pertinent to regional monitoring questions.

Priority research issues relevant to the effectiveness monitoring program—Table 5 represents an abbreviated listing of key scientific issues, discussed by the EMT, critical to the effectiveness monitoring program, particularly to support the interpretation and use of monitoring results (see Chapter 2, "Expected Values and Trends" and "Linking Monitoring Results to Decisionmaking"). To a large degree, these topics are only partially understood and represent priority areas for continued research within the field of applied ecology. We list them here to demonstrate the close connection between monitoring and research and to encourage Federal agencies to support research relevant to effectiveness and validation monitoring.

Research issues for individual monitoring modules—Critical research needs also have been identified for each of the resource issues; for example, the need to develop improved landscape-and stand-scale indicators for monitoring LSOG, develop improved predictive models relating spotted owl demographics to measures of owl habitat, improve estimates of murrelet populations and nesting habitat, and improve remote-sensing evaluation of riparian conditions (for example, see monitoring modules [Hemstrom et al., in press; Lint et al., in press; Madsen et al., in press; also see Furniss et al. 1997]). Although some of these research questions may already be under investigation, all these examples suggest a continuing need to include research as a component of the monitoring program.

Two approaches are suggested to address research needs. The first is to develop a process for communicating the research needs to the research agencies, so that the needs can be integrated into the long-term strategic research plan; needs should be prioritized so higher priority items can be given preference. Although research support for monitoring will need to compete with other priorities for available research budgets, needs should be identified in monitoring reports and provided to the heads of research agencies and agency scientists. Scientists participating in evaluating monitoring data also may identify key research activities relating to their areas of expertise. A second approach is to use pilot or test studies to investigate critical research needs for monitoring (see next section).

Pilot Testing and Development Projects

Pilot or test projects have several roles in monitoring (Brunner and Clark 1997; Ringold et al., in press). One is as a proving ground for new ideas. Because some aspects of the monitoring program could have significant budgetary implications, pilot studies offer opportunities to test whether the appropriate approaches are being taken, with less stress on budgets. Besides testing, pilot studies also can help to refine and improve selected monitoring methods, indicators, sampling designs, or data evaluation techniques.

Table 5—Priority research issues to support effectiveness monitoring

Research topic	Explanation of need
Make predictions across temporal and spatial scales	Observations often are limited to a single spatial and temporal scale (that is, the scale at which measurements are taken), but our interests usually extend beyond the scale of observation. How do we reliably make predictions from phenomena observed at one scale to other scales in the ecological hierarchy?
Select an optimum set of indicators	Of all the possible attributes of the environment that can be measured, does a step-down algorithm exist to enable the selection of a small subset of attributes whose values allow reliable inference to the "integrity" of the larger ecosystem?
Estimate "normal" rates of change of ecosystem processes	Ecological systems are inherently dynamic; that is, we expect their attributes to change through space and time. What rate of change (for example, in the sense of a time derivative) is an appropriate benchmark for a given ecological process?
Define the expected "range of variation" in natural processes	We are aware that the concept of ecosystems occupying a steady-state equilibrium position is flawed. What magnitude of observed variation should be labeled "unexpected" and therefore treated as an early warning of system degradation?
Identify threshold regions of change that trigger management responses	This problem is closely tied to the previous one. Assume many possible states of an ecosystem are integrated over some time interval or spatial domain, and these states can be characterized by a probability distribution. What frequency of states in the right (left) tail of an observed distribution should signal a change in management policy? How can threshold regions be established within the range of the probastates that we accept
Define a "desired future condition" for dynamic systems	If natural systems are inherently dynamic, how do we define the appropriate distribution of system states that we accept as "normal"? What is an abnormal state? How are benchmark conditions determined. How far back in time is an appropriate interval to establish benchmarks?
Detect cause in the presence of time lags and synergistic effects	Monitoring programs are most easily designed to detect the action of a single stressor leading to a change in the state of a single indicator variable. How do we identify cause when the state of the indicator reflects past disturbances, or the joint effects of multiple stressors, each of such limited magnitude as to appear innocuous?
Link physical and biological process in the form of predictive models	The focus of most environmental monitoring programs has been exclusively on biological resources and processes, but the key drivers of change in many ecosystems (for example, aquatic and riparian communities) may be physical processes. How do we begin to link biological processes to poorly understood or difficult to measure physical drivers of change?
Draw inferences to the population of interest from nonprobability-based samples	The realities of sampling large areas under limited budgets, and with the complexity of private property restrictions, often result in unorthodox survey designs. Given that our population of interest is usually the entire ecosystem (which crosses ownership boundaries), how do we make valid statistical inference when all possible components of an ecosystem are not within the sampling frame?
Address the uncertainty in the monitoring "signal"	The integrity of an ecosystem will be inferred from the nature of the signal based on the values of the indicator variables. Given that the meaning of the signal is subject to sampling, measurement, and interpretational error, how is this uncertainty addressed in the decision process?

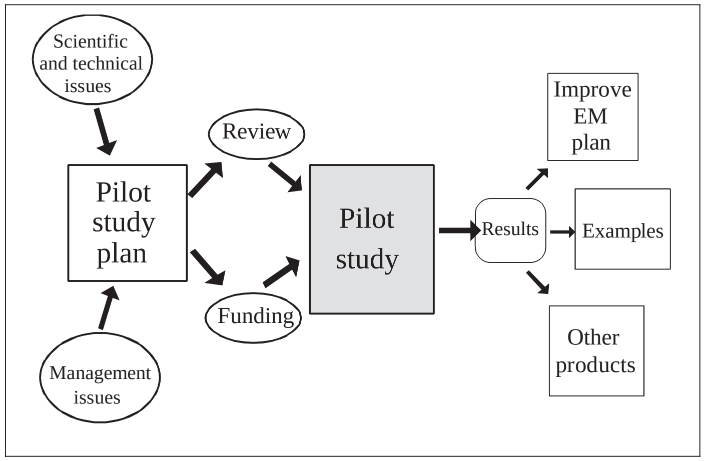


Figure 26—Use of pilot studies to improve the effectiveness monitoring program. EM = effectiveness monitoring.

Another role of pilot projects is to provide examples of potential products from monitoring, such as databases and reports. The importance of developing examples is to help cultivate the support and understanding required to make long-term monitoring successful. A monitoring plan can describe in abstract terms the products it could provide, but a pilot study can present prototype and concrete examples of these products for consideration by monitoring clients. These types of interim or test products are critical to successfully conducting a monitoring program.

A flow chart depicting the use of a pilot study in effectiveness monitoring is presented in figure 26. Scientific, technical, and management issues in need of testing or evaluation should be identified. The issues are then incorporated into a pilot study plan that identifies an approach to addressing them. After review and approval of the study plan, the pilot study is funded and implemented. The results from the pilot study are then used to improve monitoring procedures, to provide example products, and possibly to achieve other objectives.

Pilot studies, however, should not be considered a surrogate or necessary first step for implementing a monitoring program. Although important for addressing some issues, many of these issues may take considerable time to investigate. Pilot studies, as with research, should be viewed as companion components of a complete monitoring system and carried out concurrently such that continual improvements can be made to the program.

Oregon Coast Province effectiveness monitoring pilot—As a result of the effort by the EMT to develop a monitoring strategy for the Forest Plan, a province-scale monitoring pilot study was begun in October 1996 in the Oregon Coast Province to evaluate monitoring strategies and identify problems that could be addressed while the planning process was underway (Plumley et al. 1996). The study is comprehensive in that it attempts to test monitoring strategies for all four resource issues. It is the proving ground for the majority of concepts described in the monitoring plans and merits continued support from management, as well as agency funding. The project is of critical importance to the effectiveness monitoring program; it is planned to be completed concurrently with the first year of implementation of the program. The results of this effort are intended to be used to help direct implementation; the project thus needs to be carefully coordinated with program implementation.

Table 6—Oregon Coast Province effectiveness monitoring pilot

Topic area	Descriptive information
Scientific and technical objectives	Evaluate monitoring questions
	Evaluate utility of existing and readily available data
	Develop examples
	Evaluate analytical methods for data analysis
	Test integration of data across emphasis areas
Management objectives	Develop strategy for integrating results into one framework
	Determine links to adaptive management
	Revise local monitoring plans
	Identify costs
Key contacts	Harriet Plumley, Siuslaw NF, Corvallis, OR
	Tom Spies, PNW Research Station, Corvallis, OR
Scope and geographic area	Federal lands in the Oregon Coast Province
Budget	FY1997: $250,000
	FY1998: $250,000
	FY1999: $250,000
Timeline	October 1996 to September 1998

A summary of the objectives, key contacts, geographic scope, budget, and timeline for this study is presented in table 6. Proposed monitoring questions from each resource module will be reviewed (for example, see monitoring modules [Hemstrom et al., in press; Lint et al., in press; Madsen et al., in press; also see Furniss et al. 1997]). The availability and suitability of current inventory and monitoring data to answer these questions will be evaluated. If possible, a provincewide assessment will be conducted by using available data. Of particular interest is the objective to revise monitoring plans of the Siuslaw National Forest and the Salem and Eugene BLM Districts. These endeavors should help coordinate monitoring efforts for the Forest Plan with the ongoing local National Forest and District monitoring and planning efforts and help address questions about the utility of the regional program at the local scale.

This pilot study also will foster the development of technologies required to prepare summary and interpretive reports; for example, data assessment algorithms will be developed and tested. Definitions and models for specific ecological conditions, such as old-growth forests or marbled murrelet nesting habitat, will be refined. Procedures for providing confidence limits for statistical estimates will be determined, and remotely sensed data will be compared to ground-plot data. This pilot offers a unique opportunity to foster the technical development of the effectiveness monitoring program in concert with other activities proposed for the monitoring program.

Additional pilot studies—Several additional pilot or development projects are being conducted by agencies with an interest or stake in monitoring in the Pacific Northwest. For example, the Environmental Protection Agency (EPA) is funding a project to assess the use of remote imagery for characterizing riparian systems, and the FWS is cofunding a project with Forest Service Research to evaluate different remote sensing methods. Cooperative links with these projects should be developed because they will contribute to the success of the monitoring program. As the program is implemented, additional scientific and management issues are likely to develop, such as those identified in the preceding section. Pilot studies offer a cost-effective way to develop strategies to address future issues while providing opportunities to continually improve and adapt the monitoring program (Brunner and Clark 1997). Pilot proposals should be identified through the annual reporting process. Some monitoring staff will need to participate in approved pilot studies to foster coordination and integration with the program. Additional funding for pilot studies may be needed.

Information Management

The role of information management is to assist in collecting, organizing, validating, storing, and retrieving data and in preparing reports. An effective information management system is essential to any monitoring program (CENR 1997) but especially to one of this scope and complexity. Information management may be the most important support function needed for the monitoring program, but currently no information management system is in place within the agencies that can meet the needs of this program. *Failure to address this issue can have profound implications to the value and success of the program.*

An intergovernmental committee, The Interorganizational Resource Information Coordinating Council, has been coordinating development of interagency data standards for inventory, monitoring, and other information (Vegetation Strike Team 1996). These standards will provide an important tool for sharing monitoring information on forest resources within and across agencies in the region of the Forest Plan. It also can serve as a starting point for developing an information management system for the program.

Given the size of the program, an interagency information management plan needs to be developed. This is particularly important because much of the program is based on using integrated data sets that provide a basis for evaluating monitoring questions across a range of related issues (for example, vegetation databases). Because the program is a cooperative effort, this plan would detail organizational responsibilities for managing and operating the program, such as identifying data managers. The plan would identify how data will be handled and made available, from collecting through preparing reports, with a focus on maintaining data integrity and fidelity while encouraging data accessibility. The plan also would identify who will be responsible for managing the information, where and how information will be stored, and how metadata will be developed. The importance of preparing the plan early in a monitoring program cannot be overstated (Appleton 1996).

Quality Assurance

An important characteristic of the monitoring program is that it has been legally mandated by the ROD (USDA and USDI 1994) and emphasized by Judge Dwyer in his decision declaring the Forest Plan legally acceptable (Dwyer 1994). The program must therefore provide monitoring results that are legally defensible, which is one purpose of a structured quality-assurance system.

Implementing quality assurance for monitoring programs is relatively new for land management agencies. Regulatory agencies, such as the EPA and the U.S. Department of Energy, have required quality assurance as integral components of data-collection programs for many years. These agencies have learned through experience that courts will not accept monitoring results unless the quality of the data can be established. Currently, no specific mandate exists within the Forest Service or BLM that requires quality assurance for monitoring. Only components of the program that may be funded by the EPA would have that requirement. The probability that all Federal agencies will be requiring some type of quality assurance in the future for environmental monitoring activities is high (CENR 1997).

Quality assurance can provide many benefits. Quality is often evaluated according to the ability of a product to meet the needs and expectations of an end user. One benefit of structured quality assurance is that it provides a process for identifying and meeting client needs. Other benefits are to ensure that data-collection programs provide and document high-quality data, and to ensure that analyses of these data are repeatable and defensible.

A regional quality-assurance system for effectiveness monitoring should comply with the “American National Standard: Specifications and guidelines for quality systems for environmental data collection and environmental technology programs" (ANSI and ASQC 1995). This standard, developed jointly by several government agencies and industry, identifies a minimum set of quality management specifications required to conduct programs with environmental data collection and evaluation. It is directly applicable to effectiveness monitoring and describes the need for a quality management system to manage environmental programs and quality system specifications to guide collecting and evaluating of environmental data.

Quality-management system—A quality management plan should be prepared that reflects the quality-assurance philosophy of continuous quality improvement. The quality-assurance system will support all monitoring and research activities (for example, a pilot study) associated with monitoring. The system emphasizes sufficient assistance in planning data-collection activities and documenting all aspects of each study to assure that a complete record exists; that results are repeatable; and that the scientific interpretations are traceable, reviewable, defensible, and logical. Because the monitoring program is cooperative, the quality management plan will detail organizational responsibilities for managing the program and for technical staff to ensure that quality is integrated into it. An important component of a high-quality management system is to ensure that it is formally assessed and the results regularly documented. Audits will objectively evaluate quality-related practices, procedures, instructions, activities, and items, including review of documents and records. The audits would be performed in accordance with written procedures, with checklists, and by appropriately trained personnel. Evaluations of data quality would be included in summary and interpretive reports or as separate quality-assessment reports.

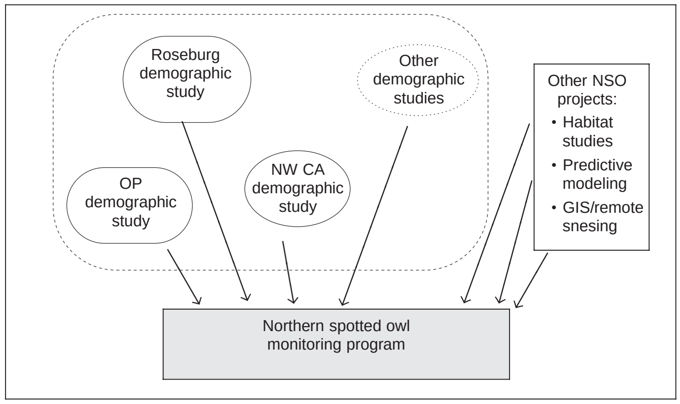


Figure 27—Spotted owl projects submitting information to the effectiveness monitoring program. OP = Olympic Peninsula; NW CA = northern California; and NSO = northern spotted owl.

Quality-system specifications—A quality-assurance plan should be prepared that lists the specific activities contributing to project quality. These activities would include defining study objectives; experimental design; procurement; measurement procedures; calibration procedures and frequency; training and certification requirements; preventive procedures; quality controls; corrective action; data collection, reduction, and verification; and data validation and reporting. To ensure that the data meet the needs of the study, realistic quality objectives should be established during the planning phase and experimental design of each project. Procedures for conducting accuracy (measurement-error) assessments for all monitoring data should be provided. All data analysis methods should be thoroughly documented and tested.

The additional costs from a quality-assurance system need not be excessive. Many large-scale data-collection activities contain most quality-assurance requirements specified by ANSI and ASQC (1995) (for example, the CVS has a very tight quality-control program for plot data). The expertise to develop a quality-management plan that addresses the needs of effectiveness monitoring is available, primarily through EPA. Training will be required in quality assurance concepts to assist with developing individual quality-assurance project plans and assessing data (estimating measurement error). Commitment by all cooperating agencies will be needed to carry out an appropriate quality-assurance for monitoring.

Example Application to the Forest Plan: Northern Spotted Owl

This chapter has introduced several concepts related to the key structural components that will be needed to manage and successfully operate the effectiveness monitoring program. To help clarify this process, an example is presented of several activities collecting data essential to the program (fig. 27). Each of the steps, from data collection, summarization, and interpretation through use in management decisions, will be discussed.

The activities chosen for this example are the demographic studies that are part of the proposed monitoring program for the northern spotted owl (Lint et al., in press [see footnote 2, Chapter 1]; also see appendix D, table 12). These eight studies have been collecting data for up to 12 years and are classified as external projects providing essential data (type B). To visualize how the effectiveness monitoring program is expected to operate, the year chosen for this example is 1998.

Data Collection

The demographic studies collect data important to answering the monitoring questions related to spotted owl populations. In 1998, these projects will continue to collect owl demographic data according to standardized procedures (Lint et al., in press [see footnote 2, Chapter 1]) that would also be described in a quality-assurance project plan. The procedures have been in use for several years and are described in Forsman et al. (1996). These and other owl projects also collect habitat data useful in developing predictive models relating owl population variation to habitat change. The procedures for habitat assessment will be evaluated as part of the current pilot project in the Oregon Coast Province (see "Pilot Testing and Development Projects," above, this chapter) and results adopted for use in assessing owl habitat.

Note that other data important to answering the spotted owl effectiveness monitoring questions also may be collected or analyzed, or both, from other projects in 1998. For example, satellite data may be collected that would provide data to assess abundance and distribution of late-successional forests (see LSOG monitoring module [Hemstrom et al., in press]) and aid interpretation of owl habitat. Regional ground surveys, such as CVS, also may collect data useful to owl habitat characterization. Research on developing and refining predictive models will be conducted, and preliminary results made available.

Data Summary

The spotted owl data summary will be an important component of the annual summary report for the effectiveness monitoring program. An evaluation team representing all the owl demographic studies would be responsible for preparing an annual summary at the end of the field season. This team would report information from each individual study area into one summary report for the spotted owl. Data collected in 1998 would be validated to ensure internal consistency and accuracy. The data summary then would be prepared by using statistical approaches, data-aggregation algorithms, tables, and maps in formats adopted for the program (for example, the annual report format used by Federal research agencies). This report will identify key issues from the individual study reports and, if appropriate, highlight any requiring management consideration, such as budget needs. Note that habitat data would be summarized following similar procedures and included in the summary report, if available in 1998.

Interpretive Report

The 1998 and 1999 summary reports will be included as important source documents during the preparation of the first interpretive report in 1999. The spotted owl report would be written by a panel of agency scientists, including those conducting research on owl demography and other specialists. The results from previous years of the demographic studies will contribute to the interpretive report, which will include information from other projects, such as spotted owl research and habitat data derived from vegetation maps through remotely sensed data interpretation and ground vegetation surveys. The results of past and current meta-analyses of owl demographic data (for example, see Burnham et al. 1996) would be included.

The interpretive report will include an analysis of population trends; if available, the report may include projected trends from predictive models of habitat change. These analyses will combine information about the relation of owl demographics and habitat, and the report will provide an evaluation of all owl information and draw conclusions about current status and trends and their implications to the Forest Plan. The primary benefit of the first interpretive report will be to establish the baseline for future trend analyses.

Management Decisions

The implications of the results of the owl monitoring studies to management will be identified at several steps in the reporting process. Monitoring results will be summarized in the 1998 summary report and subsequent summary reports. The first regional interpretive report in 1999 will identify the implications of the monitoring results to the extent that any are apparent this early in the monitoring program and will put them into a regional perspective. Data-interpretation tools, such as ecological risk assessments and statistical decision theory, will assist in highlighting the management implications of these monitoring results following the guidance in Chapter 2 ("Linking Monitoring Results to Decisionmaking"). Other information will be considered when pertinent to understanding the current situation relative to the Forest Plan (for example, owl surveys or studies on other lands).

Managers will have several options available to them for the decisions they undertake based on monitoring results from the spotted owl monitoring program. Changes may be undertaken in plans, policies, or practices; critical research needs may be identified; or changes may be made to the monitoring program.

Coordination and Support

A coordinated effort is required to accomplish these steps with staff and managers assigned tasks at every level of the owl program from each individual owl study up through the regional offices within and among agencies. The demographic studies and other spotted owl monitoring activities would be coordinated through a regional team consisting of project leaders from each of the demographic studies, project leaders responsible for other owl tasks, regional monitoring support staff, and the assigned team leader for the owl monitoring effort. The team leader will coordinate the efforts of the spotted owl team with the other modules of the effectiveness monitoring program to ensure program consistency; coordinate the preparation of an annual summary report; plan the interpretive report; provide feedback to management regarding budgetary and personnel requirements; and identify emerging research needs. The monitoring support staff will be responsible for preparing the summary and interpretive reports, planning and supporting annual monitoring activities, and managing databases, among other duties.

An important responsibility for the owl monitoring team leader and the project leader for the owl demographic study area in the Oregon Coast Ranges will be participation in the Oregon Coast Province effectiveness monitoring pilot in 1998. The technical approaches used to answer the owl monitoring questions in this pilot will provide the template for interpretation of monitoring data from the remainder of the region in summary and interpretive reports. The pilot also will provide examples of monitoring results to foster support for ongoing data collection efforts.

Summary of Key Points

This chapter presents the principal components of an effectiveness monitoring program including data collection, data summaries, interpretive reports, management decisions, and program coordination and support. Data collection will build on existing monitoring programs whenever possible. One goal of effectiveness monitoring will be to prepare annual data summaries for each resource being monitored. These summaries will serve as an important component for the preparation of 5-year interpretive reports. Effectiveness monitoring will be of value only if feedback is provided to managers to assist with land management decisions. Support will be required for all these components through research, pilot studies, information management systems, and quality assurance procedures. An example of how these components would function together is presented for the northern spotted owl module.

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Chapter 5: Strategy for Implementing the Monitoring Program

Barry S. Mulder, Craig J. Palmer, Miles Hemstrom, Joseph B. Lint, and Sarah Madsen

Goal for Effectiveness Monitoring

The ultimate goal of the monitoring program is to produce regionwide interpretive monitoring reports, at regular intervals, that address regional assessment questions (table 7) about our success in meeting the goals of the Forest Plan[1] (USDA and USDI 1994). An organized and stepwise approach to program design, data collection and management, and information assessment and reporting is needed to provide timely and efficient access to critical information to meet this goal. The challenges are great, but without this type of approach the monitoring program is unlikely to succeed.

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[1] Implicit is this statement is the expectation that, to fully address questions about the Forest Plan, implementation and validation monitoring will apply the same strict scientific standards to monitoring design, and the three programs will be closely linked and integrated.

Table 7—Goals and objectives for effectiveness monitoring

Topic areas	Criteria and questions
Goals of the monitoring program	Evaluate the success of the Forest Plan in achieving the objectives on Federal lands of: a. Protecting and enhancing habitat for late-successional and old-growth forest and related species b. Restoring and maintaining the ecological integrity of watersheds and aquatic ecosystems c. Maintaining sustainable amounts of renewable resources and rural economies and communities
Objectives of the monitoring program	1. Assess the status and trends of: a. The amount and distribution of late-successional and old-growth forests, related species, and their habitats b. The ecological integrity of watersheds and aquatic ecosystems c. The production of sustainable amounts of renewable resources in maintaining rural economies and communities 2. Compare the observed status and trends with those expected under the Forest Plan to assess whether Forest Plan goals and objectives are being met 3. Identify the implications of the results to adaptive management for the Forest Plan 4. Identify any emerging issues requiring management or research attention
Regional assessment questions	1. What are the status and trends for the resources identified above? 2. Are the goals and objectives of the Forest Plan for these resources being achieved? 3. What are the implications to the Forest Plan of the status and trend information from the monitoring program? 4. Are any issues emerging that need management or research attention?

The reader should realize from the previous chapters that this program represents a relatively new approach to ecosystem monitoring, an approach different from how most monitoring has been conducted. We realize that shifting to a new way of doing business will be difficult, and the transition will take time. Many barriers need to be overcome to set this program in place, including scientific, technical, and institutional (Ringold et al., in press). Organizational and cultural differences in how information is collected, maintained, and shared will need to be addressed, permanent monitoring programs established, links with research developed, annual monitoring responsibilities formally assigned, and stable base funding provided. Addressing these complexities will require moving away from the traditional ad hoc approach to one that institutionalizes monitoring into day-to-day operations (CENR 1997; Morrison and Marcot 1995; Morrison et al., in press; Noble and Norton 1991; Olsen and Schreuder 1997; Vora 1997).

The issues of immediate interest are related to schedules (What is the work? and When does it need to be done?), people (Who will do it?), and money (What will it cost?) (fig. 28). Addressing these questions will require close collaboration among all participating research, land management, and regulatory agencies. The information in this chapter is provided to help agencies begin to address these questions. A general strategy is described to implement and manage the monitoring program, a strategy applicable regardless of the options selected for monitoring the different resource issues.

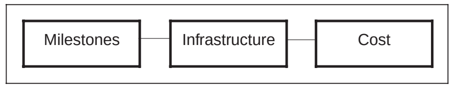


Figure 28—Conceptual model for the primary issues to be addressed in implementing the monitoring program.

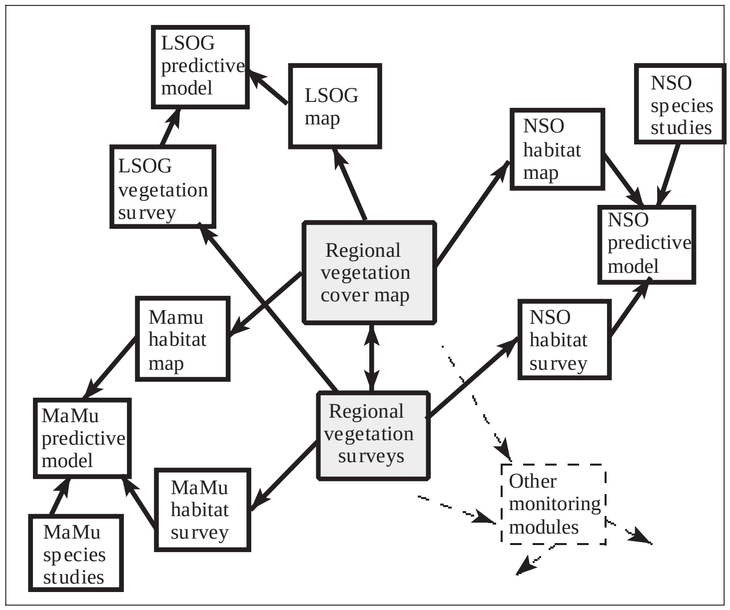
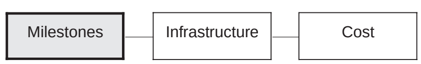


Figure 29—Generalized relation between monitoring components and base forest and vegetation data; each component represents different projects that produce information to be used in evaluating status and trends. LSOG = late-successional old growth; NSO = northern spotted owl; and MaMu = marbled murrelet.

Road to Producing Effectiveness Monitoring Reports



The effectiveness monitoring system implemented by the Federal agencies in the Pacific Northwest will result in a complex and large-scale program consisting of multiple parts, including the current modules (Hemstrom et al., in press; Lint et al., in press; and Madsen et al., in press; also see Furniss et al. 1997 [see footnote 2, Chapter 1]), new modules, and links between modules and other monitoring, research, and related activities (fig. 29). In addition, each module is multifaceted and includes subcomponents of data collection, information management, assessment, and reporting that will result in numerous databases, products, and reports.

Table 8—Tasks needing to be addressed in the initial phases of implementing the effectiveness monitoring program for the Forest Plan[a]

Subject area	Issue to address
Program management	Managers and program support staffing
	Plans for:
	data-information management system
	quality-assurance system
	Guidance for:
	methods for integrating program components
	methods for linking effectiveness to implementation monitoring
	approaches to using new information (adaptive management process)
Monitoring modules	Project leaders and field-project staffing
	Allocation of funds
	Annual work plans
	Manuals, field protocols, forms
	Database management system
Research support	Project leaders-research support staffing
	Investigations into:
	candidate indicator usage
	indicator thresholds and values
	habitat-population variables
	methods for linking results to decisionmaking
	other research studies to support monitoring
Oregon coast pilot project	Support for project completion
	Methods to apply findings to effectiveness monitoring

[a] See Furniss et al. 1997; Hemstrom et al., in press; Lint et al., in press; Madsen et al., in press for details (see footnote 2, Chapter 1).

Because many years will be needed to begin to discern trends in resources under the Forest Plan, this will be a program that spans many decades. And, because this is a relatively new approach to resource monitoring, the program will need to be phased in over several years and will require periodic changes and improvements. As a result, a planned sequence will be needed to time decisions and implementation each year. This sequencing will be most critical in the first few years as monitoring activities for individual resources are implemented and decisions are made about pilot projects, research, and other necessary supporting efforts to develop or refine methodologies, technologies, and new study designs. Deciding on a schedule for producing key monitoring reports will set the schedule for intermediate tasks and products. Immediate needs associated with initial implementation of the monitoring program are listed in table 8 (see appendix E, table 18); see individual modules for specific tasks for initiating the monitoring plans.

The steps followed to address these issues will help identify opportunities and needs for establishing an infrastructure, allocating resources among participating agencies, and setting a schedule for completing necessary products for the long-term success of the program. Considerations include the following:

1. Staffing and funding allocations for collecting, managing, and assessing monitoring data

2. Work plans with annual work objectives, timelines, and performance standards tied to monitoring and ecological resource goals—including training needs

3. Budget requests for annual congressional appropriations hearings

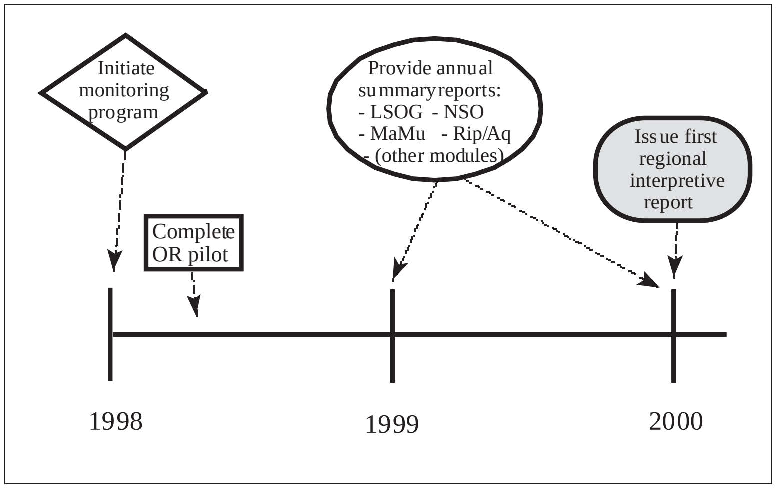


Figure 30—Milestones leading to the first regionwide interpretive report for effectiveness monitoring. LSOG = late-successional old growth; NSO = northern spotted owl; MaMu = marbled murrelet; Rip/Aq = riparian and aquatic; and OR pilot = Oregon coast pilot project.

4. Research plans identifying the research needed to support monitoring, pilot and other projects important to improving the program

5. Supporting documentation for monitoring staff, including field manuals, reporting forms, protocols and methods, and formats for data analysis and reporting

6. Specific guidance for monitoring staff, including approaches for quality assurance and control, and a system for data management

7. Management and coordination of all the above activities among agencies

The First Effectiveness Monitoring Report

The collective interpretation of information from the monitoring modules will allow a regional assessment of the Forest Plan (see table 7 and Mulder et al. 1995). Two questions will be used to evaluate whether that assessment, and hence the monitoring program, is successful: How useful is the information produced by the first regionwide interpretive monitoring report? and Is this information used as part of the decision process? That is, to what extent do the monitoring reports allow the agencies to assess progress towards achieving the goals and objectives of the Forest Plan? And, if progress is unsatisfactory, do the monitoring reports provide insights into how standards and guidelines may need to be changed?

To initiate the monitoring program, we propose that the first regionwide interpretive report be completed at the end of 1999; subsequent interpretive reports would follow on a 5-year schedule. In addition to being a test of the functioning of the program, the first report will establish the baseline for future comparisons of trend information for all resources being monitored. Several immediate steps are needed to produce this report; otherwise our ability to produce the first report by 2000 will be delayed. Between the time of implementing the program and publishing this first regionwide report, data need to be collected, organized, and analyzed; results of the pilot project applied (see Plumley et al. 1996 for details); supporting research initiated (see Chapter 4); and summary and interpretive reports prepared for each module (fig. 30 and table 8).

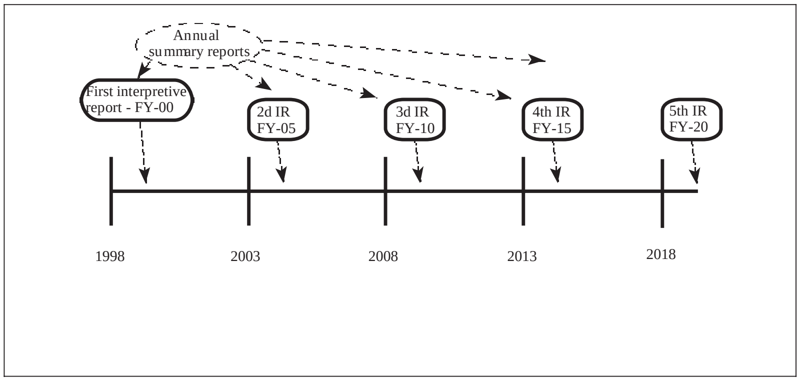


Figure 31—Schedule for interpretive reporting (IR) through the first two decades of the effectiveness monitoring program. FY = fiscal year.

There will be more work associated with producing this report than seems apparent. Initial results from the Oregon Coast Range pilot (see Chapter 4) indicate about a 2-year schedule for a variety of staff to evaluate the information and produce the report. Steps for producing this report include:

1. Assemble a planning group for the interpretive report
2. Prepare a draft outline to identify information and staff needs
3. Conduct a peer and user review of the draft approach
4. Assign the staff expertise needed to conduct the review
5. Collect the pertinent information, summary reports, and other input
6. Conduct special studies (for example, modeling) needed for the review
7. Prepare a draft interpretive report
8. Conduct peer and user review of the draft report
9. Finalize the draft report
10. Document lessons learned from the exercise

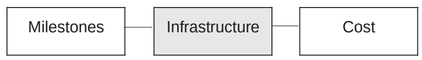
These steps assume that the infrastructure, staff, and work plans for individual monitoring activities at the field level (see table 8) are in place. It will take a concerted and planned effort both within and among agencies, and will require specific assignments to a variety of staff and managers representing a range of disciplines with sufficient expertise (see “Infrastructure Requirements: Institutionalizing the Program,” below, this chapter), to handle the needed tasks.

Long-Term Reporting Schedule

The initial results or output from the monitoring program will represent only the first data points in a long-term program; multiple data points gathered over several additional years will be needed to discern trends. As such, the reporting schedule for the effectiveness program is portrayed over two decades to illustrate the long-term nature of the program and to highlight the relations among the various monitoring components (fig. 31). Figure 31 also is intended to give managers a sense of the importance of the products and how they fit into the research, regulatory, and land management planning processes (for example, recovery planning under the ESA; land management planning under NEPA, NFMA, and FLPMA).

Timing for intermediate products and reports is critical; interdependencies in data needs among different components of the program require careful scheduling and close coordination. Delays in initiating monitoring activities may change the schedule but will not change the need for the expected products. Delays also may disrupt the quality or consistency in ongoing or long-term data sets (for example, spotted owl demographic studies), and careful consideration should be given to avoiding breaks in data sets that may be critical to evaluating future monitoring trends (Wolfe et al. 1987).

Infrastructure Requirements: Institutionalizing the Program



The effectiveness monitoring program focuses on the Forest Plan at the regional scale, which will require managing and coordinating numerous monitoring modules (see fig. 29) as well as other resource programs important to monitoring among several Federal agencies, over a three-state area, and for a long time. This means collecting and then moving a considerable amount of information to the appropriate locations on a timely basis. This will be a large increase in work from what we have been used to. The primary question to be addressed then is, Who is responsible for conducting and managing the program and its individual components? This question involves all Federal agencies cooperating under the Forest Plan; the primary land management agencies (Forest Service and BLM), and the cooperating agencies (Bureau of Indian Affairs, EPA, FWS, National Marine Fisheries Service, National Park Service, and the U.S. Geological Survey—Biological Resources Division).

Managing a program of this nature will be new to agency cultures, and managing interagency programs has not been very successful (CENR 1997, U.S. GAO 1994). Most monitoring has been handled in the field with little regional management, but managing operations regionally, as with any other resource program, is critical to the long-term success of this program so that data are available to address the policy questions that govern land management planning decisions. As such, ties between local and regional administrative units are essential to help increase efficiencies, avoid duplication or redundancy, and reduce costs. As the U.S. GAO (1994) notes from its evaluation of current efforts in ecosystem management, the result requires an era of unparalleled coordination and cooperation within and among agencies for all aspects of this program to ensure:

- Program design that meets agency information needs
- Data collection that includes standards, methods, and quality control within and across agencies
- Data management that is accessible to all interested parties within and across agencies
- Assessment and evaluation of information across agency boundaries
- Summary and interpretive reporting that is consistent across agencies
- Adaptive management responses to monitoring results coordinated between agencies
- Improvements to the monitoring program to meet emerging needs across agencies

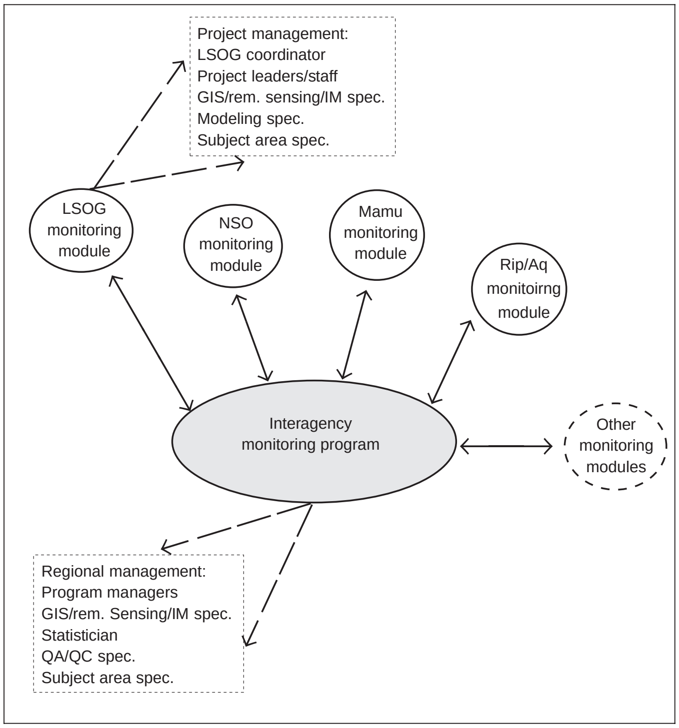


Figure 32—Example (using LSOG) of the supporting infrastructure for effectiveness monitoring. LSOG = late-successional old growth; NSO = northern spotted owl; MaMu = marbled murrelet; Rip/Aq = riparian and aquatic; IM = information management; spec. = specialist; and QA/QC = quality assurance and quality control.

To satisfy these requirements, the monitoring program should be institutionalized into the day-to-day activities at both the regional and project scales. And an infrastructure that addresses all aspects of the program, including data collection, information management, assessment, and reporting (Persson and Janz 1997), is needed. Questions of this nature may be more appropriately addressed at the national than the regional level.

Annual assignments and scheduled products are basic to the program at project (for example, data collection and management) and regional scales (for example, assessment and reporting), and dedicated and accountable staff and managers will be needed from all participating agencies to carry these out. Figure 32 illustrates the management, coordination, and staffing needs for one of the monitoring resources as an example; a similar structure is applicable to support each module. Core staff will be the focal point for collecting (project scale) and using information (regional scale) and need to be kept involved throughout the entire process to ensure consistency and responsiveness. Specific staff at the project (for example, see individual monitoring modules [Hemstrom et al., in press; Lint et al., in press; and Madsen et al., in press]) and regional scales will need to be assigned monitoring responsibilities associated with program design, data collecting, information management, and assessment and reporting. Similarly, other staff will be needed at both scales to manage and coordinate day-to-day activities within and among agencies. As Vora

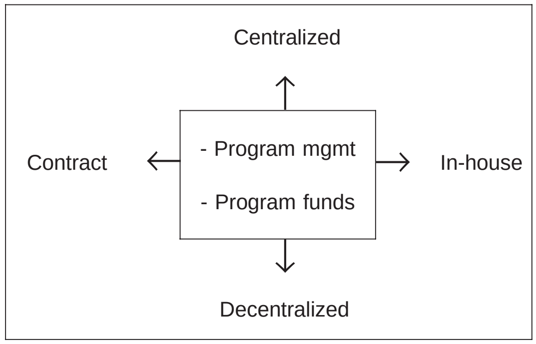


Figure 33—Options for operating the program.

(1997) notes from the study of National Forest monitoring in the Great Lakes region, "the expertise needed to evaluate monitoring data are not always available." Areas of needed staff expertise include knowledge of special analytical tools (GIS, statistical software) and expertise in applied statistics and plant and animal ecology. In addition, expertise from the Federal research agencies will be needed to develop methodologies and support analyses and interpretations.

Permanent and full-time administration also will be needed to manage the large number of involved staff to meet schedules, provide consistent direction and guidance, produce needed products, and address planning and budgetary needs at the regional and project scales. Administrators must be able to provide clear expectations about tasks, products, and due dates, and develop performance standards and job descriptions that assign responsibilities and accountability to monitoring and associated resource goals.

Answering questions about adding new staff, reallocating staff, and prioritizing staff assignments will be necessary to ensure the availability of needed expertise for program activities. A combination of approaches for each module and for the region as a whole may be appropriate to handle these operations, including contracts and in-house staffing (fig. 33); the agencies will have to weigh the available options given funding and other limitations. See table 9 (and appendix E, table 19) for a summary of anticipated staffing needs; actual full-time staff needs were not evaluated, but we anticipate the need for a range of full-time, part-time, and some temporary staff.

At this time no infrastructure exists in Federal agencies to take full responsibility for handling a program of this size; the closest model is the Forest Service's CVS program (Max et al. 1996). In the recent past, the Forest Service's Research, Development, and Application program provided informal coordination among a variety of entities involved with monitoring the northern spotted owl. Although the scope and magnitude of these two examples is large, they do not directly compare with the size of the effectiveness monitoring program for the Forest Plan. These considerations lead to the conclusion that a permanent management team may be necessary that includes managers for each of the monitoring modules as well as for the overall program; an evaluation of the management and staffing needs is essential to the long-term success of this program.

Table 9—Summary of staff expertise needed to support the effectiveness monitoring program[a]

Subject area	Needed disciplines and specialties
Program level	Program managers Information management specialists Quality assurance and control specialists GIS-remote sensing specialists Statisticians Subject area specialists (data analysts, modelers, ecologists, etc.)
Monitoring modules	Module managers-coordinators Field project leaders-field technicians and staff Database managers Data analysts, statisticians Computer, mathematical modelers GIS-remote sensing specialists Subject area specialists (see monitoring modules[a])

[a] See Furniss et al. 1997; Hemstrom et al., in press; Lint et al., in press; Madsen et al., in press, for details (see footnote 2, Chapter 1).

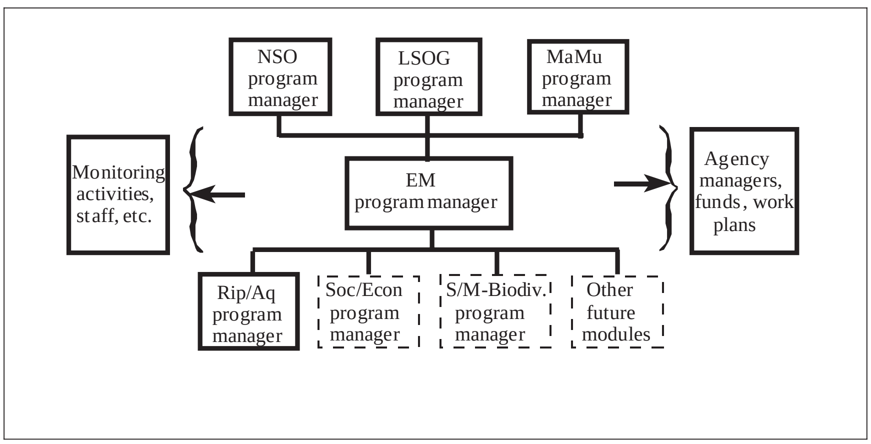
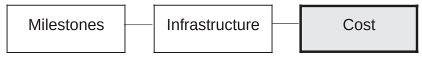


Figure 34—Suggested interim team structure to coordinate the initial implementation of the effectiveness monitoring (EM) program through completion of the first interpretive report at the end of 1999, showing links and feedback among the agencies and on-the-ground monitoring activities. NSO = northern spotted owl; LSOG = late successional old growth; MaMu = marbled murrelet; Rip/Aq = riparian and aquatic; and S/M = survey-and-manage species.

Given the complexity of this program, it may be appropriate for the agencies to consider establishing an initial or interim management team to be assigned full-time to oversee implementation of this program through completion of the first interpretive report at the end of 1999 (fig. 34). An interim team should consist of a manager for each of the monitoring modules, plus an overall team leader. These individuals would represent both their agencies (for links to budgets and staff) and the individual monitoring modules (for links to work plans and products).

Costs and Budgets



The costs of the monitoring program will be directly related to the degree of risk or uncertainty in the amount and type of data collected and how those data will be made available for future decisions. That is, the more confident that people want to be that implementing the standards and guidelines (USDA and USDI 1994) is having the desired ecological outcome, the greater the investment in the monitoring program. The ability to successfully conduct the program, however, depends on our understanding of the system or resources being monitored (fig. 35). For example, for the marbled murrelet (Madsen et al., in press [see footnote 2, Chapter 1]; also see appendix E, tables 15 to 17), the early phases of the proposed program emphasize the need for research to improve the ability to design and implement a monitoring program for that species. On the other hand, the more that is known about a resource (for example, LSOG), the greater the likelihood of reducing the scope and cost of the program. For ecological systems, in most cases our knowledge or ecological understanding is at the low end of the continuum (U.S. GAO 1994).

Given the scope and magnitude of the monitoring program, a stable and long-term base commitment to funding and staffing will be required for each individual module and the integrated program responsibilities. Because most current funding is not part of existing agency base appropriations, it needs to become a routine part of the annual budget appropriations with links from the modules to the offices within Federal agencies controlling the funds. This commitment is essential regardless of the options selected for monitoring. This is an interagency program, however, and as the CENR (1997) report notes, funding interagency programs has not always been workable, with continuing questions about availability and allocations of funds within and among agencies—questions that may need to be addressed at the national level.

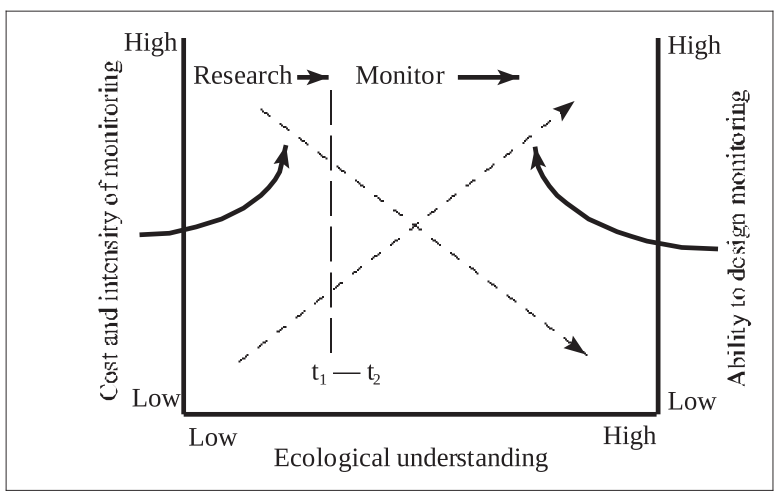


Figure 35—Value of a monitoring program where certainty in decisionmaking is related to ecological understanding.

Table 10—Summary of estimated costs for some components of the effectiveness monitoring program[a] [b]

Topic areas	Fiscal year 1998	1999	2000
	Thousand dollars		
Program management:			
Agency managers and staff	tbd	tbd	tbd
Monitoring modules:			
LSOG[c]	70	170	—
Northern spotted owl	2240	2585	2520
Marbled murrelet[d]	994	879	940
Aquatic and riparian	tbd	tbd	tbd
Other modules	tbd	tbd	tbd
Oregon coast pilot project	240	tbd	tbd
Totals (estimated)	3784	3634	3460

tbd = to be determined
[a] See Furniss et al. 1997; Hemstrom et al., in press; Lint et al., in press; and Madsen et al., in press, for details (see footnote 2, Chapter 1).
[b] These costs are illustrative only; actual costs will differ as the programs are implemented.
[c] Costs of monitoring LSOG (about $700,000) are covered by other agency vegetation inventory programs; LSOG costs noted here are for data analysis and reporting only (see appendix E, table 19).
[d] Costs of monitoring murrelets will be revised and are expected to be higher.

The projected costs of the monitoring program are based on meeting the suggested timeline for implementing the recommended options (table 10; appendix E, tables 20 and 21; and see individual monitoring modules [Hemstrom et al., in press; Lint et al., in press; and Madsen et al., in press]). Our assessment focused on the costs associated primarily with data collection. Because information was not available, we did not evaluate costs for administration, management, research, or other support. These are, however, important parts of the program and funding will be needed. The immediate implications from our assessment are the need to establish base funds and to obtain additional funds to collect data and support monitoring staff in the first year of the program.

Costs will differ by year and agency. Because this program is new, current estimates should be viewed as starting points only. As a result, our primary focus should be on what is needed to support the first three years of the program up to and through the production of the first interpretive report. Although most of the funds will be needed for collecting data, equal consideration needs to be given to funding data management, assessment, and reporting (fig. 36), and the organization and infrastructure that will underlie all the components of the monitoring program, including:

- Assessing and reporting monitoring information

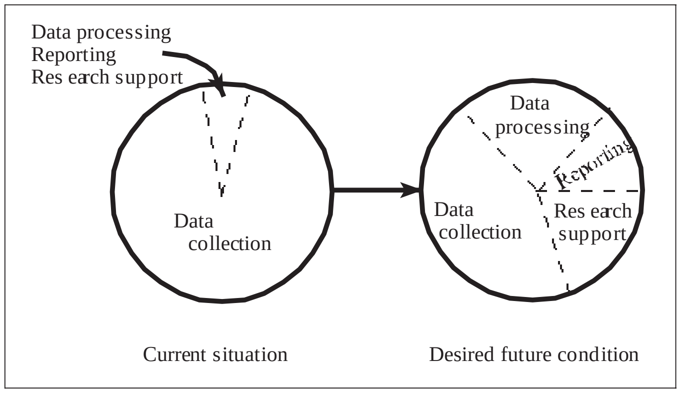


Figure 36—Generalized cost distribution comparison. The dotted lines are representational only.

- Technical support and oversight and management of the program regionally and at the project scale
- Future program design and modification
- Collecting and managing monitoring information
- Pilot projects, and research studies

Questions about future allocations of funds will need to be considered among the agencies as decisions are made about implementing the specific monitoring modules. Changes or delays in timing of funding for key components may change the total annual costs for a particular year, but would not change the total costs of the full program over time. The program will be phased in over several years, and new modules (for example, socioeconomic or survey-and-manage species) or special projects (for example, research or pilot tests) may be added to the program. As a result, the annual allocation of resources may change in the future, in both staffing and funding. Although annual resource allocations may differ, support for the base program will need to be relatively stable, particularly to provide a constant resource base for data management, quality assurance, and assessment and reporting.

Because a large part of the monitoring program will rely on existing external (type B) activities, identifying costs solely for effectiveness monitoring is difficult. This adds another complexity to the funding issue. For example, the annual costs associated with activities such as vegetation inventories (for example, CVS), species research (for example, spotted owl studies), and other agency monitoring programs (for example, FHM) would be distributed among various agency programs and not attributed solely to effectiveness monitoring. The proposed monitoring program should not increase the costs of these other efforts, but should help refine them and make better use of collected data. How funds and staff will be allocated relative to those programs and the monitoring program, however, will require careful review and evaluation among the agencies. Changes in decisions about essential activities expected to contribute to meeting monitoring needs, such as vegetation inventories or species research, will affect both timing and cost of the monitoring program. If funding rates change, either the effectiveness monitoring program will be delayed or costs will increase proportionally because the program will then have to develop or fund alternative sources of information.

Conclusions

The goal of the effectiveness monitoring program is to provide periodic interpretive reports addressing success in achieving the goals and objectives of the Northwest Forest Plan. The selection of this monitoring goal has provided the focus for developing the effectiveness monitoring program. From our investigations, we have come to realize that the scope, complexity, and magnitude of the resulting program mandate that an innovative approach be taken to monitoring important resources. We only wish that this knowledge could have been gained earlier in the process—it might have made the task easier. We hope that our efforts, described here, have advanced the understanding of ecosystem monitoring, so that necessary changes can be successfully managed.

The new approach will require a shift in thinking from how the agencies have traditionally viewed and managed monitoring within each agency's culture, and it provides a unique challenge. Key concepts emerging from our efforts include:

- Taking a more structured and scientific approach to monitoring design, data collection, assessment, and reporting
- Integrating monitoring and related programs to make better use of existing data and data collected for other purposes
- Adopting an adaptive approach to monitoring, in collaboration with Federal research agencies, that improves the program over time
- Institutionalizing the monitoring program on a par with other traditional resource programs
- Establishing dedicated programs for data collection, data management, information assessment, and reporting
- Maintaining permanent monitoring staff and stable base funding that cross agency boundaries

The ultimate test of the success of the proposed program will be whether, in upcoming years, staff and managers routinely ask, "What does our monitoring program show?" The approach to monitoring the Forest Plan that we describe, including the steps needed to support implementation and to improve the program as it proceeds, is intended to be responsive to the information needs of the participating agencies, and to improve management decisions. To do so, however, will require careful consideration of the activities, milestones, and projected costs for implementing the monitoring program and how best to manage the program over time. Although seemingly complicated, future management should be routine and straightforward, if steps are taken to institutionalize it into our operational culture. Establishing a core-resource program with full-time staff and base funding will overcome the barriers to successful application of the monitoring program and will make the long-term program more cost-effective and responsive.

The agencies have an opportunity to be pragmatic and begin to implement these concepts and proposals, but it will take time and commitment to make the transition to a new way of doing business. The first test will be in producing the first regional interpretive report in 1999, and whether it meets the needs for adaptive management. Immediate decisions about staffing and funding should focus on meeting that short-term goal. Decisions about the long-term implementation of the program, and its related costs, should be reevaluated after the first report is completed, so that appropriate and necessary improvements can be made for the future.

Acknowledgments

The following individuals contributed to the ideas expressed in this chapter: Jim Alegria, Timothy Lewis, Paul Ringold, Martin Raphael, and Tim Tolle.

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Appendices

Appendix A: Authors, Team Members, and Acknowledgments

History and Process

The effort to develop a monitoring program to support the Northwest Forest Plan began after completion of the FEMAT (1993) report when it was realized that a land management plan of this scope and complexity would require a new and more comprehensive approach to ecosystem monitoring. The initial definitions and concepts for the different types of ecosystem monitoring—implementation, effectiveness, and validation—were described by Tolle et al. (1994) and incorporated into the ROD (USDA and USDI 1994) as Forest Plan requirements. Under the direction of the Regional Interagency Executive Committee (RIEC), the first step was to develop a plan for implementation monitoring (Tolle et al. 1995); the resulting program has been conducted since 1996 (Alverts et al. 1997). Concurrently, a more detailed introduction into effectiveness monitoring was developed (Mulder et al. 1995) that describe general concepts and identified the considerable difficulties associated with large-scale monitoring for resource issues, such as late-successional old-growth forests, aquatic and riparian systems, northern spotted owl, marbled murrelet, and survey-and-manage species. This 1995 report served as the catalyst for intensifying interagency efforts to develop a strong science-based effectiveness monitoring program.[1]

[1] Considerable appreciation is given to Tim Lewis (group leader), Craig Palmer, Barry Noon, Martin Raphael, Thomas Spies, David Cassell, and Martin Stapanian for their ideas and struggles in 1996 to begin development of the effectiveness monitoring program.

In response, the Federal research executives[2] from the USDA Forest Service, EPA, and USGS—BRD took responsibility for establishing and directing a formal team of Federal scientists—called the Effectivess Monitoring Team (EMT)—to complete development of the effectiveness monitoring program. These executives, relying on recommendations from the RIEC and Intergovernmental Advisory Committee (IAC), established the sideboards, tasks, and schedules that governed the EMT efforts. Most importantly they established a formal process to manage the complexity of this planning effort. A core science team was established (the EMT) that was responsible for developing the strategy and design of a large-scale effectiveness monitoring program and for providing day-to-day guidance for work groups assigned to develop monitoring plans for specific resources. The core team included management representatives from the BLM and Forest Service who provided liaison with and feedback from the land management agencies; the team also included the work group leaders[3] to ensure consistency and enhance understanding of key concepts with the work groups. The Regional Ecosystem Office (REO) and Research and Monitoring Committee (RMC) provided day-to-day support for this large effort.

The core team followed a fairly rigorous research-based approach for carrying out its assignment, emphasizing peer review and feedback at every step in designing the overall strategy and developing the individual monitoring modules (Hemstrom et al., in press; Lint et al., in press; Madsen et al., in press; also see Furniss et al. 1997 [see footnote 2, Chapter 1]), beginning with review and consensus on the core attributes of a good monitoring plan—goals and objectives, conceptual models, monitoring questions, and candidate indicators (see appendix E). Formal peer reviews also were conducted for the final draft products (see appendix C). Finally, agency feedback was solicited throughout the effort through briefings with the RIEC and IAC, and at numerous discussion sessions with key agency personnel (see appendix C) to ensure acceptance and understanding of the final proposed approaches to effectiveness monitoring. The final products were reviewed and accepted for implementation by the RIEC and IAC.

Effectiveness Monitoring Team

Technical coordinators—

Barry S. Mulder, Wildlife Biologist, U.S. Fish and Wildlife Service, Portland, Oregon. He served as the overall coordinator for the Effectiveness Monitoring Team (EMT) and effectiveness monitoring work groups. He has participated in or led development of the monitoring plans for the Forest Plan since FEMAT (1993). Since 1987, he has served as coordinator for the spotted owl activities and related forest ecosystems projects for the FWS.

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[2] Credit for the EMT's success in completing development of the effectiveness monitoring program is due to the leadership of Thomas Mills (PNW), Thomas Murphy (EPA), and Michael Collopy (USGS—BRD).

[3] Work group leaders were selected from the land management agencies to establish a link with the agencies responsible for implementing these monitoring plans; work group members were scientists and specialists who provided the expertise to develop credible monitoring plans.

Barry R. Noon, Research Ecologist, USDA Forest Service, Pacific Southwest Research Station, Arcata, California. He served as the lead scientist for the effectiveness monitoring effort and was a member of the northern spotted owl monitoring work group. His recent research includes demography and habitat relations of spotted owls, effects of forest fragmentation on biological diversity, and ecological modeling. He is currently with the Department of Fishery and Wildlife Biology, Colorado State University, Fort Collins, Colorado.

Anthony R. Olsen, Mathematical Statistician, Environmental Protection Agency, National Health and Environmental Effects Research Laboratory, Corvallis, Oregon. In addition to serving on the EMT, he was an advisor to the marbled murrelet work group. Since 1990, he has led research and coordination of statistical monitoring designs for the EPA Environmental Monitoring and Assessment Program and has led the development of monitoring designs applied to streams, rivers, lakes, Great Lakes, estuaries, coastal waters, and forests.

Martin G. Raphael, Chief Research Wildlife Biologist, USDA Forest Service, Pacific Northwest Research Station, Olympia, Washington. In addition to serving on the EMT, he was a member of the northern spotted owl work group and was an advisor to the marbled murrelet work group. He is a team leader for research with emphasis on habitat relations and population dynamics of threatened and endangered species, landscape ecology, and ecology of old-growth forest communities.

Gordon H. Reeves, Research Fisheries Biologist, USDA Forest Service, Pacific Northwest Research Station, Corvallis, Oregon. In addition to serving on the EMT, he was a member of the riparian and aquatic work group. His recent research focuses on freshwater ecology of anadromous salmonids and the influence of land management on aquatic systems.

Thomas A. Spies, Research Forester, USDA Forest Service, Pacific Northwest Research Station, Corvallis, Oregon. In addition to serving on the EMT, he was a member of the late-successional and old-growth work group. His research includes old-growth ecosystems, landscape ecology, and remote-sensing applications to monitoring. He is coleading the Oregon Coast Pilot monitoring project to develop techniques to support monitoring.

Hartwell H. Welsh, Jr., Research Ecologist, USDA Forest Service, Pacific Southwest Research Station, Arcata, California. In addition to serving on the EMT, he served as an advisor to the riparian and aquatic work group. His current research focuses on the aquatic-upland interface as it relates to forest management and reptile and amphibian biology and the use of these species as indicators of ecosystem stress.

Technical consultant—

Craig J. Palmer, Research Scientist-Soil Scientist, Harry Reid Center for Environmental Studies, University of Nevada, Las Vegas, Nevada. In addition to serving as technical advisor to the EMT, he was a member of the late-successional and old-growth work group. He conducts research related to the development of monitoring programs for terrestrial ecosystems nationally and internationally. He formerly coordinated development of forest health monitoring efforts for the EPA Environmental Monitoring and Assessment Program.

Management consultants—

Michael Crouse, Natural Resource Policy Advisor, BLM Oregon and Washington State Office, Portland, Oregon. He served as the BLM management representative to the EMT and other policy level forums related to Forest Plan monitoring and implementation. He is currently serving as a policy level liaison between Federal agencies and the State of Oregon for the development and implementation of the Oregon Plan, a cooperative statewide restoration strategy to address salmon and water quality issues.

Arnie Holden, Deputy Director, Strategic Planning, USDA Forest Service, Pacific Northwest Region, Portland, Oregon. He served as the Forest Service management representative to the EMT and other policy level forums related to Forest Plan monitoring and implementation. He manages planning activities relating to Forest Service monitoring and Forest Plan development and revision.

Monitoring work group leaders—

Michael J. Furniss, Watershed Group Leader, USDA Forest Service, Six Rivers National Forest, Eureka, California. He led the riparian and aquatic work group. His work includes managing and coordinating activities for the Forest Service on issues relating to geomorphology, hydrology, and soils. He helped develop the guidance for conducting watershed analysis for the Forest Plan.

Miles Hemstrom, Regional Ecologist, USDA Forest Service, Pacific Northwest Region, Portland, Oregon. He served as leader of the late-successional and old-growth work group. He coordinates activities of National Forest ecology programs in the Pacific Northwest Region. His major emphases include sampling and classification of vegetation, developing models and maps of potential natural vegetation, describing vegetation successional relations, and predicting vegetation response to management.

Joseph B. Lint, Wildlife Biologist, BLM Oregon and Washington State Office, Roseburg District Office, Roseburg, Oregon. He led the northern spotted owl work group. He functions as a coordinator in the BLM state office. His responsibilities include threatened and endangered species management with emphasis on northern spotted owls, marbled murrelets, and implementation of the Forest Plan.

Sarah Madsen, Wildlife Biologist, USDA Forest Service, Siuslaw National Forest, Corvallis, Oregon. She led the marbled murrelet work group. She served as the Forest's threatened, endangered, and sensitive species coordinator, and as the marbled murrelet coordinator for the Pacific Northwest Region of the Forest Service with emphasis on Forest-related issues and regional coordination of marbled murrelet management issues. She currently is with the Regional Office in Portland, Oregon.

Acknowledgments

Primary direction came from the research executives of the Federal research agencies, Tom Mills (Forest Service, PNW), Mike Collopy (USGS—BRD), and Tom Murphy (EPA). Their strong support and continuing dedication to this project was greatly appreciated. We also thank members of the RMC (Dan McKenzie and Dave Busch), Jerry McIlwain (Forest Service, PNW), and Bob Alverts (BLM) for their valuable day-to-day support and guidance. Many people provided reviews, feedback, support, and ideas throughout this effort, with special thanks to Tim Lewis (Humboldt State University), Paul Ringold (EPA), David Cassell (BLM), Jim Alegria (BLM), and Tim Tolle (Forest Service). In addition, many agency staff and managers provided valuable feedback through briefings and workshops (see appendix C), including members of the IAC, RIEC, REO, and RMC, as well as participating Federal agencies at the local and regional level. Finally, we especially thank Martha Brookes (Forest Service, PNW) for her excellent comments, and Karen Esterholdt for her fine editing and publication assistance. Their help, as well as the support and input from all those noted above, is greatly appreciated.

The peer reviews were invaluable. Tim Lewis, Bruce Marcot (Forest Service, PNW), Doug Powell (Forest Service), Paul Ringold, and Kurt Ritters (Tennessee Valley Authority) reviewed the management concepts (Chapters 1, 4, and 5). Jon Bart, John Emlen, Dan Fagre, Paul Geissler, Jim Nichols, Rusty Rodriguez, Peter Stine (USGS—BRD); Hart Welsh (Forest Service, PSW); Gary Davis and Dave Graber (NPS); and Ted Case (University of California, San Diego), L. Scott Mills (University of Montana), David Peterson (University of Washington), James Quinn (University of California, Davis), and Gerald Wright (University of Idaho) participated in an expert workshop, held in Olympic National Park, to review the science and theory (Chapters 2 and 3).

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Appendix B: Acronyms and Key Terms Used in This Report

Acronyms

ACS—Aquatic conservation strategy

BIA—Bureau of Indian Affairs

BLM—Bureau of Land Management

CVS—Current vegetation survey

EM—Effectiveness monitoring

EPA—Environmental Protection Agency

EMAP—Environmental Monitoring and Assessment Program

EMT—Effectiveness Monitoring Team

ESA—Endangered Species Act

FEMAT—Forest Ecosystem Management Assessment Team

FIA—Forest Inventory and Analysis

FHM—Forest health monitoring

FLPMA—Federal Land Policy Management Act

FWS—U.S. Fish and Wildlife Service

GIS—Geographic Information System

IAC—Intergovernmental Advisory Committee

IRICC—Interorganizational Resource Information Coordinating Committee

LSOG—Late-successional old growth

MaMu—Marbled murrelet

NEPA—National Environmental Policy Act

NFMA—National Forest Management Act

NPS—National Park Service

NSO—Northern spotted owl

QA/QC—Quality assurance and quality control

REO—Regional Ecosystem Office

RIEC—Regional Interagency Executive Committee

Rip/Aq—Riparian and aquatic

RMC—Research and Monitoring Committee

ROD—Record of decision

S/M—Survey-and-manage species

U.S. GAO—U.S. Government Accounting Office

USGS-BRD—U.S. Geological Services-Biological Resources Division

Key Terms

Although many words or phrases could or should be explained, a few that appear many times in this report are listed below because they are critical to the proposed program. They are provided as explanations, not definitions.

Adaptive management—the process of action-based planning, monitoring, research, evaluating, and adjusting to accelerate learning and improve the ability to manage resources effectively

Adaptive monitoring—a continuing approach to refine the monitoring program as a result of experience in implementing it, assessing its results, and interacting with users of the information

Conceptual model—a method to outline the interconnections among ecosystem processes, structure, composition, and function, the strength and direction of those links, and the attributes that characterize the state of the ecosystem

Effectiveness monitoring—monitoring to document the status and trends of resource conditions; in the context of the Forest Plan, to evaluate whether the goals and objectives of the plan are being achieved

Implementation monitoring—monitoring to document compliance with direction; in the context of the Forest Plan, to evaluate whether the agencies are implementing the standards and guidelines in the ROD

Indicator—any living or nonliving feature of the environment that can be measured or estimated and that provides insights to the state of the ecosystem

Information management—an organized system to assist in collecting, storing, and retrieving data needed for reporting and making decisions and that is computer based and linked to GIS

Integrated monitoring system—an approach to monitoring that brings together all the critical data collection, information management, and reporting components into a unified interactive program

Interpretive report—a report that evaluates and interprets the ecological significance of trends demonstrated by the monitoring data and evaluates these trends based on summary reports and other associated information

Monitoring—collecting and assessing information on measurable ecosystem attributes to evaluate whether the goals of the Forest Plan are being met and to determine whether the integrity of the ecological system and its processes are being maintained

Pilot project—a short-term study to test, evaluate, or develop methods or processes for the monitoring program

Regional scale—the spatial scale or extent addressed by the monitoring program; this scale implies answering questions about status and trends across the entire area covered by the Forest Plan

Stressor—intrinsic and extrinsic drivers of change, either positive or negative; in the context of this report it refers to natural and human-induced disturbance events resulting in significant ecological effects

Summary report—brief, comprehensive summaries, tables, and maps of essential data periodically collected to address the monitoring questions for specific resources

Validation monitoring—monitoring to document cause-and-effect relations; in the context of the Forest Plan, to evaluate the link between implementing the standards and guidelines and the observed effects

Appendix C: Chronology of Key Meetings and Reviews

Numerous briefings, discussions, and meetings occurred among the effectiveness monitoring team (EMT), Intergovernmental Advisory Group (IAC), Regional Interagency Executive Committee (RIEC), Federal research executives, and agency staff specialists and managers on guidance, issues, and proposals for effectiveness monitoring of the Forest Plan. Table 11 lists only formally scheduled sessions applicable to the current effort. Day-to-day interactions, discussions, preparation sessions for these meetings, ongoing EMT and monitoring work group meetings, and other work sessions are not included; they were too numerous to list here.

Table 11—List of formal briefings and meetings on effectiveness monitoring

Meeting date	Type of presentation	Participants	Comments and issues	Followup and documentation
May 30, 1996	Briefing on planning effort	IAC meeting	Discussion	IAC issue summary
Aug. 2, 1996	(none)	Research executives	Assignments and direction	Letters to participants
Aug. 28, 1996	Planning meeting for EMT	EMT, REO, and Research executives	Assignments and direction	Informational
Sept. 19, 1996	Briefing on status	IAC meeting	Discussion	IAC issue summary
Nov. 26, 1996	Briefing on status and approaches	FS, BLM, FWS, NMFS, EPA mid-level managers	Discussion	Informational
Dec. 5, 1996	Briefing on status	IAC meeting	Discussion	IAC issue summary
Jan. 24, 1997	Briefing on status and approaches	FS, BLM, FWS, NMFS, EPA mid-level managers	Discussion	Informational
Feb. 2, 1997	Briefing on status and approaches	Research executives	Discussion	Summarized comments
Mar. 20, 1997	Briefing on status and approaches	BLM State, District, Res. Area staff and managers	Verbal and written questions	Written response
April 3, 1997	Briefing on status and approaches	IAC meeting	Verbal questions	IAC issue summary
April 29, 1997	(none)	Selected peer reviewers	Peer review comments (mgmt. concepts)	Peer review summary
April 30, 1997	Briefing on status and approaches and discussion on information mgmt	IRICC meeting	Verbal questions and comments	Followup briefing; copies of draft EM reports
May 8, 1997	Briefing on status and approaches	Forest Service and FWS mid-level field managers	Discussion	Followup briefing
May 10-12, 1997	Science peer review workshop	Selected scientists and monitoring specialists	Discussion on science theory and concepts	Peer review summary
May 19, 1997	Briefing on status and approaches	Forest Service regional managers	Verbal questions	Followup briefing
May 22, 1997	Update on status and approaches and discussion on information mgmt.	IRICC meeting	Verbal questions	Summarized comments
June 3, 1997	Workshop on EM proposals	Interagency staff and managers (regional and field)	Verbal and written questions and comments	Summarized comments
June 11, 1997	Workshop on EM proposals and science discussion	Research executives and interagency staff and managers	Verbal questions and comments	Summarized comments; written response
June 13, 1997	Discussion on EM proposals and decision process	RIEC members and staff	Verbal questions and comments	Summarized comments
June 19, 1997	Briefing on status, proposals, and decision process for draft reports	IAC meeting	Verbal questions and comments	IAC issue summary
June 23, 1997	Briefing on proposals (staffing and costs)	Forest Service and BLM planning staff	Verbal questions and comments	Summarized comments
July 7, 1997	Meeting on staffing and costs	Agency policy and management team	Discussion and verbal questions	Further review; followup materials
July 31, 1997	Meeting on staffing and costs	Agency policy and management team	Discussion	Further review
Aug. 7, 1997	Briefing on status	IAC meeting	Verbal questions and comments	IAC issue summary
Sept. 4, 1997	Meeting on staffing and costs	Agency policy and management team	Discussion	Further review
Oct. 2, 1997	Conference call on final draft reports	IAC members	Discussion; final approval	IAC issue summary
Nov. 6, 1997	Briefing on implementation	RIEC and IAC meetings	Discussion; agreement on implementation	IAC issue summary; summary comments

Appendix D: Supplemental Information on Essential and Related Projects That May Contribute to the Effectiveness Monitoring Program

Tables 12 and 13 provide lists of existing data collection activities that may contribute useful information to the effectiveness monitoring program. This is not a complete list but is intended only as examples of these kinds of activities (refer to Chapter 4).

Table 12—Examples of existing projects that provide essential data to effectiveness monitoring (type B projects)

Title	Coordinating agency	Geographic scope	Duration	Description
		Vegetation inventories and survey efforts[a]		
Vegetation map	USDA Forest Service	Region of NW Forest Plan (OR, WA, CA)	Planned	Remotely sensed map characterized to Vegetation Strike Team[b] data standards
Current vegetation survey	USDA Forest Service	National Forests (WA, OR)	4 years	3.4- and 1.7-mile grids of 1-ha[c] plots, live and dead trees, plant indicators, down woody material
Current vegetation survey	USDA Forest Service	National Forests (CA)		3.4-mile grid of 1-ha plots, live and dead trees, plant indicators, down woody material
Current vegetation survey	BLM	BLM Districts (OR)	Begin in 1997	3.4-mile grid of 1-ha plots, live and dead trees, plant indicators, down woody material
Ecology program; potential vegetation classification and mapping	USDA Forest Service	National Forests (WA, OR, CA)		Classification based on current vegetation, environment, disturbance competition, and time
Forest inventory	BLM	BLM Districts (CA)		Forest mensuration variables
		Northern spotted owl demographic studies[d]		
Olympic Peninsula owl demographic study	Pacific Northwest Research Station and USGS-BRD	Olympic Peninsula (WA) (814 544 ha)	10 years	Owl survey data
Cle Elum owl demographic study	Pacific Northwest Research Station	Cle Elum (WA) (176 272 ha)	8 years	Owl survey data
H. J. Andrews owl demographic study	Pacific Northwest Research Station	H.J. Andrews, Willamette NF (OR) (234 400 ha)	10 years	Owl survey data
North Coast Range owl demographic study	Pacific Northwest Research Station	North Coast Range, (OR) (391 392 ha)	8-10 years	Owl survey data

Table 12—Examples of existing projects that provide essential data to effectiveness monitoring (type B projects) (continued)

Title	Coordinating agency	Geographic scope	Duration	Description
		Northern spotted owl demographic studies[d] (continued)		
Roseburg owl demographic study	Pacific Northwest Research Station, BLM, and USGS-BRD	Roseburg (OR) (105 584 ha)	12 years	Owl survey data
Klamath owl demographic study	BLM	Klamath Province (CA) (137 728 ha)	12 years	Owl survey data
South Cascades owl demographic study	USDA Forest Service	South Cascades (OR) (240 528 ha)	9 years	Owl survey data
NW California owl demographic study	USDA Forest Service	National Forests (NW CA) (178 416 ha)	12 years	Owl survey data
		Aquatic and riparian analyses[e]		
Watershed analysis	USDA Forest Service and BLM	Watersheds throughout Forest Plan region (OR, WA, CA)	3 years	Characterize watershed and ecological processes

[a] See Hemstrom et al., in press (see footnote 2, Chapter 1).
[b] See Vegetation Strike Team 1996.
[c] Although grid plots are spaced 1.7 or 3.4 miles apart, data are collected for 1-hectare (ha) units.
[d] See Lint et al., in press (see footnote 2, Chapter 1).
[e] See Furniss et al. 1997 (see footnote 2, Chapter 1).

Table 13—Examples of existing projects that provide information of value to effectiveness monitoring (type C)

Title	Coordinating agency	Geographic scope	Duration	Description
		Vegetation inventories and survey efforts[a]		
Plant association grouping	BLM	Salem-Eugene Districts (OR)	2 years	Plant association mapping
Ecological unit inventory	USDA Forest Service	National Forests (WA, OR)	—	Stratification of ecological units based on soil, climate, potential natural vegetation, landform, and lithology
Forest inventory and analysis	Pacific Northwest Research Station	Non-federal forest lands (WA, OR, CA)	—	3.4-mile grid of live and dead trees, vegetation profiles, down woody material, and tree cover and species
Forest health monitoring	Pacific Northwest Research Station	National Forests (CA, WA, OR)	5 yr in CA; began WA, OR in 1997	27-km triangular grid of 1-ha plots, growth, regeneration, crown condition, tree species, damage, and mortality
Insect and disease survey	USDA Forest Service	National Forests (WA, OR, CA)		Annual aerial surveys of insect and disease damage

(*continues on next page*)

Table 13—Examples of existing projects that provide information of value to effectiveness monitoring (type C) (continued)

Title	Coordinating agency	Geographic scope	Duration	Description
		Marbled murrelet surveys[b]		
Marbled murrelet marine surveys	Pacific Northwest Research Station, National Council for Air and Stream Improvement	San Juan Islands, Hood Canal (WA)	3 years	Marbled murrelet population and reproductive data
Marbled murrelet marine surveys	WA Department of Fish and Wildlife	Puget Sound, San Juan Islands, coast (WA)	5 years	Marbled murrelet population and reproductive data
Marbled murrelet marine surveys	Sustainable Ecosystems Inst.; NW Indian Fisheries Commission	Puget Sound, Hood Canal (WA)	2 years	Marbled murrelet population and reproductive data
Marbled murrelet marine surveys	OR Department Fish and Wildlife	OR coast	4 years	Marbled murrelet population and reproductive data
Marbled murrelet marine surveys	Pacific Southwest Research Station, CA Department of Fish and Game, Fish and Wildlife Service	Northern CA coast	8 years	Marbled murrelet population and reproductive data
Marbled murrelet marine surveys	CA Department of Fish and Game	Central CA coast	4 years	Marbled murrelet population and reproductive data
Marbled murrelet aerial surveys	MARZET Marine and Estuarine Research Co.	North and central CA, OR and WA coast	4 years	Marbled murrelet population data
		Aquatic and riparian inventories[c]		
Aquatic Inventories	USDA Forest Service	National Forests (WA, OR, CA)	—	Channel morphology, habitat attributes, and riparian vegetation

[a] See Hemstrom et al., in press (see footnote 2, Chapter 1).
[b] See Madsen et al., in press (see footnote 2, Chapter 1).
[c] See Furniss et al. 1997 (see footnote 2, Chapter 1).

Appendix E: Summary Information Used To Evaluate Schedules, Staffing, and Costs of the Effectiveness Monitoring Program

The Effectiveness Monitoring Team (EMT) used a rigorous, science-based approach to design the program for effectiveness monitoring and identify monitoring options for the assigned resources. The resulting information was used to propose a schedule for implementing program components, identify potential staffing needs, and estimate costs. The following summarizes the steps used by the EMT and monitoring work groups to evaluate and develop the information presented in the following tables.

Part 1: Steps To Identify Options

The effort to identify options for monitoring selected resources followed the general multistep process for designing a monitoring plan (see Chapter 2). The primary focus of the effort was to identify the information needed to evaluate the Forest Plan within the criteria provided by the IAC so that methods for obtaining that information could be evaluated. This effort can be described as a series of distinct steps:

1. Evaluation of scientific literature on monitoring and the needs of the Forest Plan led to identification of a basic framework for effectiveness monitoring: monitoring for status and trends in forest vegetation and species habitat, and in species populations. Predictive modeling was proposed as a means to improve the use of monitoring data, anticipate trends, and reduce long-term costs; species-habitat relations can be addressed only if both of the other components are included (see table 14 for narrative description of basis monitoring components).

EMT conclusions—

- Application of the two-component approach for status and trend monitoring addresses the primary ecological assumptions underlying the Forest Plan
- Inclusion of predictive modeling is a desired component of monitoring

2. This framework was applied to each of the selected resource issues. Following the multistep process, each EMT work group identified the information needed to address status and trends for the selected resource (see table 15; also see monitoring modules [Hemstrom et al., in press; Lint et al., in press; and Madsen et al., in press; also see Furniss et al. 1997]).

EMT conclusions—

- The general framework is applicable to monitoring status and trends under the Forest Plan for the assigned resources.
- Information at the landscape and stand scales and understanding species-habitat relations are basic information needs.

3. Sampling methods were identified and evaluated for gathering status and trend (see Chapter 3; also see monitoring modules [Hemstrom et al., in press; Lint et al., in press; Madsen et al., in press; also see Furniss et al. 1997]). The primary evaluation criterion was whether the method provided the information needed to address the Forest Plan (see table 16). In addition, at a minimum the methods had to be scientifically valid (consistent, comparable, repeatable, quantifiable, etc.), contribute to trend prediction, link to other uses, be synergistic, and provide adequate spatial coverage. As a result of this evaluation, alternative methods not meeting these criteria were dropped from further consideration; in general there are not many competing approaches to trend monitoring.

EMT conclusions—

- The process to evaluate sampling methods identified specific methods to meet Forest Plan information needs for status and trends.
- In most cases existing methods (remote sensing, vegetation surveys, species habitat and population studies) met these criteria, although techniques may need to be improved or modified.
- New methods were identified where needed.

4. After eliminating unproductive methods, the work groups identified a range of options for implementing those methods meeting agency information needs (see Chapter 3; also see monitoring modules [Hemstrom et al., in press; Lint et al., in press; and Madsen et al., in press; also see Furniss et al. 1997]). These options are summarized in table 17.

EMT conclusions—

- The recommended options will provide information to meet agency needs to evaluate the Forest Plan and key resources.
- The options provide a range of funding levels for gathering status and trend information for the assigned resources.
- The quality and utility of the information collected under the different options is primarily related to the intensity of the monitoring effort and the amount of funds available.

Part 2: Information To Support Management of the Program

A framework for managing a monitoring program was described (see Chapter 4). The structure is identified in the monitoring literature as basic to successful monitoring programs and was used as the template for program operations. It includes an infrastructure for data collection and management and for information assessment and reporting (see table 18). This structure is independent of the options; it was provided to give context for evaluating the options from a program management perspective, such that schedules and estimates of funding and staffing could be made.

EMT conclusions—

- The framework identifies the major components of an operational program from data collection and management to assessment and reporting.
- The framework needs to be applied to each separate module as well as the whole program to maintain continuity in information quality and availability.
- The success of a large-scale, multifaceted program depends on institutionalizing the components and providing stable funding and staffing for these components.

Part 3: Information To Support Implementing the Program

Material was evaluated around a schedule for implementing the program through its first 3 years for each of the resources being monitored (see monitoring modules [Hemstrom et al., in press; Lint et al., in press; Madsen et al., in press; also see Furniss et al. 1997]), and for management and support at the regional scale. The intent was to provide a strategy for implementing the program and producing the first regionwide interpretive report (see Chapter 5). This schedule does not depend on the selection of options, although funding levels and staffing requirements will differ by option selected (see tables 19 and 20); although not fully evaluated by the EMT, information also is provided for needs at the regional level.

EMT conclusions—

- Tasks, assignments, and schedules will exist at both regional and project levels.
- Long-term, multiyear managerial and staff support is necessary at both regional and project levels.
- Documentation and guidance are needed to implement a program, including field manuals, annual work plans, staff assignments, and schedules.
- The program should be evaluated and redirected, if necessary, after completion of the first report.

Part 4: Information to Evaluate Costs

An evaluation was conducted on the estimated costs for each of the completed monitoring modules based on costs of activities in previous years (see monitoring modules [Hemstrom et al., in press; Lint et al., in press; Madsen et al., in press; also see Furniss et al. 1997]). This included an evaluation of the full- and part-time (and temporary) staff needed to manage and carry out each component of the program. Because there were few examples of what it would take to manage and operate this program at the regional level, only general information is provided (see Chapter 5). The information is based on the recommended options for assigned resources (see tables 20 and 21).

EMT conclusions—

- Funds will be needed at both regional and project scales.
- Long-term, multiyear, stable funding is necessary.

Table 14—Narrative description of proposed activities for the effectiveness monitoring program

Monitoring topic	Activity	Description
Regional	Program management	Management and oversight of interagency efforts for all monitoring modules at the regional office level
	Technical support	Provide plans and technical support, including research support, for monitoring program at regional and field levels
	Assessment and reporting	Analysis of regional monitoring results to identify regional Forest Plan trends
Late-successional old growth (LSOG)	Vegetation trend	Use of agency remote sensing and vegetation surveys (grid plot) to develop regionwide databases
	Trend model development	Development and use of modeling to link remotely sensed and grid plot data to anticipate trends
	Assessment and reporting	Analysis of remotely sensed and grid plot data to identify regional vegetation trends
	Management and coordination	Management and oversight of project and regional efforts
Northern spotted owl	Population trend:	
	Population studies	Use of demographic studies to determine population trends
	Habitat association (stand)	Refinement of owl habitat relations and habitat definitions for use in predictive modeling
	Habitat trend (landscape)	Analysis of remotely sensed and grid plot data to identify regional vegetation trends for owl habitat
	Trend model development	Development and use of modeling to link owls and habitat and remotely sensed data to anticipate trends
	Assessment and reporting	Analysis of demographic and habitat data to identify regional trends
	Management and coordination	Management and oversight of project and regional efforts
Marbled murrelet	Population trend	Test and improve marine survey methods for tracking population trends
	Habitat trend:	
	Landscape studies	Develop consistent trend model classification methods for murrelet habitat
	Stand level studies	Define key murrelet nesting habitat variables and link ground-based variables to trend model imagery
	Trend model development	Development and use of modeling that links remotely sensed and grid plot data to anticipate trends
	Assessment and reporting	Analysis of population and habitat data to identify regional trends
	Management and coordination	Management and oversight of project and regional efforts
Coast pilot project	Evaluate methods and reporting	Test approaches to answering key effectiveness monitoring questions by using existing data and techniques; provide example monitoring report in FY1998 (Siuslaw NF, Salem and Eugene BLM, PNW)

Table 15—Comparison of proposed approaches and methods for monitoring assigned resources under the Forest Plan

Monitoring topic	General approach to monitoring	Methods to apply approach	Options for level of expenditure	Operating assumptions	Comments
Late-successional old growth (LSOG)	Vegetation trend	Remote sensing (landscape) and grid plot (standscale)	2 levels	Continued funding of remote sensing and grid plot programs	Decision on vegetation map is critical to all programs
	Predictive trend model	Develop vegetation models	yes or no	Availability of grid plot data	
	Assessment and reporting	Develop analytic and reporting methods		Necessary to draw results from data	
Northern spotted owl	Population trend	Demographic and habitat (stand) studies	3 levels (phase 1)	Habitat (stand) and population studies needed for habitat-species association	Outcome of phase 1 may affect direction and cost of phase 2
	Habitat trend	Remote sensing and grid plot studies	3 levels	Continued funding of remote sensing and grid plot programs	
	Predictive trend model	Develop species-habitat models	yes or no	Availability of population and habitat (stand-scale) data	
	Assessment and reporting	Develop analytic and reporting methods		Necessary to draw results from data	
Marbled murrelet	Population trend	Marine surveys	4 levels (phase 1)	Initial development of new survey techniques	Outcome of phase 1 may affect direction and cost of phase 2
	Habitat trend	Remote sensing, grid plot, and habitat (stand) studies	4 levels (phase 1)	Initial refinement of nesting habitat (continued funding of remote sensing and grid plot programs); habitat (stand) and population studies needed for habitat-species association	Outcome of phase 1 may affect direction and cost of phase 2
	Predictive trend model	Develop species-habitat models	yes or no	Availability of population and habitat (stand-scale) data	No immediate decision necessary
	Assessment and reporting	Develop analytic and reporting methods		Necessary to draw results from data	
Aquatic and riparian	Watershed trend	Under development	yes	Effectiveness of agency watershed analyses; initial development of sampling techniques	Continued availability of watershed analyses
	Predictive trend model	Under development	yes	Initial development of techniques	
	Assessment and reporting	Develop analytic and reporting methods		Necessary to draw results from data	
Other modules	tbd	tbd	tbd		

tbd = to be determined.

Table 16—Description and rationale for recommended options for effectiveness monitoring of assigned resources

Monitoring topic	Approach	Recommended method or option		Selection rationale
		Option	Description	
Late-successional old growth (LSOG)	Vegetation trend	2	Analyze vegetation maps and grid plots	Higher quality and more useful information using landscape and stand-scale views Improved accuracy for detecting “real” change Synergistic use of data and funds
	Predictive trend model	—	Refine trend estimates	Extrapolation, prediction, cost reductions
Northern spotted owl	Population trend	1	Habitat assessment (for model development) and population surveys in 8 demographic study areas	Wider coverage given range variation Maintain capability and improve quality of meta-analyses Develop species-habitat association data for model
	Habitat trend	2	Rangewide habitat assessment using LSOG vegetation maps	Same rationale as LSOG vegetation above
	Predictive trend model	1	Pursue model development	Extrapolation, prediction, cost reductions
Marbled murrelet	Population trend	2	Test and improve marine survey methods with Federal and non-Federal participation (phase 1)	Establish consistency in survey techniques to obtain higher quality and more useful data Improve methods for monitoring Improve collaboration and acceptance
	Habitat trend	4	Establish baseline by using 4 study areas and develop process for monitoring trends using LSOG vegetation maps and grid plots (phase 1)	Obtain better characterization of habitat given range variation Improve baseline for monitoring (same rationale as LSOG above)
	Predictive trend model	—	Pursue model development	Extrapolation, prediction, cost reductions
Aquatic and riparian	Watershed trend	tbd	Under development	Under development
	Predictive trend model	tbd	Pursue model development	Extrapolation, prediction, cost reductions
Other modules	tbd	tbd	tbd	tbd

tbd = to be determined.

Table 17—Summary of existing and new monitoring activities proposed for developing methods and conducting activities for assigned resources

Monitoring topic	Approach	Developing methods: Existing	Developing methods: New	Monitoring activities: Existing	Monitoring activities: New
Late-successional old growth (LSOG)	Vegetation trend			Remote sensing and grid plot efforts	Assessment and reporting process; trend projection
	Predictive trend model		Develop and validate model		
	Assessment and reporting		Develop procedures		
Northern spotted owl	Population trend			Demographic and habitat association studies	
	Habitat trend				Rangewide habitat assessment
	Predictive trend model	Develop model	Validate model		
	Assessment and reporting		Develop procedures		
Marbled murrelet	Population trend	Develop new survey techniques		Marine surveys (to be modified)	
	Habitat trend		Refine habitat definitions and analytic techniques	Habitat surveys (to be modified)	
	Predictive trend model		Develop and validate model		
	Assessment and reporting		Develop procedures		
Aquatic and riparian	Watershed trend		Develop sampling methods	FS and BLM watershed analyses; existing monitoring activities to be evaluated	
	Predictive trend model		Develop and validate model		
	Assessment and reporting		Develop procedures		
Other modules	tbd	tbd	tbd	tbd	tbd

tbd = to be determined.

Table 18—Summary of expected monitoring reports, proposed reporting schedule, and responsibilities

Monitoring topic	Monitoring report	Reporting schedule	Information content	Database location	Responsible monitoring staff	Important disciplines[a]
Regional	Regionwide data summary	Annual	Combined summaries: Maps and tables Tables and reports	Project summaries	Regional and module monitoring managers	QA/QC; statistician; information management; GIS and remote sensing
	Regionwide interpretive report	5-year	Forest Plan analysis	Regional summaries	Regional and module monitoring managers	Statistician-modeler
Late-successional old growth (LSOG)	Data summary:		Evaluate project information: Maps and tables Tables and reports	Project summaries	Project and regional managers	QA/QC; statistician; information management; GIS and remote sensing
	Landscape	5-year				
	Stand-level	Annual				
	Interpretative report	5-year	Regional trend analysis	Regional summaries	Regional and managers	Statistician-modeler
Northern spotted owl	Data summary:		Evaluate project information:	Project summaries	Project and regional managers	QA/QC; information management; GIS and remote sensing
	Demographic sites	Annual	Tables and reports			
	Demographic site habitat	5-year	Tables and reports			
	Rangewide habitat	5-year	Maps and tables			
	Interpretive report: Population meta-analysis	4-year	Demographic analysis	Regional	Project and managers	Statistician-modeler
	Trends	5-year	Regional trend analysis	Regional summaries	Regional and managers	
Marbled murrelet	Data summary:		Evaluate project information:	Project summaries	Project and regional managers	QA/QC; statistician; information management; GIS and remote sensing
	Marine	Annual	Tables and reports			
	Terrestrial	Annual	Tables and reports			
	Landscape	5-year	Maps and tables			
	Stand-level	Annual	Tables and reports			
	Interpretive report	5-year	Regional trend analysis	Regional summaries	Regional and managers	Statistician-modeler
Aquatic and riparian	Data summary:	Annual	Evaluate project information:	Project summaries	Project and regional managers	QA/QC; statistician; information management; GIS and remote sensing
	Watershed analysis		Maps, tables, reports			
	Sampling		Maps and tables			
	Interpretive report	5-year	Regional trend analysis	Regional summaries	Regional and managers	Statistician; modeler
Other modules	tbd	tbd	tbd			
Coast pilot project	Example interpretive report	FY 1998	Data analysis for monitoring questions	Siuslaw NF, Salem and Eugene BLM	PNW; FS; BLM staff and module managers	GIS and remote sensing; information management; statistician; modeler

tbd = to be determined.
[a] In addition to the disciplines identified, additional support may be needed from subject area specialists.

Table 19—Staffing and technical expertise needs for conducting the effectiveness monitoring program through the first 3 years (fiscal year 2000)

Monitoring topic	Subject area	Position type	Full-time staff	Part-time or temporary staff
Regional	Program management	Regional monitoring managers	x	
		Regional monitoring module managers	x	
	Technical support	Information management specialists		
		GIS and remote sensing specialists	x	
		QA/QC specialists	x	
		Statisticians	x	
		Subject area specialists	x	
	Assessment and reporting	Data analysts and modeling specialists		x
Late-successional old growth (LSOG)	Vegetation trend	Project managers and field staff	x[a]	x[a]
	Predictive trend model	Model specialists	x	
	Assessment and reporting	Data analysts		x
Northern spotted owl	Population trend	Project managers, coordinators, and field staff	x	x
	Habitat trend	Project managers and coordinators	x	
		GIS and remote sensing specialists	x	x
		Subject area specialists	x	x
	Predictive trend model	Coordinator and model specialists	x	x
	Assessment and reporting	Data analysts		x
Marbled murrelet	Population trend	Project managers, coordinators, and field staff	x	x
	Habitat trend	Project managers, coordinators, and field staff	x	x
		GIS and remote sensing specialists	x	x
	Predictive trend model	Coordinator and model specialists	x	x
	Assessment and reporting	Data analysts		x
Aquatic and riparian	tbd	tbd	tbd	tbd
Other modules	tbd	tbd	tbd	tbd
Coast pilot project	Evaluate methods and report	Coordinator and subject area specialists		x[b]

tbd = to be determined.

[a] Many of these staff would be part of an agency's existing GIS-remote sensing programs who would contribute information to the monitoring program.

[b] Staff are included in the funding identified for the pilot project (including coordinators and technical support).

Table 20—Implementation schedule and summary of estimated annual funding for monitoring (recommended options) and related programs[a]

Monitoring topic	Existing funds, 1997	Funding fiscal year 1998	1999	2000	2001	2002	2003	2004	2005
		Thousand dollars							
Regional	—	tbd	tbd	tbd	tbd	tbd	tbd	tbd	tbd
Late-successional old growth (LSOG)	See below	70	170	—	—	—	70	70	—
Northern spotted owl		**Phase 1[b]**					**Phase 2**		
	1,884	2,240	2,585	2,520	3,290	3,155	1,265	1,228	1,328
Marbled murrelet		**Phase 1[b]**		**Phase 2**					
	600	994	879	940	880	435	435	435	435
Aquatic and riparian	tbd	tbd	tbd	tbd	tbd	tbd	tbd	tbd	tbd
Other modules:	tbd	tbd	tbd	tbd	tbd	tbd	tbd	tbd	tbd
Socioeconomics									
Tribal									
Biodiversity									
Coast pilot project	240	240							
Estimated totals	2,724	3,544	3,634	3,460	4,170	3,590	1,770	1,733	1,763
Estimated funding for producing vegetation information (for comparison)[c]									
Image analysis (remote sensing)	Data not available	680	1,000	May differ	May differ	May differ	May differ	May differ	May differ
Grid plot data (e.g., CVS)	2,500-3,500	2,500-3,500	2,500-3,500	2,500-3,500	2,500-3,500	2,500-3,500	2,500-3,500	2,500-3,500	2,500-3,500

tbd = to be determined.
[a] Costs will change as the programs are implemented.
[b] The spotted owl and murrelet monitoring programs are divided into phases based on research needed to improve or modify the programs; costs will change as the research is completed (see Lint et al., in press; Madsen et al., in press).
[c] These funding estimates are for comparison purposes only; these costs are covered by other agency programs and would not be expected to change regardless of the size or scope of the EM program.

Table 21—Summary of estimated annual funding for each specific monitoring component (for completed modules only)[a]

Monitoring topic	Activity	Existing funds 1997	Fiscal year funding 1998	1999	2000	2001	2002	2003	2004	2005
			Thousand dollars							
Regional	Program management	—	tbd	tbd	tbd	tbd	tbd	tbd	tbd	tbd
	Technical support	—	tbd	tbd	tbd	tbd	tbd	tbd	tbd	tbd
	Assessment and reporting	—	tbd	tbd	tbd	tbd	tbd	tbd	tbd	tbd
Late-successional old growth (LSOG)	Vegetation trend	See table 20	Same	Same	Same	Same	Same	Same	Same	Same
	Predictive trend model	0	30	30	—	—	—	70	70	—
	Assessment and reporting	0	40	140	—	—	—	—	—	—
	Management and coordination	0	tbd	tbd	tbd	tbd	tbd	tbd	tbd	tbd
Northern spotted owl	Population trend	1,690	1,870	2,050	2,050	2,150	2,150	1,100	1,100	1,200
	Habitat trend	0	50	200	120	40	45	45	48	48
	Predictive trend model	194	320	335	350	1100	960	120	80	80
	Assessment and reporting	—	tbd	tbd	—	—	—	tbd	tbd	—
	Management and coordination	—	tbd	tbd	tbd	tbd	tbd	tbd	tbd	tbd
Marbled murrelet	Population trend	400	175	60	400	340	340	340	340	340
	Habitat trend	200	819	819	540	540	95	95	95	95
	Predictive trend model	0	0	0	tbd	tbd	tbd	tbd	tbd	tbd
	Assessment and reporting	—	tbd	tbd	—	—	—	tbd	tbd	—
	Management and coordination	—	tbd	tbd	tbd	tbd	tbd	tbd	tbd	tbd
Coast pilot project	Evaluate methods and report	240	240							
Totals, estimated		2,724	3,544	3,634	3,460	4,170	3,590	1,770	1,733	1,763

tbd = to be determined.

[a] Costs will change as the programs are implemented.

References

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Mulder, Barry S.; Noon, Barry R.; Spies, Thomas A.; Raphael, Martin G.; Palmer, Craig J.; Olsen, Anthony R.; Reeves, Gordon H.; Welsh, Hartwell H. 1999. The strategy and design of the effectiveness monitoring program for the Northwest Forest Plan. Gen. Tech. Rep. PNW-GTR-437. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 138 p.

This report describes the strategy and design of an effectiveness monitoring program for the Northwest Forest Plan. The described premise is to implement a prospective and integrated habitat-based approach to monitoring that provides a gradual transition from an intensive, individual species-resource focus to a more extensive, ecosystems approach by using surrogates to measure the pattern and dynamics of habitat structure in place of monitoring biota. The report describes the scientific framework for monitoring, starting with conceptual models, that is the basis for designing plans for monitoring specific resources.

Keywords: Northwest Forest Plan, ecological monitoring, effectiveness monitoring, adaptive management, regional scale, habitat basis, conceptual model, predictive model, integration, summary report, interpretive report, institutionalize.

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