United States
Department of
Agriculture

Forest Service

Pacific Northwest
Research Station

General Technical
Report
PNW-GTR-438
December 1998

Late-Successional and Old-Growth Forest Effectiveness Monitoring Plan for the Northwest Forest Plan

Miles Hemstrom, Thomas Spies, Craig Palmer, Ross Kiester,
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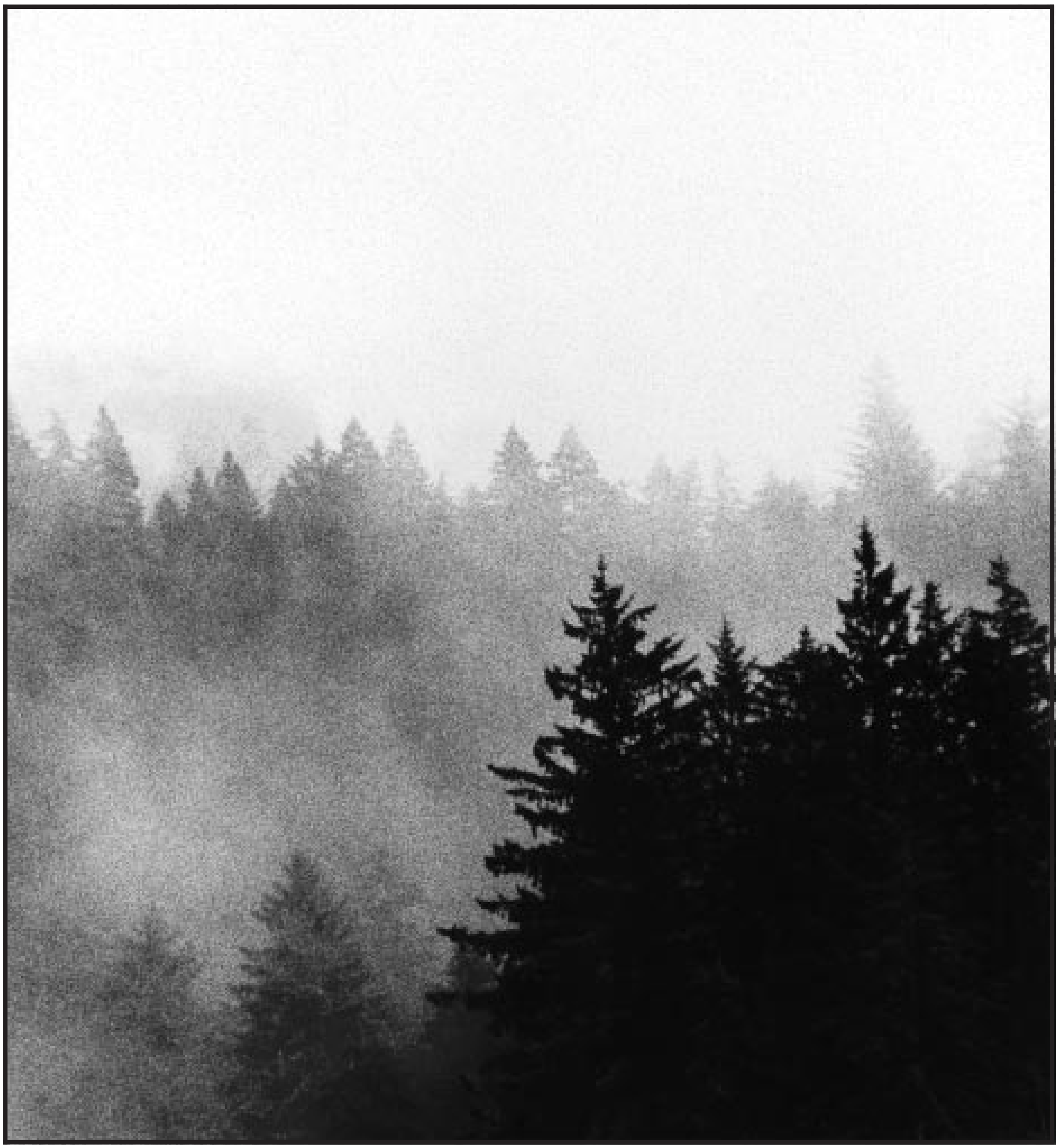

Authors

MILES HEMSTROM is a regional ecologist and JOHN TEPLY is an inventory program manager, U.S. Department of Agriculture, Forest Service, Pacific Northwest Region, P.O. Box 3623, Portland, OR 97208; THOMAS SPIES is a research forester and ROSS KIESTER is a mathematical statistician, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Forestry Sciences Laboratory, 3200 Jefferson Way, Corvallis, OR 97331; CRAIG PALMER is a program director, Harry Reid Center for Environmental Studies, University of Nevada—Las Vegas, 505 South Maryland Parkway, Las Vegas, NV 89154-4009; PHIL McDONALD is a research forester, U.S. Department of Agriculture, Forest Service, Pacific Southwest Experiment Station, 2400 Washington Ave., Redding, CA 96001; and RALPH WARBINGTON is a section head, U.S. Department of Agriculture, Forest Service, Pacific Southwest Region, Remote Sensing Laboratory, 1920 20th St., Sacramento, CA 95814.

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Published by:

U.S. Department of Agriculture
Forest Service
Pacific Northwest Research Station
Portland, Oregon
General Technical Report PNW-GTR-438
December 1998

Abstract

Hemstrom, Miles; Spies, Thomas; Palmer, Craig; Kiester, Ross; Teply, John; McDonald, Phil; Warbington, Ralph. 1998. Late-successional and old-growth forest effectiveness monitoring plan for the Northwest Forest Plan. Gen. Tech. Rep. PNW-GTR-438. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 37 p.

This report presents options for long-term effectiveness monitoring of late-successional and old-growth forests under the Northwest Forest Plan. It describes methods to answer questions about how much late-successional forest exists on Federal land, its pattern, how it's changing, and if the Forest Plan is providing for its conservation and management. It specifies data needed, analytic methods for using remotely sensed and grid plot data, and implementation options. A periodic process for reporting the status and trend of late-successional and old-growth forests on Federal lands is described, and links to finer scale monitoring of silvicultural and salvage effects on late-successional and old-growth forests are provided.

Keywords: Northwest Forest Plan, effectiveness monitoring, late-successional and old-growth forest, vegetation map, remote sensing, grid plot, GIS, landscape, stand-scale, trend model.

Preface

This report is part of a series describing the approach for monitoring effectiveness of the Northwest Forest Plan that has been approved by the Intergovernmental Advisory Committee. Other reports present the plans for monitoring the northern spotted owl, marbled murrelet, and aquatic and riparian ecosystems. Future reports may address survey-and-manage species and biodiversity of late-successional and aquatic ecosystems, socioeconomics, and tribal resources. These reports follow the framework for effectiveness monitoring described in "The Strategy and Design of the Effectiveness Monitoring Program for the Northwest Forest Plan." The purpose of this report is to present a range of options for monitoring late-successional and old-growth forests from which the Federal agencies responsible for the Forest Plan can select an approach meeting their respective information needs given current and expected resource availability. This report responds to the assignment from the Federal resource agencies through the Intergovernmental Advisory Committee and incorporates responses to all comments and peer reviews, as requested. The options, recommended by the authors and the interagency Effectiveness Monitoring Team, have been selected for implementation in fiscal year 1998. Manuals, protocols, specific tasks, and annual funding allocations will be provided in individual agency work plans. All these documents, including manuals and work plans, will comprise the full set of guidance for conducting the effectiveness monitoring program for the Forest Plan.

Executive Summary

How much late-successional forest is there on Federal land? What is its pattern across the landscape? Is the amount of late-successional and old-growth (LSOG) forests on Federal land changing? If so, from what causes and at what rates? Is the Northwest Forest Plan providing for conservation and management of LSOG forests as anticipated?

The LSOG effectiveness monitoring plan provides methods to answer those questions. It specifies data needed, analytic methods, and implementation options with estimates of necessary resources.

Data Sources

This plan relies on two kinds of information:

- Permanent grid plot data, on at least a 3.4-mile plot spacing, remeasured at least every 10 years
- Existing and potential vegetation maps

If these data sources are not implemented or developed, this monitoring plan cannot be implemented as designed, which will affect other monitoring plans dependent on forest vegetation and habitat data.

Approach

Vegetation maps and data from permanent grid plots will be stratified and analyzed to provide answers to the monitoring questions and estimates of future trends. Statistical reliability of these analyses will be estimated. A monitoring report will be prepared every 5 years, describing the status and trend of LSOG forests in the Northwest Forest Plan area. A panel of experts will review the report and recommend actions to the regional interagency executives. Links are provided to finer scale monitoring of silvicultural and salvage effects on LSOG forests, but a sample design is not provided.

Costs

This plan relies on collection of information from permanent grid plots and on the existence of vegetation maps, which are produced through other agency programs. Monitoring costs are for data analysis, additional modeling of expected trends, a pilot effort to refine methods, and report generation but not for installing permanent grid plot or building vegetation maps. Continued existence and updating of vegetation maps and grid plot data are critical to this plan.

Timelines

The monitoring approach depends on continuation of existing agency programs for the production of vegetation maps and data, and thus the schedule for monitoring depends on the provision of data from these programs. The intent is to conduct trend analyses in 1999 and produce the first monitoring report at the beginning of 2000.

Contents

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Introduction

The record of decision (ROD) for the Northwest Forest Plan (also Forest Plan) was developed and signed to address managing and conserving late-successional and old-growth forests (LSOG) on Federal lands in the range of the northern spotted owl (USDA and USDI 1994b: 2). The Forest Ecosystem Management Assessment Team report (FEMAT 1993) and the final supplemental environmental impact statement (FSEIS; USDA and USDI 1994a) provide the scientific assessment the ROD was based on and focus on the status and management of late-successional and old-growth forests. The ROD requires monitoring of the effectiveness of Forest Plan implementation (USDA and USDI 1994b: app. E, p. 8 and 9). In addition, late-successional and old-growth forests provide habitat for northern spotted owls (*Strix occidentalis caurina*), marbled murrelets (*Brachyramphus marmoratus*), and many other species.

This plan provides a conceptual framework and methods for monitoring LSOG forests on Federal lands under the Forest Plan. It focuses on regional and large landscape scales (fig. 1) (FEMAT 1993: 27) and provides links for finer scale monitoring of silviculture and salvage effects. The analysis for this monitoring plan will include all lands in the region of the Forest Plan to provide a context for LSOG on Federal lands. Any management decisions resulting from this analysis will apply only to Federal lands. Maps and data will be used to assess and evaluate forest vegetation and habitat for effectiveness monitoring of other Forest Plan resources, such as the spotted owl (Lint et al., in press), marbled murrelet (Madsen et al., in press), and other resources.

This effectiveness monitoring plan is part of a larger effort to monitor the effectiveness of the Forest Plan (Mulder et al., in press). That report describes seven steps, which are addressed in this effectiveness monitoring plan: (1) specify goals (refer to the section "Goals and Objectives"), (2) identify stressors (refer to "Monitoring Approach"), (3) develop conceptual models (refer to "Monitoring Approach"), (4) select indicators (refer to "Indicators"), (5) establish sampling design (refer to "Monitoring Approach"), (6) define methods of analysis (refer to "Data Analysis and Reporting"), and (7) ensure links to decisionmaking (refer to "Link to Decisionmaking").

Goals and Objectives

This plan will provide information that will allow managers to evaluate the success of the Forest Plan in reaching the desired amount and distribution of LSOG on Federal lands. Specific objectives include:

- Assess changes in the status and trends of late-successional and old-growth forest on Federal lands at large landscape scales in the region of the Forest Plan
- Provide a scientifically credible process for answering those questions, based on a conceptual model
- Provide a process to evaluate those answers and provide a link to management decisions

Figure 1—Physiographic provinces in the Northwest Forest Plan region.

Background

FEMAT and FSEIS Basis

The FEMAT report (1993: 49-52) and the FSEIS (USDA and USDI 1994a: 35-40) list three attributes against which the quantity and quality of late-successional ecosystems may be judged: abundance and ecological diversity, process and function, and connectivity. Descriptions in the FSEIS provide a starting point for developing specific monitoring questions.

Abundance and ecological diversity—

> Abundance of late-successional and old-growth communities and ecosystems refers to the total acreage of forest meeting structural, functional, or minimum age criteria based ecological conditions and definitions for each physiographic province. The standards that define forests are based on the extent of three stages of late-successional and old-growth forest. The three stages are the (1) maturation, (2) transition, and (3) shifting small gap stages of late-successional and old-growth forest development. Ecological diversity is also indicated by the distribution of late-successional and old-growth communities on the landscape, and the interrelationships among a variety of geographic, climatic, elevational, topographic, soil distributions [USDA and USDI 1994a: 35].

Process and function—

> Process refers to ecological changes or actions that lead to the development and maintenance of late-successional and old-growth ecosystems at all spatial and temporal scales. Examples include: (1) tree establishment, maturation, and death, (2) gap formation and filling, (3) understory development, (4) small and large scale disturbances such as fire and wind, (5) decomposition, (6) nitrogen fixation, and (7) canopy interceptions of energy and matter, and (8) energy and matter transfers between the forest and atmosphere [USDA and USDI 1994a: 37].

> Functions . . . refer to ecological values of the late-successional ecosystem or its components that (1) maintain or contribute to the maintenance of populations of species that use these ecosystems, and (2) contribute to the diversity and productivity of other ecosystems (such as carry over of large dead trees to early successional ecosystems, and storage of carbon in the global ecosystem). Examples of ecosystem function include habitat for organisms, climatic buffering, soil development and maintenance of soil productivity through inputs of large woody debris, nitrogen fixation, spread of biotic and abiotic disturbances through landscapes, and nutrient cycles production, storage, utilization, and decomposition [USDA and USDI 1994a: 37].

Connectivity—

> Connectivity is a measure of the extent to which the large landscape pattern of the late-successional and old-growth ecosystem provides for biological and ecological flows that sustain late-successional and old-growth animal and plant species across the range of the northern spotted owl. Connectivity does not necessarily mean that late-successional and old-growth areas have to be physically joined in space, because many late-successional and old-growth species can move (or be carried) across areas that are not in late-successional ecosystem conditions. Large landscape features affecting connectivity are (1) distance between late-successional and old-growth areas, and (2) forest conditions in areas between late-successional and old-growth areas [USDA and USDI 1994a: 38].

Two Definitions of LSOG

This effectiveness monitoring plan uses two perspectives of LSOG, one from remotely sensed characteristics and one from plot data at the stand scale. It establishes the statistical relation between them and evaluates trends in each (Czaplewski and Catts 1992). Remote sensing information allows answers to one set of questions (spatial features), and plot data provide information about stand-scale structure and composition. Because permanent plot methods are easier to repeat over time, they provide the most accurate estimators of LSOG amount.

Late-successional and old-growth forests can be described from remotely sensed information about upper canopy features, such as canopy cover, the size of tree crowns and inferences about tree diameter, canopy structure (single versus multiple layers), and to some extent, tree species (Cohen and Spies 1992). Maps depicting LSOG that use these features also can be used to examine large landscape extent, patterns, and amounts. Remote sensing, however, cannot detect some critical features (dead wood, canopy layers below the top layer, understory vegetation, elements of the spatial distribution of these features) that determine LSOG condition at the stand scale.

The Regional Interagency Executive Committee adopted a standard, minimum set of vegetation attributes for large landscape-scale mapping. These standards (appendix A), from the Vegetation Strike Team (1995), are more than sufficient for the LSOG effectiveness monitoring outlined in this plan. Development of remotely sensed information about the structure and composition of forests in the Forest Plan region is critical for implementation of this monitoring plan. An assessment of the accuracy of remotely sensed attributes will be necessary.

Late-successional and old-growth forests also can be defined from stand-scale, ground-based measurements of vegetation features (such as species, sizes, canopies, and amount of dead material). A uniform grid plot system that measures these attributes has been established in parts of the Forest Plan area (Max et al. 1996). Estimates of LSOG amounts by stratum can be derived from these data. Because definitions, attributes, and scale differ between remotely sensed and plot-based analyses of LSOG, estimated amounts of LSOG also are likely to differ.

Table 1—Forest vegetation mapping units for use in LSOG effectiveness monitoring analysis

	Composition class		
Structure class	Deciduous (D)	Mixed (M)	Conifer (C)
Potentially forested (PF)	PF	PF	PF
Seedling and sapling (SS)	SS-D	SS-M	SS-C
Small single-storied (SSS)	SSS-D	SSS-M	SSS-C
Medium and large single-storied (MSS)	MSS-D	MSS-M	MSS-C
Medium and large multistoried (MMS)	MMS-D	MMS-M	MMS-C
Large multistoried (LMS)	LMS-D	LMS-M	LMS-C

Remote sensing definitions—Forest classes for LSOG analysis can be defined from remotely sensed attributes, as was done by FEMAT (1993) and the FSEIS (USDA and USDI 1994a). This LSOG effectiveness monitoring plan adds supplemental classes to allow description of a full range of potentially forested conditions and to identify stands dominated by trees more than 30 inches in diameter, which often are favored habitat for old-growth-related species. Class breaks are slightly modified from those in FEMAT (1993: 9) because the Vegetation Strike Team (1995) used standard diameter classes with breaks every 10 inches. Under these definitions, LSOG stands are dominated by trees 20 inches in diameter and larger. In addition, FEMAT and FSEIS definitions distinguish stands with one canopy layer from stands with two or more canopy layers. Determining canopy layers from remotely sensed information may be impossible (Cohen and Spies 1992), but simple canopy structure (even upper canopies with relatively uniform crowns and few canopy breaks) can be distinguished from complex structure (uneven canopies with variable crown sizes and common canopy breaks).

Forest classes interpreted from remote sensing—The effectiveness monitoring plan uses nine forest class strata that can be combined into 16 forest vegetation mapping units (table 1). These classes parallel those in the FEMAT report and the FSEIS, except as noted below:

Potentially forested—Land with tree canopy cover less than 10 percent. Ten percent canopy cover is a long-established standard for distinguishing forested from nonforested land. This class is restricted to lands that have been forested recently and that likely will be forested again in the near future, but where trees cannot be detected in imagery. This class is in addition to those specified by FEMAT and the FSEIS.

Seedling and sapling forest—Land with average dominant and codominant tree diameters between 0 and 10 inches.

Small single-storied stands—Land with average dominant and codominant tree diameters of 10 and 20 inches and simple canopy structure.

Medium to large single-storied stands—Land with average dominant and codominant tree diameters between 20 and 30 inches and simple canopy structure. These stands qualify as late-successional forest.

Medium to large multistoried stands—Land with average dominant and codominant tree diameters between 20 and 30 inches and complex canopy structure. These stands qualify as late-successional or old-growth forest.

Large multistoried stands—Land with average dominant and codominant tree diameters of 30 inches or more and complex canopy structure. These stands qualify as late-successional or old-growth forest. This class, which is in addition to those specified by FEMAT, separates stands that are more likely to be optimum habitat for LSOG-dependent species.

Conifer, deciduous, and mixed stands—Each of the forested land classes above will be assigned one of three categories: conifer dominated (hardwood canopy tree cover less than 20 percent of total tree cover), deciduous dominated (conifer canopy tree cover less than 20 percent of total tree cover), and mixed (conifer and hardwood canopy tree cover are both more than 20 percent of total tree cover). These classes are in addition to those specified by FEMAT and the FSEIS.

Plant communities—To deal with FEMAT specifications that the acreage and variety of plant communities are important characteristics of LSOG, land will be additionally stratified by potential vegetation series (Vegetation Strike Team [1995] standard) at the province scale. If series maps are not available for California, Society of American Foresters (SAF) cover type will be used. This stratification is called plant community in this document.

Stand-scale definitions—The FEMAT report also discusses the structure and composition of LSOG forests at the stand scale. The four major structural elements are live old-growth trees, standing dead trees, fallen trees or logs on land, and logs in streams (FEMAT 1993: 28, 29; Franklin et al. 1981). Additional important elements typically include multiple canopy layers, smaller understory trees, canopy gaps, and patchy understory. Structural characteristics of old forests differ with vegetation type, disturbance regime, and developmental stage. Structural and compositional characteristics differ among physiographic provinces, so standards and guidelines intended to promote the desired conditions also will differ. A partial set of stand-scale definitions of old-growth conditions is available for USDA Forest Service lands in Washington, Oregon, and California (USDA Forest Service 1992, 1993b). These definitions continue to evolve and currently cover only part of the Forest Plan area. Additional research is needed on definitions or descriptions of LSOG across the region (see "Research Needed" below). Note that "old growth" is a subset of LSOG as defined by FEMATand the FSEIS. The large multistoried forest class closely represents old growth (Franklin et al. 1981), and the medium large single-storied and medium large multistoried classes represent mature forest conditions. As defined by FEMAT and the FSEIS, LSOG includes mature and old forests. Because site-scale permanent plots measure stand-scale features upon which old-growth definitions are based, they may provide a more reliable estimate of the total area and kinds of LSOG than will remote sensing analysis. Field plots unfortunately cannot adequately address large landscape spatial distribution issues.

Monitoring Questions

A set of monitoring questions focuses on important LSOG characteristics that will result from implementing the Forest Plan. Each includes a subset of questions related to measurable characteristics of LSOG forests described in the ROD (USDA and USDI 1994b), FSEIS (USDA and USDI 1994a), and FEMAT (1993).

What are the distribution and amount of forest classes, including LSOG, at the large landscape scale?

What are the distribution (map) and amount (acreage) of forest classes from remote sensing information for the region? For the region by land management allocation? Within each province by plant community (potential vegetation series [Pacific Northwest Region] or SAF cover type [Pacific Southwest Region])? Within each province by plant community and land management allocation?

What is the amount (acreage) of forest classes from stand-scale (permanent grid plot) samples for Federal lands in the region? For the region by land management allocation? Within each province by plant community (potential vegetation series [Pacific Northwest Region] or SAF cover type [Pacific Southwest Region])? Within each province by plant community and land management allocation?

What are the structure and composition characteristics (for example, tree diameter distribution, snags, and down woody debris) of forest classes from stand-scale samples for each stratum?

How much have the structure and composition characteristics changed since the last measurement cycle? How much are they likely to change in the foreseeable future?

What is the error associated with these estimates?

Are trends within expectations derived from the FSEIS and FEMAT reports?

What are the stand-size distribution, stand interior area distribution, and interstand distance distribution of LSOG at the large landscape scale?

For the region as a whole? For the region by land management allocation? For each province? For each province by land management allocation? For each province by plant community? For each province by plant community and land management allocation?

What is the error associated with these estimates?

How have these attributes changed since the last measurement cycle? How much are they likely to change in the foreseeable future?

Is the trend within expectations derived from the FSEIS and FEMAT?

What changes are produced by stressors in distribution and amount of forest classes, starting with the year of the FEMAT analysis (1993), from stand-scale data?

What are the gains from growth and succession?

What are the losses from logging, fire, wind, insects, and disease?

What are the ramifications of these changes to future trends, especially in LSOG classes?

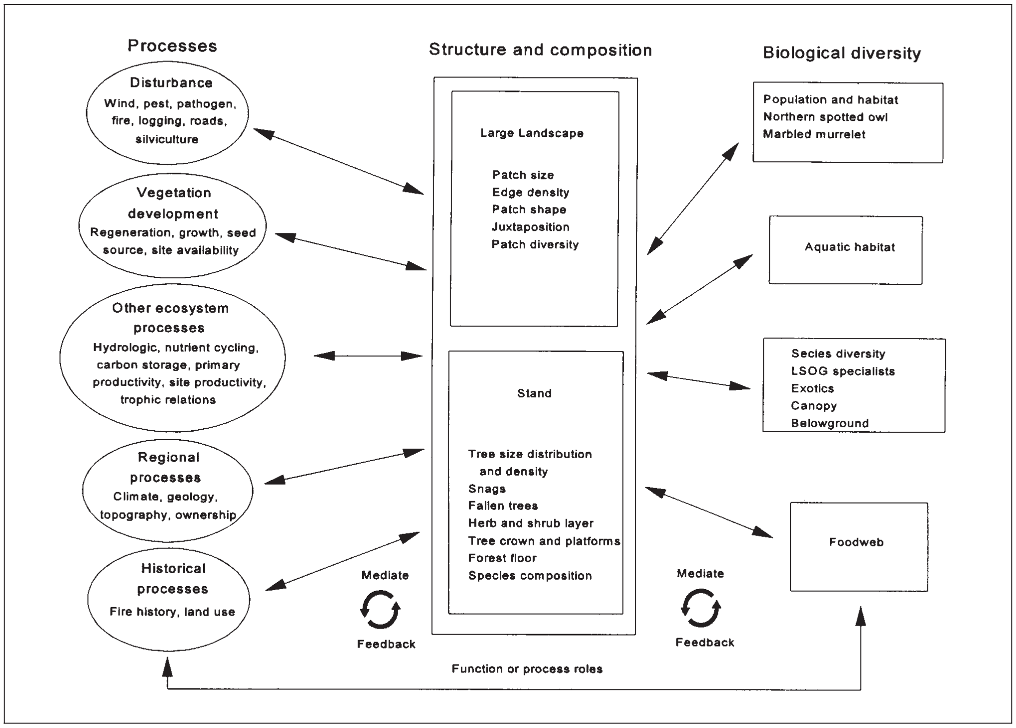

Figure 2—Conceptual model of late-successional and old-growth forest effectiveness monitoring plan.

For the region as a whole? For the region by land management allocation? For each province? For each province by land management allocation? For each province by plant community? For each province by plant community and land management allocation?

What are the effects of silvicultural treatment and salvage on the development of LSOG structure and composition at the stand scale?

Because these attributes must be sampled at the stand scale by using a different set of plots (treated versus control or case study experimental plots), this regional and provincial-scale effectiveness monitoring plan does not provide a sampling or analysis scheme.

Is the relation of forest structure and composition (in stands at various ages and at multiple scales) to ecological processes and biological diversity assumed by FEMAT, the FSEIS, and the conceptual model (fig. 2) accurate?

This is a validation monitoring question not addressed in this effectiveness monitoring plan. It is included as a reminder for those developing a validation monitoring plan. It also helps distinguish effectiveness monitoring from validation monitoring while establishing a link between them.

Monitoring Approach

Stressors

Change agents and dynamic factors that may alter the amount, distribution, structure, and composition of LSOG forests at regional and provincial scales include a variety of disturbance elements. The following list is not complete, but includes major change agents. Other elements also stressing LSOG structure and composition (for example, air pollution, and global climate change) will not be considered because their effects are difficult to assess accurately.

Human development and use—Human use changes LSOG through a wide variety of mechanisms (for example, timber harvest, recreation, mining). Such changes may or may not be discernible in Landsat thematic mapper (TM) and other remotely sensed information, but they will be detectable at the stand and site scales.

Fire—Wildfire and prescribed fire can cause significant changes in the amount, distribution, structure, and composition of LSOG. Fire can play many roles, ranging from stand replacement to slight alteration of understory structure and composition. Fire causing complete or partial stand replacement has effects that should be visible at large landscape scales. Underburns may not produce visible change at large landscape scales but may generate significant changes at the stand scale through changes in understory vegetation and the generation and composition of dead standing trees and logs.

Insects and pathogens—Insect outbreaks and pathogen epidemics can play a role similar to fire, though effects generally are more selective and of finer scale, especially on the west side of the Cascade Range. Changes range from stand replacement (rarely) to mortality of selected species and size classes within species. Effects may be hard to detect from Landsat TM data but may be visible from other remote sensing platforms. Insects and pathogens often generate considerable dead and down woody structure in stands and may actually move stands farther along the successional continuum.

Wind—Wind can have effects similar to those of fire, including partial to complete mortality of the overstory canopy. Severe blowdown often results in releases of understory vegetation from shade and competition, resulting in changed canopy structure and composition over time. Wind effects often are difficult to detect in Landsat TM data because they tend to be patchy and partial.

Growth, regeneration, and succession—Although these processes are not generally considered stressors, they do produce changes in the amount, distribution, composition, and structure of LSOG forests. They tend generally to reduce fragmentation, interstand distance, and edge while increasing stand size, stand structure, and connection. At one extreme, in late-seral forests, succession can cause a decline in composition and structural diversity as stands lose long-lived, early seral species and move to climax condition. This circumstance is rare, however, given the time required and rates of disturbance. Analysis of early seral stages and projections of growth will be necessary to project trends.

Exotic species—Some exotic species are highly competitive or pathogenic and could have long-term effects on LSOG.

Required Information

The LSOG effectiveness monitoring plan uses data and information from several sources, including permanent grid plot data and remotely sensed information. Remotely sensed information on potential vegetation and existing vegetation structure and composition, summarized in remotely sensed forest classes, above, is key. If permanent grid plots or map information on existing and potential vegetation are not developed or maintained as planned, this LSOG effectiveness monitoring plan cannot be implemented as designed.

Information on stressors (see below) and models that project both stand and large landscape development of forest classes also are required.

Plan Components

The LSOG effectiveness monitoring plan includes analysis of large landscape-scale and stand-scale indicators of amounts and distributions of LSOG and stressors that might alter amounts, distributions, and trends of LSOG; it also provides links to analysis of silviculture and salvage effects at stand scales (fig. 3).

Conceptual Model

The conceptual model (fig. 2) for LSOG effectiveness monitoring relies on the structure and composition of stands, from large landscape to stand scales, as intrinsic parts of and reasonable indicators of process, function, and biological diversity. This model presumes that structure and composition both influence and are influenced by process and function (Edmonds et al. 1989, Franklin et al. 1989, Peterken 1996, Spies and Franklin 1988). For example, disturbance processes change stand- and landscape-scale structure and composition by killing trees, changing amounts of snags and down woody debris, and changing stand size and shape (Forman and Godron 1986, Morrison and Swanson 1990). Stand size and shape influence the spread of disturbances across the landscape because some kinds of stands transmit the disturbance more readily than others (Turner et al. 1989, White 1979). Stand structure and composition also influence disturbance; some stand conditions are usually more favorable to the generation and spread of particular disturbances than others (Turner et al. 1989). Certainly, changes in composition, structure, and landscape pattern can influence ecological process and function (Allen and Hoekstra 1992, Spies and Franklin 1996, Turner 1989), and changes in structure and composition may indicate changes in underlying process and function. This conceptual model is implicitly stated in FEMAT (1993: 36): “In many respects, the test of providing a functional, interacting late-successional and old-growth forest ecosystem subsumes the test of viability for the system’s component species and groups of species.” From this perspective, the structure and composition of vegetation at large landscape and stand scales is a reasonable indicator of the processes, functions, and diversity of ecological systems (fig. 2). This conceptual framework may apply most clearly to plants. Measures of viability for some individual species of plants and animals, especially the northern spotted owl and marbled murrelet, will need to be monitored (see Lint et al., in press; Madsen et al., in press).

A similar relation exists between structure and composition, and biological diversity. Species diversity is the biological foundation on which structure and composition are built. In turn, structure and composition determine habitat conditions that may support species diversity. This feedback loop is highly complex. Certainly, changes in structure and composition of forest stands indicate direct changes in biological diversity and may indicate habitat alteration and change in the composition of associated species. Relations of many wildlife species to habitat in Douglas-fir (*Pseudotsuga menziesii* [Mirbel] Franco) dominated forests are summarized by Ruggiero et al. (1991).

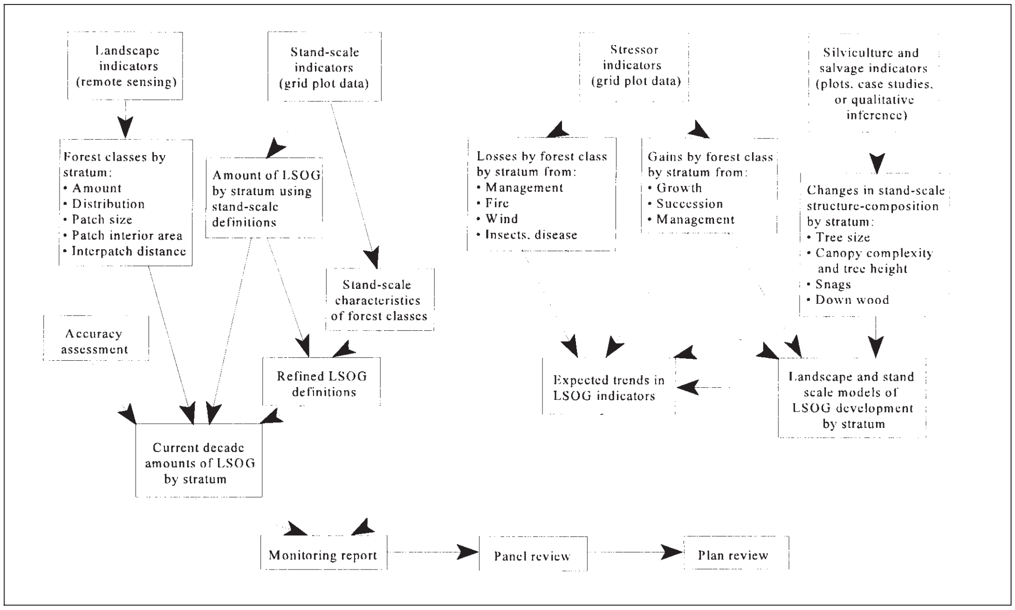

Figure 3—Components of the late-successional and old-growth forest effectiveness monitoring plan.

The relation between biological diversity and structure has been a major focus of ecology for the last 30 years. In general, two major classes of functional factors determine the biological diversity in a given large region. The first is the amount of energy that the ecosystem can capture, which in turn is governed by latitudinal variation in solar radiation and a host of climatic and soil factors (often called site quality by foresters) that affect carbon fixation and primary productivity. The second major class is structure: structure is defined as the physical arrangement of objects in three-dimensional space and their complexity. Much of the recent work on the relation of structure and biological diversity is summarized by Bell et al. (1991), who consider structure as having three components: scale, heterogeneity, and complexity. In a general way, all these components are related to biological diversity, but the details in any particular ecosystem can be very different.

Structure depends on spatial scale and can be described at any scale in the biological hierarchy, but it may have different associations and correlations with biological diversity at each scale; for example, at the scale of biomes, mammal species richness in the United States is strongly correlated with topographic relief: more species live in mountainous areas. At the opposite end of the spatial scale, the number of lizard species on a single tree is well correlated with canopy complexity: trees with more complex canopies have more species. At the scales of stands and large landscapes, which are the foci of LSOG effectiveness monitoring, general relations exist between vegetation structural complexity and bird species diversity. Perhaps the best known of these relations is between foliage height diversity and bird species diversity first described by MacArthur and MacArthur (1961). In these studies, a correlation was found between the number and evenness of layers of vegetation in a canopy and the number of bird species and the evenness of distribution of individuals among those species. A general summary of most work is that structural complexity and heterogeneity are positively correlated with diversity for many groups of organisms.

Studies of the Pacific Northwest's Douglas-fir and western hemlock *(Tsuga heterophylla* [Raf.] Sarg.) forests show that the general pattern holds at both the landscape and stand scales. Hansen et al. (1995) show that, at the landscape scale, greatest diversity results from a mix of successional stages each with a different canopy structure. Some bird species, for example, prefer open clearcuts while others prefer LSOG forests. Thus, a diversity of stand types including an important component of LSOG promotes diversity at the landscape scale. These different stand types and the changes in their distribution can be estimated relatively accurately from remotely sensed imagery. At the stand scale, greater canopy structural complexity is correlated with a great abundance in some bird species. Further, the response of the abundance of some bird species is nonlinear, with a distinct threshold (Hansen et al. 1995); that is, as structural complexity increases, a point is reached where abundance for LSOG associated species increases dramatically. These results are species specific in the shape of the relations, in thresholds that may exist, and in possible causal factors. Results from other groups of organisms are lacking, but all indications are that the Pacific Northwest forests roughly follow this general pattern. Stand structure thus should be a useful indicator of biological diversity. Further, Cohen and Spies (1992) found that stand structural differences of a kind related to biological diversity can be estimated with remotely sensed data and in particular with Landsat TM data, which means that the detection of change of an important biological diversity indicator is logistically feasible.

Indicators

Indicators developed in this effectiveness monitoring plan hinge on the relation of structure and composition to ecological system process and function and to biological diversity (fig. 4). Four kinds of indicators are considered: (1) large landscape-scale indicators that can be addressed through analysis of remotely sensed imagery, (2) stand-scale indicators that can be addressed through analysis of field plots, (3) change agent indicators, and (4) stand-scale silviculture and salvage effect indicators. This list is a starting point, based on existing knowledge. Future indicator development will follow the process described in the overall effectiveness monitoring plan (Mulder et al., in press).

Large Landscape-Scale Indicators

Several indicators for large landscape-scale LSOG distribution can be estimated and summarized.

Amount—The acreage of land meeting forest class definitions will be estimated by physiographic province by plant community and land management allocation.

Distribution—The distribution of land by forest class will be depicted in a map, which for some analyses will be a polygon map with attributes and for others will be a pixel map.

Stand size—The areal extent of stands of vegetation that meet tree size and canopy layering criteria for LSOG forest classes will be analyzed from remotely sensed imagery. The unit of measure is acres. Stands will be aggregates of pixels from remotely sensed images. A frequency distribution or cumulative distribution function will display the abundance of stands by size; be stratified by region, province, and plant community; and be stratified by physiographic province, plant community, and land management allocation.

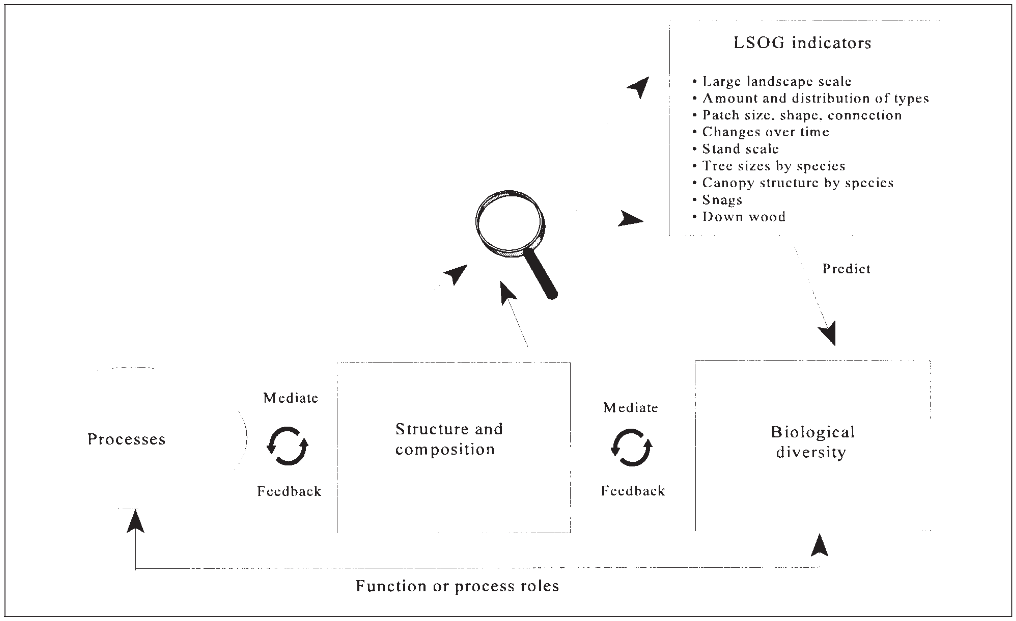

Figure 4—Late-successional and old-growth forest effectiveness monitoring plan indicators.

Stand interior area—Indices of stand shape (edge to area, fractal dimension, and so forth) often are hard to relate to specific habitat issues. Interior core area of stands, after sharp edges are buffered, will be used as an index of stand shape. Interior core area will be analyzed from remotely sensed data by using a buffer of 330 feet from LSOG edges with nonforested and small, single-storied forest classes. Other edge conditions may be analyzed, if needed. Chen et al. (1992) found edge effects extending more than 1300 feet in some cases. Most effects seem to occur within 330 feet, however. Edge effects will be projected into LSOG stands from potentially forested and seedling and sapling forest classes. Stands of the small single-storied forest class are likely tall enough to substantially reduce or eliminate microclimatic edges that might extend into LSOG stands. It may be necessary to analyze stand interior area given other edge effect distances. Pixel data will be available for analysis, because some species find appropriate habitat in much smaller stands. A frequency distribution or cumulative distribution function of stand interior area will be produced for the region; for each province by plant community; and by province, plant community, and land management allocation.

Interstand distance—The distance between LSOG stands for the region and for each province by plant community will be displayed in a frequency distribution or cumulative distribution function. A frequency distribution or cumulative distribution function of interstand distances will be produced for the region; for each province by plant community; and by province, plant community, and land management allocation.

Stand-Scale Indicators

Stand-scale structural and compositional attributes will be summarized from permanent grid plots and compared with LSOG definitions. Comparison of grid plot data with remotely sensed information will allow development of statistical relations between remotely sensed and stand-scale definitions of LSOG (Czaplewski and Catts 1992). The following attributes will be analyzed.

Amount—This is the forested area that meets forest class definitions and ground-based definitions of LSOG (for example, USDA Forest Service 1992, 1993b) by stratum. In addition, the amount of forested area that meets other indicators of old-growth characteristics will be estimated as new descriptions of old growth evolve.

Stand-scale structure and composition—The stratumwide averages and variation for the stand-scale structural and compositional characteristics given below will be calculated for each LSOG definition used at the stand scale by physiographic province and plant community.

The following attributes should be summarized for each grid plot to provide data for analysis of stand-scale LSOG amount and structure.

- **Tree diameter class distribution by species, per acre**. The diameter class distribution of all trees, and of selected species, separately, in all the permanent grid plots within each province, plant community, LSOG class, and land management allocation stratum.
- **Canopy structure and height class distribution by species, per acre**. The height class distribution of all trees, and of selected species, separately, in all the permanent grid plots in each province, plant community, LSOG class, and land management allocation stratum. Tree height distributions can be used to separate single-storied and multistoried stands.
- **Snag (standing dead tree) height and diameter distribution by species, per acre**. The height class distribution by decay class and diameter class distribution will be determined for snags in all the permanent grid plots within each province, plant community, LSOG class, and land management allocation stratum.
- **Down woody debris (fallen trees), per acre**. Tons, linear feet, and pieces per acre of down wood by diameter class and decay class in all the permanent grid plots in each province, plant community, LSOG class, and land management allocation stratum.

Other attributes that may be useful for characterizing LSOG will likely emerge from research on stand-scale characteristics, ecological process, and function. Stand age, where it can be determined, may be important for some species (Halpern and Spies 1995). Ongoing research indicates that the spatial arrangement of structure at the stand scale may be important for old-growth function.[1] The existing permanent grid plot design does not track spatial distribution of trees, snags, or down wood. There may be a need to add this to a subset of permanent grid plots.

Change-Agent Indicators

Change agents that alter remotely sensed forest classes will be tracked from both remotely sensed information and permanent grid plot data. Remote sensing will allow detection of changes in amount and distribution of forest classes and of changes in stand size, stand interior area, and interstand distance for LSOG classes. Remotely sensed information will not generally allow determination of the change agent, except

[1] Personal communication. 1997. Jerry Franklin, professor, University of Washington, College of Forest Resources, Seattle, WA 98195.

possibly for timber harvest and large, intense fires. Most information about change agents will come from examining permanent grid plots. Data recorded on each grid plot include causes of tree damage (such as fire, logging, insects, and disease). These data will be summarized by stratum to provide a summary of the sources of change from mortality or loss.

Increases in area of remotely sensed forest classes are generally caused by growth and succession. Overall increases in amounts, distributions, and large landscape patterns will be depicted and analyzed from remotely sensed information. Change in LSOG amounts and spatial distribution as detected in remotely sensed images also can come from changes in methods used to process remotely sensed data. It will be important to quantify changes in spatial attributes due to methods alone. However, the inherently variable nature of interpreting remotely sensed information produces apparent change that must be examined by a professional panel or workshop that uses the analyses and reports developed in the monitoring process. In this sense, remotely sensed information about LSOG attributes is less statistically reliable than information from permanent grid plot remeasurement.

Large landscape change indicators—

- Change in amount and distribution by forest class and stratum
- Change in stand size distribution, stand interior area, and interstand distance by LSOG class and stratum
- Change in amount, distribution, stand size, stand interior area, and interstand distance due solely to change in remote sensing interpretation and analysis methods

Stand change indicators—

- Amount of forested area in each stratum that has changed forest class as a result of human use (for example, logging), fire, wind, insects, disease, including transitions among forest classes by change agent and stratum
- Amount of forested area that has changed forest class as a result of growth or succession including transitions by forest class and stratum

Predictive Models

Forest growth and development can be projected in the grid plot data by using stand growth simulation models. Models can project growth trends for each forest class by stratum. Current growth models unfortunately are oriented toward tree growth and volume (and not well calibrated for stands beyond age 100) or toward detailed stand succession models that may not work well for large landscapes. Models will have to be calibrated for each stratum (see “Research Needed” below).

Stand-Scale Silviculture- and Salvage-Effect Indicators

The ROD (USDA and USDI 1994b: app. C, p. 12) allows silvicultural (such as thinning, under planting, prescribed fire, and killing trees to produce snags or down woody debris) and salvage activities in late-successional reserves, as long as treatments benefit, or at least do not retard, development of late-successional forest conditions. For the most part, these activities are confined to younger stands within late-successional reserves. The set of attributes listed above (tree diameter class distribution, canopy structure and tree height, snag height and diameter, down woody debris amounts) could be analyzed to track changes in structure and composition in stands manipulated by silvicultural or salvage activities. Tracking these elements at the stand scale over time will test the effectiveness of silvicultural and salvage activities in maintaining or enhancing LSOG stand-scale attributes. Because these attributes must be sampled at the stand scale by using a different set of plots (treated versus control experimental plots or case studies), this regional- and provincial-scale effectiveness monitoring plan does not provide a sampling or analysis scheme. Each province should develop a sampling plan that uses the stratifications developed in this plan to allow aggregation of results. Minimum attributes to be sampled or studied should include those listed above, though others may be added as necessary. Sample areas might be drawn at random from sites chosen to monitor Forest Plan implementation. This is an adaptive management process that should provide feedback from management experiments to future management activities.

Data Acquisition Methods

Large Landscape-Scale Indicators

Amount, distribution, stand size, stand interior area, and interstand distance of forest classes will be analyzed from maps and data derived from remotely sensed images. Remote sensing analyses and processes exist for producing map data in polygon and raster form and for preparing accuracy assessments. Mapping standards identified by the Vegetation Strike Team (1995) are more detailed than needed for this analysis and can be simplified through aggregation into the required stratification, including physiographic provinces, forest classes, and plant communities. Forest classes will include at least those called for in FEMAT (1993: 49-50) and the ROD (USDA and USDI 1994b) for characterizing LSOG forests. Analysis of earlier seral stages will be necessary to estimate future trends, hence the addition of earlier seral stage land classes. A forest class with dominant trees more than 30 inches in diameter was added because many LSOG-dependent species find optimum habitat in stands with large trees.

The minimum polygon size required by the Vegetation Strike Team (1995) standards (2 acres) is smaller than feasible for large landscape-scale LSOG analysis. Ten acres seems a reasonable minimum polygon size for stand analysis, as it allows for some interior core area with an edge effect of 330 feet. Polygons will be lumped to a minimum of 10 acres. It may be necessary to analyze smaller stand sizes.

Stand-Scale Indicators

The diameter of trees below the emergent canopy, tree heights, snags, and down wood cannot be reliably estimated from remotely sensed data, but they have been sampled on a grid of permanent plots. Measurement errors on permanent grid plots are known from a remeasurement of randomly selected plots (Max et al. 1996). Stand-scale attributes will be characterized from grid plots falling in each stratum. The 3.4-mile grid is the common, minimum grid plot density across Federal lands in the Forest Plan region. Some areas may have grid plots at higher density (1.7 miles and 0.85 mile between plot centers). These plot data will be included where they are available.

Change-Agent Indicators

Maps and databases derived from remotely sensed information will be analyzed for changes in amounts, distributions, and large landscape patterns of forest classes. These data are the same as needed for large landscape-scale indicators. Change due to different remotely sensed data analysis methods in subsequent time steps will be quantified.

Grid plot information will be analyzed for changes in forest class by stratum. Stand development or succession models (for example, Forest Vegetation Simulator) will be used to project growth and development. Data needed are the same as for stand-scale indicators.

Silviculture- and Salvage-Effects Indicators

This regional and provincial monitoring plan does not develop a sampling scheme for stand-scale silviculture or salvage effects. Large local variation in silviculture and salvage treatment kind and intensity make sampling stratification at the regional and provincial scales difficult. Sufficient numbers of permanent grid plots are unlikely to fall in areas treated by silvicultural manipulation or salvage logging to characterize effects of silviculture and salvage activities on LSOG attributes. Monitoring the effects of silviculture and salvage treatments on the development of LSOG forests should begin as soon as possible, however. The following discussion provides links (common attributes, sampling schemes, and stratifications) that can help tie results of silviculture and salvage monitoring to regional and provincial effectiveness monitoring.

Minimum attributes to be measured include those necessary to use existing and emerging old-growth definitions (tree diameter class distributions, canopy structure and tree height class distributions, snag height and diameter class distributions, and down woody debris amounts). Over several decades, remotely sensed images and grid plot data may begin to show the effects of these treatments. In the nearer term, stand growth models can be used to predict trends in stand structure and composition given measured plot data and silvicultural treatment. Stand growth models could be used to predict development patterns on different sites, which could be used to guide the location of field sample plots to cover the variability displayed in models. The field units (National Forests, Bureau of Land Management [BLM] Districts) will have to develop a statistically reliable process for selecting manipulated and control stands for sampling, by using the provincial, plant community, and forest class stratification provided in this effectiveness monitoring plan as a starting point. Finer stratifications may be necessary for field unit purposes, but results should be aggregated to the strata proposed in this plan. Administrative studies may be required.

Several possible sampling schemes exist for documenting the effects of silvicultural and salvage treatments at the stand scale. Two general approaches could be taken. A statistical design could be developed that would provide reliable, quantitative information. Alternatively, qualitative information could be developed. The following sample designs illustrate possibilities within a range of statistical robustness and attendant cost. These designs are merely examples to illustrate possible ranges of effort, cost, and information reliability. They are not suitable for implementation without additional study and refinement. The Regional Inventory Advisory group, which has assisted in designing the permanent grid plot system, could help establish a sampling design, once decisions have been made about the degree of statistical reliability needed and the items to be sampled. It might be possible to select control and manipulated plots from those selected for Forest Plan implementation monitoring.

- **Establish a randomly selected set of permanent plots and controls in stands manipulated by silvicultural and salvage treatments that are stratified by province, plant community, and treatment type.** Plots should be selected at random before treatments are applied. Treatment should be applied to one of either the control or treated pair at random. The sample design for this alternative could become huge. The 12 physiographic provinces each have 4 to 10 or more plant community strata and many possible kinds of silvicultural and salvage treatment. Each sample unit would consist of a treated plot and an untreated control. Here is a simple scenario: in each of the 12 provinces, five plant communities would each receive four management treatments (two rates of removal from silviculture and salvage). Each combination would be sampled 10 times, yielding a total of 2,400 sample plots. The addition of 10 untreated controls per stratum would add another 600 plots, bringing the total number of sampled plots to 3,000. The number of plots could easily be much higher if stand age or structural condition before treatment were an additional stratification criterion. This process would allow statistical analysis of whether treated stands differ from control stands in meeting old-growth definitions and providing LSOG structures by stratum.

- **Establish fewer plots in a stratified random sample design of less complexity**. Strata might include physiographic province and general treatment type (precommercial thinning, commercial thinning, and others as appropriate). A set of treatment and control plots could be established for a reduced stratified random sample design, which might distribute treated and untreated pairs of plots by physiographic province. This design would be considerably less expensive and time consuming to install than the one above. For example, 10 pairs of treated and untreated plots might be selected at random from areas used for Forest Plan implementation monitoring across the 12 physiographic provinces, producing a sample of 240 plots. This design would not allow separation of effects by province, plant community, or kind of treatment, but would allow statistical analysis of whether treated stands differ from control stands in meeting old-growth definitions and providing LSOG structures.

- **Establish a set of case studies to examine the effects of various silvicultural or salvage treatment intensities**. Ongoing studies of stand growth and development should be examined for opportunities to track the development of LSOG after treatment. If appropriate sites are available, a time series might be established that allows retrospective analysis of treatments. This would shorten the lag time in producing results. No statistical analyses would be possible. This design would not allow separation of effects by province, plant community, or kind of treatment. No quantitative extrapolation of results would be possible. Qualitative inferences could be provided.

Detecting Change and Trend

Large Landscape-Scale Indicators

Several ways of organizing change and trend detection in LSOG large landscape-scale attributes are possible. Generally speaking, the more confidence needed in the reality of apparent change, the more costly the process. Because the state of remote sensing science continues to evolve, analysis at each subsequent time step likely will involve different techniques and result in apparent change in LSOG from changes in methods alone. To account for changing methods, both old (previous time step) methods and new methods will be applied at each time step, thereby producing an estimate of change due to methods alone.

Stand-Scale Indicators

The permanent grid plot system is designed for systematic remeasurement. This process will provide measurements with known measurement error for LSOG elements on the plots. Change detection and rates of change can be quantified with known reliability for the stand-scale indicators.

Change-Agent Indicators

Maps and data derived from remotely sensed information will be analyzed for changes in amounts, distributions, and large landscape patterns for forest classes. These data are the same as needed for large landscape-scale indicators.

Changes in remotely sensed LSOG attributes may be due to changed remote sensing interpretation or analysis methods. If remote sensing interpretation or analysis methods have changed from the previous time step, two analyses will be performed. The new remotely sensed data will be analyzed by using procedures from the previous time step and the new procedures. Differences in spatial attributes due to new methods will be quantified for each spatial element (amount, stand size, stand interior area, and interstand distance) for each stratum.

Grid plot information will be analyzed for changes in forest class by stratum. Stand development or succession models (such as the Forest Vegetation Simulator) will be used to project growth and development. Grid plot data needed are the same as for stand-scale indicators.

Silviculture- and Salvage-Effects Indicators

Plots established to track the effects of silvicultural and salvage treatment should be permanently marked and remeasured periodically to allow updates in conditions and trends. Standard methods, used on permanent grid plots or in stand exams, should be used. Stand development or succession models will be used to project growth and development.

Expected Values and Trends

FEMAT (1993: 49-53) and the FSEIS (USDA and USDI 1994a: 36-43) provide a beginning basis for thresholds. They discuss abundance and ecological diversity, process and function, and connectivity outcomes for LSOG. Thresholds provided in these documents are general, regionwide, and apply only to Federal lands. Outcomes in FEMAT and the FSEIS link to the likelihood of maintaining both the viability of LSOG-related species (FEMAT 1993: 28) and the likelihood of maintaining a functional, interacting LSOG forest ecosystem on Federal lands (FEMAT 1993: 25).

The following discussion translates outcomes supplied in FEMAT and the FSEIS into thresholds against which change can be evaluated. The outcomes were used to help rank alternatives considered in the FSEIS and ROD (USDA and USDI 1994b). Alternative 9, which was chosen with slight modification in the ROD, was among the more highly ranked of the alternatives in terms of the probability that its implementation would produce a functional, interacting LSOG forest ecosystem on Federal lands. Alternative 9 has a 75-percent, or better, chance of providing abundance and diversity, process and function, and connectivity within the long-term average conditions in the moist physiographic provinces over the next 100 years (USDA and USDI 1994a: 44; table 2). All the alternatives were more likely to produce functional, interacting LSOG forest ecosystems in the moist physiographic provinces (Washington Olympic Peninsula, Washington Western Lowlands, Washington Western Cascades, Oregon Coast Range, Oregon Willamette Valley) than in the intermediate and dry physiographic provinces (Oregon Western Cascades, California Coast Range, Washington Eastern Cascades, Oregon Eastern Cascades, Oregon Klamath, California Klamath, California Cascades).

The FEMAT report (1993) and the FSEIS (USDA and USDI 1994a: 43) do not project reaching these outcomes for a considerable time, because it takes decades or centuries for young stands to develop into LSOG. Changes in the first several decades should be projected for 100 years or more to evaluate likely outcomes. FEMAT and the FSEIS provide some initial estimates of long-term trends. These initial estimates should be improved with a more comprehensive large landscape-scale stand-

Table 2—Likelihood of achieving a functional, interacting late-successional and old-growth forest ecosystem on Federal lands for alternative land management strategies considered in the Forest Plan

	Moist provinces				Dry provinces			
Alternative	A[a]	P[a]	C[a]	Average	A	P	C	Average
	Percent							
1	86[b]	52	92	77	66	34	76	59
3	92	71	90	85	75	53	78	69
4	93	62	90	82	75	46	76	65
5	80	59	80	73	69	47	66	60
7	66	50	68	62	64	41	51	52
8	69	59	74	68	64	38	53	51
9	76	75	80	77	69	53	66	63

[a] Attributes: A = abundance and ecological diversity; P = process and function; C = connectivity.

[b] Numbers of at least 80 percent represent the likelihood that the given alternative will meet minimum requirements for these attributes.

development modeling effort (see “Research Needed” below). Tracking sources of projected change (for example logging, fire, insect epidemics, and disease) will be important. Although the outcome elements provided in FEMAT and the FSEIS represent the state of science at the time, several are qualitative or difficult to measure. The outcomes from FEMAT and the FSEIS may not reflect current thinking, but they do provide a starting point for analysis.

Long-Term Averages

The FEMAT report (1993) and the FSEIS (USDA and USDI 1994a) call for developing long-term average reference conditions, ranges of LSOG by province and plant community (potential vegetation series).

> Long term is defined as a period of at least 200 to 1,000 years, or the time over which the full potential range of late-successional and old-growth communities can develop following severe disturbance [USDA and USDI 1994a: 36].

The following discussion of presumed long-term average conditions is taken from the FSEIS [USDA and USDI 1994a: 37].

> The long-term average regional abundance of late-successional and old-growth communities can only be approximated from a few local studies of fire history. Assuming that the average regional natural fire rotation was about 250 years for severe fires (those removing 70 percent of more of the basal area), then 60 to 70 percent of the forested area of the region was typically dominated by late-successional and old-growth forests, depending on the age at which “mature” forest conditions develop (assume a range

> of 80 to 100 years). Converting this to a single number, 65 percent, provides an estimate of the long-term average percentage of the regional landscape covered by late successional forest. This average percentage would certainly differ by physiographic province; moist, northerly provinces would have higher averages than drier provinces with higher fire frequencies.
>
> The total percentage of late-successional and old-growth forest would apply to a wide range of stand sizes, from less than 1 acre, to hundreds of thousands of acres. Most of the total percentage (perhaps 80 percent or more) would probably have occurred as relatively large (greater than 1,000 acres) areas of connected forest.
>
> The average centurial-low coverage (average of the lows that occur in 100-year periods) by late-successional forest is defined as setting the lower limit of the “typical” range. There is no data from which to estimate the average low from the preceding millennium. Consequently, this value was estimated based on the subjective opinions of the ecosystem experts. The Forest Ecosystem Management Assessment Team hypothesized that the average low amounts might be about 40 percent coverage by late-successional forests, with lower values expected for individual provinces.

Long-term averages have not been well documented for much of the Forest Plan region. In addition, it is important to recognize expected variation around the average, because a single average condition may never have actually occurred. The following set of thresholds addresses the intent of FEMAT (1993) until long-term averages by province and plant community can be developed. The Forest Plan does not project achieving threshold amounts for at least 100 years because current conditions are substantially below these amounts and stand development takes considerable time. The FSEIS (USDA and USDI 1994a: 43) projects that achieving about half the threshold acres will occur in the first 50 years (fig. 5). Analyses in FEMAT and the FSEIS were preliminary and general. Additional research is needed to refine expected trends. Simple succession models (seral-stage transition models) will be used to project growth from LSOG amounts measured at each monitoring point to estimated 50- and 100-year conditions. Model projections at each monitoring time step should be evaluated against the following thresholds.

Uncertainty

The following thresholds should be used with caution because LSOG forest development takes many decades, long-term reference conditions by stratum are poorly understood, climatic conditions for the long-term average conditions may have been significantly different than they are now, and scientific understanding about forest development and succession is not well developed for many strata. The thresholds provide an indication of the anticipated direction of change in LSOG forests under the Forest Plan. Findings from this effectiveness monitoring plan should be reviewed by a panel of experts from management and science who have full appreciation for the inherent variability in projected trends.

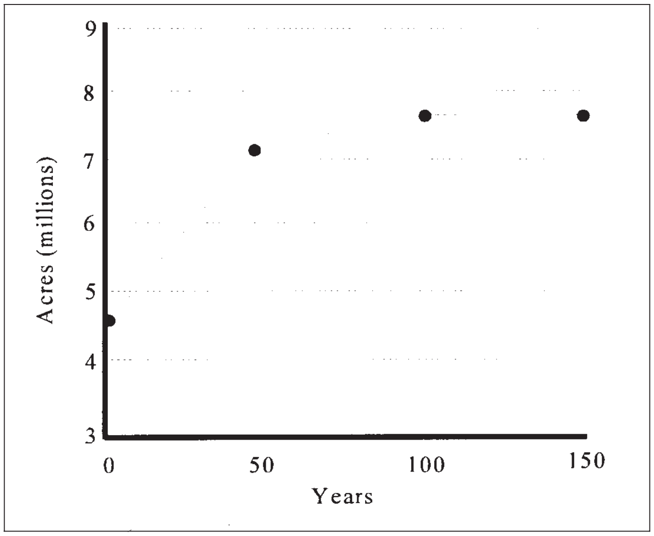

Figure 5—Expected trends in amount of late-successional and old-growth forest after implementing the Northwest Forest Plan for the next 150 years

Abundance and Ecological Diversity Thresholds

These outcomes are from FEMAT (1993: 50 and 51) and the FSEIS (USDA and USDI 1994a: 35-43), with interpretations that allow quantification where possible.

Outcome 1—

> Late-successional and old-growth ecosystem abundance and ecological diversity on Federal lands at least as high as the long-term average...prior to logging and extensive fire suppression....Relatively large areas (50,000 to 100,000 acres) would still contain levels of abundance and distribution of late-successional forests which are well below the regional average for long periods. However, within each physiographic province, abundance would be at least as high as province-level long-term averages, which might be higher or lower than the regional long-term average [USDA and USDI 1994a: 36].

The long-term average proportion of LSOG for the entire Forest Plan area was estimated at 65 percent in FEMAT (1993: 51). Because this criterion is the same as LSOG cover in connectivity (below), the same number (60 percent) was used for outcome for both abundance and connectivity (table 3). Most (more than 80 percent) of the LSOG in the long-term average was assumed to have occurred in large blocks (more than 1,000 acres).

Outcome 2—

> Late-successional and old-growth ecosystem abundance and ecological diversity on Federal lands is less than the long-term conditions (prior to logging and extensive fire suppression) but within the typical range of conditions that occurred during previous centuries [USDA and USDI 1994a: 36].

Late-successional and old-growth is present in all provinces and at all elevations but with larger gaps in distribution than in outcome 1. The average of the low end of the range for LSOG amount in the long-term average was assumed to be 40 percent in FEMAT (1993: 51). The range in amounts under outcome 2 is between 40 and 65 percent. Less than 80 percent of the LSOG would be in stands of more than 1,000 acres (table 3).

Table 3—Outcomes and thresholds for late-successional and old-growth forests used in ranking alternative land management strategies considered in the Forest Plan

Outcome	Land covered by LSOG	Lands in stands of more than 1,000 acres	Provinces meeting both amount and stand size
	- - - - - - - - - - - - -	*Percent* - - - - - - - - - - - - -	- -
1	60 to 100	80 to 100	100
2	40 to 60	5 to 80	100
3	5 to 40	1 to 5	50 to 100
4	less than 5	less than 1	less than 50

Outcome 3—

> Late-successional and old-growth abundance and ecological diversity on Federal lands is considerably below the typical range of conditions that have occurred during the previous centuries, but some provinces are within the range of variability....The ecological diversity (age-class diversity) may be limited to the younger stages of late-successional ecosystems. Late-successional and old-growth communities and ecosystems may be absent from some physiographic provinces and/or occur as scattered remnant patches within provinces [USDA and USDI 1994a: 36].

Amounts of LSOG would be less than the average century lows from the long term (40 percent; FEMAT 1993: 51), but some LSOG would still exist (for example, more than 1 percent of the Federal land area). Less than 80 percent of the LSOG would be in stands of more than 1,000 acres (table 3). The LSOG may be absent from some physiographic provinces or elevations within provinces and occur as scattered remnant stands within provinces.

Outcome 4—

> Late-successional and old-growth ecosystems are very low in abundance and may be restricted to a few physiographic provinces or elevation bands or localities within provinces. Late-successional and old-growth communities and ecosystems are absent from most physiographic provinces or occur only as small remnant patches [USDA and USDI 1994a: 36].

Late-successional and old-growth ecosystems covers less than 1 percent of the Federal lands. Less than 80 percent of the LSOG is in stands of more than 1,000 acres (table 3). The LSOG is absent from most provinces or occurs only as small remnant forest stands.

Amounts of LSOG will be estimated from both remotely sensed and grid plot data. Spatial patterns (stand size) will be analyzed from remotely sensed information. Currently existing LSOG definitions (for example, USDA Forest Service 1992, 1993b) emphasize the old-growth component. Amounts of old-growth, by these definitions, will be less than amounts of LSOG determined from remotely sensed information.

Existing stand-scale old-growth definitions also provide discontinuous answers to whether stands are old growth, while real world structure and composition differ in gradients (Franklin and Spies 1991). Revised indicators of LSOG characteristics at stand scales are needed (see "Research Needed" below).

Process and Function Thresholds

The FSEIS (USDA and USDI 1994a: 38) provides descriptions of process and function outcomes that could result from implementing the Forest Plan.

Outcome 1—"The full range of natural disturbance and vegetative development processes and ecological functions are present at all spatial scales from microsite to large landscapes."

Outcome 2—"Natural disturbance and vegetative development processes and ecological functions occur across a moderately wide range of scales but are limited at large landscape scales through fire suppression and limitation of areas where late-successional ecosystems can develop."

Outcome 3—"Natural disturbance and vegetative development processes are limited in occurrence to stand and microsite scales. Many stands may be too small or not well developed enough to sustain the full range of ecological processes and functions associated with LSOG ecosystems."

Outcome 4—"Natural disturbance and vegetative development processes associated with LSOG ecosystems are extremely restricted or absent from most stands and large landscapes. Most LSOG stands are too small or not well developed enough to sustain the full range of processes and ecological functions associated with late-successional and old-growth ecosystems."

No quantitative criteria are provided in FEMAT (1993), the FSEIS (USDA and USDI 1994a), or the ROD (USDA and USDI 1994b) for process and function thresholds. In the near term, process and function will be assumed to be provided to the extent that ecological abundance and diversity outcomes are met. Thresholds for abundance and ecological diversity will be used. In the first 20 years of implementing the Forest Plan, a series of studies should be undertaken to document the long-term expected amounts of forested lands affected by fire, wind, insects, and pathogens.

Connectivity Thresholds

The following outcomes are from FEMAT (1993: 52) and the FSEIS (USDA and USDI 1994a: 40), with interpretations that allow quantification where possible. Strong relations exist between connectivity and abundance of LSOG, as these are defined in FEMAT and the FSEIS.

Outcome 1—

> Connectivity is very strong, characterized by relatively short distances (less than 6 miles on average) between late-successional and old-growth areas. Smaller patches of late-successional and old-growth forest frequently occur....The proportion of the landscape covered by late-successional and old-growth conditions of all stand sizes exceeds 60 percent, a threshold when many measures of connectivity increase rapidly. At regional scales, physiographic provinces are connected by the presence of landscapes containing areas of late-successional and old-growth forests [USDA and USDI 1994a: 40].

Table 4—Connectivity thresholds for late-successional and old-growth forest used when ranking land management alternatives considered in the Forest Plan

Outcome	Mean distance between stands of more than 1,000 acres	LSOG cover	LSOG stands less than 1,000 acres	Adjacent provinces connected with large LSOG stands
	Miles	*Percent*		*Percent*
1	less than 6	60 to 100	common	100
2	6 to 12	50 to 60	common	100
3	12 to 24	25 to 50	present	less than 100
4	more than 24	less than 25	absent to few	less than 100

Mean distances of less than 6 miles between LSOG stands of 1,000 acres or larger and LSOG cover greater than 60 percent indicate outcome 1 (table 4). Small stands of LSOG (riparian buffers, green tree retention in harvest units, etc.) are common, as indicated by cumulative frequency distributions of LSOG stand sizes. Large LSOG stands connect between adjacent provinces.

Outcome 2—

> Connectivity is strong, characterized by moderate distances (less than 12 miles on average) between large late-successional and old-growth areas. Smaller patches of late-successional forest occur as described in outcome 1. At regional scales, physiographic provinces are connected by the presence of landscapes containing areas of late-successional and old-growth forests. The total proportion of landscape in late-successional and old-growth conditions, including smaller patches, is at least 5[0] percent, so that the late-successional condition is still the dominant cover type (USDA and USDI 1994a: 40).

Mean distances of 6 to 12 miles between LSOG stands of 1,000 acres or larger and LSOG cover greater than 50 percent indicate outcome 2 (table 4). Small stands of LSOG (riparian buffers, green tree retention in harvest units, etc.) are common as indicated by cumulative frequency distributions of LSOG stand sizes. Large LSOG stands connect between adjacent provinces.

Outcome 3—

> Connectivity is moderate, characterized by distance[s] of 12 to 24 miles between large old-growth areas. There is limited occurrence of smaller patches of late-successional forest in the matrix. The late-successional forest is at least 25 percent of the landscape, and the matrix contains some smaller areas for dispersal habitat [USDA and USDI 1994a: 40].

Mean distances of 12 to 24 miles between LSOG stands of 1,000 acres or larger and LSOG cover greater than 25 percent indicate outcome 3 (table 4). Small stands of LSOG occur in matrix lands.

Outcome 4—

> Connectivity is weak, characterized by wide distances (greater then 24 miles) between old-growth areas. There is a matrix in which late-successional and old-growth conditions occur as scattered remnants or are completely absent [USDA and USDI 1994a: 40].

Mean distances of over 24 miles between LSOG stands of 1,000 acres or larger and LSOG cover less than 25 percent indicate outcome 4 (table 4). The LSOG occurs as small remnant stands or is absent in matrix lands.

Baselines

Current Conditions Baseline

Detection of trends depends on a baseline for comparison. Baselines will be established for remotely sensed and stand-scale indicators.

A remotely sensed vegetation baseline for large landscape-scale indicators should be established from vegetation maps used in the FEMAT analysis (1993), from remotely sensed imagery from 1994-95 (the beginning of Forest Plan implementation), or from 1997-98 imagery used in the first monitoring report. Vegetation maps used for baselines could be one of the following:

- **FEMAT vegetation maps.** The vegetation maps used in the FEMAT analysis (1993) are poorly suited for use as a monitoring baseline because they were compiled from a variety of information sources, all using different mapping methods. Future mapping efforts cannot replicate those methods. Changes detected when comparing new maps to the FEMAT maps would contain large and unknown variation due to differing methods alone. The maps exist, however, and could be used if their limitations are recognized.
- **New baseline from 1994-95 imagery.** Baseline vegetation maps could be developed by using 1994-95 remotely sensed imagery. This approach would provide vegetation maps from imagery dating from the beginning of Forest Plan implementation. No attempt would be made to reconcile vegetation maps used in the FEMAT analysis with the new baseline. Although several sources of vegetation maps from this imagery exist, complete coverage of the region does not exist, and methods used in existing work differ.
- **New baseline from 1997-98 imagery**. Baseline maps could be developed from 1997-98 imagery, which will be used in the first monitoring report. In this case, the 1997-98 imagery would be accepted as approximating the conditions at the start of Forest Plan implementation even though some change would have occurred in the 3 to 4 years between the date of Forest Plan implementation and the date of the remotely sensed imagery. No attempt would be made to reconcile vegetation maps used in the FEMAT analysis with the new baseline.

A stand-scale baseline will be established from the permanent grid plots established across the region by the end of 1998. In addition, maps and descriptions of the strata used in the first report (physiographic provinces, plant communities, land allocations) will be archived for future use. These baseline information sets should be housed in a permanent facility, accessible to anyone who needs to use them.

Long-Term Average Baseline

FEMAT (1993: 51) and the FSEIS (USDA and USDI 1994a: 37) call for comparing existing LSOG conditions (amounts, distribution, connection, process, function) to long-term averages and long-term average lows. These are defined as the LSOG conditions in the last several centuries to the last 1,000 years. The FEMAT report and the FSEIS suggest developing this information through fire history studies, stratified by province and plant community, but these studies do not exist for much of the region. An initial attempt, using expert opinion and existing information, was compiled for National Forest lands in Oregon and Washington (USDA Forest Service 1993a). This report could be used as a starting point, but it is not complete. The FEMAT report and the FSEIS provide estimates of long-term average conditions based on expert opinion, but they call for better estimates. This monitoring plan does not require a retrospective analysis of conditions prior to FEMAT for the first report. Analysis of the long-term averages could be used in subsequent reports as research is completed.

Quality Assurance

Accuracy assessments must be performed on any maps used in LSOG analysis to understand the confidence interval associated with any results. Because the 3.4-mile grid plots are independent of vegetation maps (assuming the plots are not used for training sites in developing vegetation maps), they could be used to perform an accuracy assessment of the vegetation map as aggregated for LSOG analysis (Czaplewski and Catts 1992).

To establish a new baseline for LSOG forests, or to compare results with older baseline map information, the imagery used for developing the vegetation map should be of the same date (usually within 2 to 3 months) across the province being analyzed.

Data Analysis and Reporting

Analysis of the large landscape-scale attributes proposed in this effectiveness monitoring plan will be done every 5 years, starting in 1998. After the first measurement cycle and report (1999), updates to forest class maps should be relatively inexpensive and quick. Several other effectiveness monitoring efforts will use these data (for example, northern spotted owl, marbled murrelet, aquatic and riparian, and other monitoring efforts that use forest-vegetation data). This plan assumes remotely sensed information on existing vegetation, sufficient to analyze forest classes defined above, will be available in early 1999 for the entire Forest Plan region.

Grid plot data are collected through standardized efforts, on fixed remeasurement cycles. Grid plots system have been installed for most National Forest lands in the region. The Oregon State Office of the BLM has started installing 3.4-mile grid of plots under the same methodology. It is possible that some other permanent plots on other ownerships could be used (for example, forest inventory and analysis plots) if methodologies are sufficiently similar. This LSOG effectiveness monitoring plan does not propose collection of additional permanent plots. It does depend on the initial installation and systematic remeasurement of the existing permanent grid plots.

Link to Decisionmaking

A report will be generated every 5 years, more often if needed, detailing the status of threshold attributes and their projected 50- and 100-year trends in comparison to FSEIS (USDA and USDI 1994a) expectations (see Mulder et al. [in press] for details of the reporting process for the effectiveness monitoring program). Attributes that depart significantly from projected trends (more than 10 percent) will be highlighted. Attributes that fall below projected trends (LSOG amounts more than 10 percent below projected trends or for which the projected trends fall 10 percent below reference conditions) trigger a variety of actions, ranging from review of stand succession models and mapping methods, to an examination of the Forest Plan and its implementation. Because results may require interpretation, a panel of scientists, managers, and others (as necessary) will review results and develop interpretations and recommendations for regional executives. The agencies will decide how to proceed.

Organizational Infrastructure

This monitoring plan proposes analyses of existing data from permanent grid plots and the availability of existing and potential vegetation maps at the beginning of the LSOG effectiveness monitoring plan analysis period. Plans for implementing those activities have been developed elsewhere and are not reviewed here (for example, Max et al. 1996). Analysis in the LSOG effectiveness monitoring plan of those data will not be extremely expensive or time consuming.

An interagency cooperative geographic information system (GIS) should be put in place as a foundation for analysis. A GIS and database staff of two should be sufficient to do the LSOG effectiveness monitoring analysis. The first report will be the most difficult and time consuming, because methods likely will require some adjustment and finalizing. A pilot LSOG effectiveness monitoring report should be done for a portion of the Forest Plan region to determine methodologies, report formats, and cost estimates.

Estimated Costs

Alternatives

Several possible approaches to collecting the necessary information were considered (appendix B). Alternative approaches for generating a monitoring report include two possibilities (table 5).

- **Analyze grid plot data only**. Make no attempt to analyze large landscape patterns or generate maps. This alternative supposes that either vegetation maps are not available or that a decision is made not to fund additional analyses of those data to produce maps of forest classes. This alternative would allow calculating acres of forest classes by stratum and establishing statistical confidence the estimates. It would not allow analyzing large landscape-scale indicators (LSOG distribution maps, stand size, stand interior area, and interstand distance). Changes in forest classes, including LSOG, could be tracked through remeasurement of the grid plots over time, only in terms of acreage and stand-scale structural indicators.

- **Analyze vegetation maps and grid plots**. Permanent grid plot data would be analyzed as proposed. A baseline forest class map would be compared with the map for the first reporting period. This would provide estimates of change in large landscape-scale LSOG indicators and stand-scale structural conditions. If baseline vegetation map data from 1994-95 imagery are available, quantitative information about amounts, stand-scale structures, and large landscape patterns could be produced. This is the recommended alternative (see appendix B for comparison of alternatives for trend monitoring). Cost estimates for producing the first monitoring report are based on this alternative (table 6).

Costs for remote sensing analysis of large landscape-scale features for the first monitoring report assume that vegetation maps suitable for delineating forest classes and potential vegetation series are available. Costs for producing those maps are not included. Note that the costs for LSOG monitoring are primarily associated with reporting, because the data are collected and managed through other agency programs, such as the Forest Service's current vegetation survey.

Table 5—Costs of alternatives for large landscape and permanent grid plot data for late-successional and old-growth forest effectiveness monitoring

Alternative	Funding and staff needs	GIS database	Total
Grid plots only	$30,000 (1/2 person-year)	$ 5,000	$ 35,000
Vegetation baseline and grid plots	$120,000 (2 person-years)	$20,000	$140,000

Table 6—Proposed costs for LSOG effectiveness monitoring

	Fiscal year		
Monitoring activity	1998	1999	Total
1997 image and grid plot analysis		$140,000	$140,000
Pilot monitoring analysis and report	$40,000		$ 40,000
Trend projection by stratum (for interpretive report)	$30,000	$ 30,000	$ 60,000

Table 7—Proposed implementation schedule for LSOG effectiveness monitoring

	Fiscal year		
Monitoring activity	1998	1999	2000
Build vegetation maps	X	X	
Image and grid plot analysis		X	X
Pilot monitoring analysis and report	X		
Trend projection by stratum	X	X	
Interpretive report			X

Pilot LSOG Effectiveness Monitoring Report

Although the methods used to generate the first monitoring report are not new, the integration of them into one effort needs considerable work. In addition, development of the actual format and character of the first report, which will set the tone for subsequent efforts, will require substantial effort. A pilot monitoring effort and report is proposed to test and refine analysis methods, refine estimates of work and cost, and provide executives with a product on which to base funding decisions.

The cost for a pilot LSOG monitoring effort and report would be about $40,000 in fiscal year 1998. A task for producing an LSOG effectiveness monitoring report has been added to an existing pilot effort (Plumley et al. 1996); the pilot report should be available by fall 1998.

Refined Trend Estimates

The FEMAT report (1993) and the FSEIS (USDA and USDI 1994a) use broad, region-wide estimates of expected trends in LSOG (abundance, distribution, stand interior area, interstand distance). Both recommend analyses to project trends for 100+ years, stratified by province and plant community. Some initial work in estimating expected trends will be necessary to evaluate change. Although this work is listed as a research need (see below), refined trend estimates will be necessary to evaluate results beyond the very broad regional generalization of LSOG amounts provided in FEMAT and the FSEIS. Developing refined trend estimates will take about 1 year and cost about $60,000. After the first analysis, costs will decline substantially because subsequent analysis will require fine tuning rather than model development. This effort should be cooperative, involving research and management.

Implementation Schedule

An implementation schedule illustrates accomplishment of the proposed LSOG effectiveness monitoring effort for the first 3 years of the monitoring program (table 7). Because completion of vegetation mapping is crucial to the effectiveness monitoring effort, a more detailed schedule of work for the first time period, including vegetation mapping, shows the necessary flow of tasks:

Task	Expected completion date
Complete pilot LSOG report	End of fiscal year 1998
Completion of grid plot data processes through 1998	End of fiscal year 1998
Completion of expected trend analysis	End of fiscal year 2000
Provide baseline and initial vegetation maps and data	March 2000
Analysis of large-landscape and permanent grid plot data	Fiscal year 2000
First report (1988-89 to 1998 period)	December 2000
Administrative review of report	Fiscal year 2001

Analyses and reports should be generated every 5 years (table 8). Although changes in vegetation may not be striking over 5-year time intervals, an ongoing monitoring effort with frequent updates to vegetation maps for planning purposes should be developed. This will allow maintenance of skills and organization to perform effectiveness monitoring.

Research Needed

Several issues will require research investment in the near future. Priorities and budgets will have to be established when work plans for these research items are available. Among the most critical research issues are:

- **The use of remotely sensed information to detect forest structure and composition**. In addition, analysis of the sources of error in remote sensing classifications and change detection is needed.
- **Expected rates of transition among forest classes over time (succession models, disturbance models) using plant community and province strata**. Existing models are probably more accurate for transitions and growth in young stands than in LSOG. These models should be calibrated by series to give more accurate predictions. Remeasured permanent grid plot data can be used to help calibrate models, which should become more accurate over time and with repeated measurements.

Table 8—Proposed LSOG monitoring schedule

Activity	Fiscal year							
	1998	1999	2000	2001	2002	2003	2004	2005
Implement monitoring plan	X	X	X	X	X	X	X	X
Pilot test of methods	X	X						
Develop refined trend analysis	X	X	X					
Generate analysis and interpretive report		X	X				X	X

- **Refined estimates of LSOG trends (abundance, stand core area, interstand distance) by province and plant community for the next 100+ years**. This will require work on succession and disturbance models.
- **Baseline, long-term conditions for LSOG by province and plant community**. This might include a combination of disturbance history analysis, disturbance modeling, and stand growth modeling. It will be important to describe ranges of conditions for LSOG attributes, not just average conditions, for the last several centuries.
- **Refined definitions or indices of LSOG forests to help in assigning plots and remotely sensed stands to a position along a continuum of LSOG structure and composition conditions by stratum**. This includes the need to examine within-stand spatial distribution of structural components (Franklin and Spies 1991).
- **Better stand-scale projection models for LSOG stand structure and composition attributes (live trees, snags, down wood, species) that allow long-term projections (for example, 100+ years) by stratum.**
- **Basic research on the relations among forest structure, stand age, disturbance history, biological diversity, and ecosystem processes and functions.** This is needed to support (or modify) and refine the conceptual model.

Acknowledgments

Thoughtful peer reviews were provided by Ray Czaplewski, Ken Denton, Tom Hoekstra, and Hart Welsh, Forest Service; Jerry Franklin, University of Washington; John Gordon, Yale University; Bill McComb, University of Massachusetts; Tony Olson, EPA; and Marty Stapanian, BLM. We also are grateful for the assistance of Barry Mulder (U.S. Fish and Wildlife Service) in finishing this report, the fine comments from Martha Brookes, and the editorial and publication assistance from Karen Esterholdt.

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Appendix A: Vegetation Strike Team Standards

The Regional Interagency Executives accepted a set of standard elements for vegetation map information for interagency use in western Oregon, western Washington, and northern California (Vegetation Strike Team 1995). These are for use in remotely sensed information, in particular. The standard elements include:

- **Total tree canopy cover** is the vertical projection of tree canopy (or the canopy visible from above) as seen from above to the ground. Ten-percent classes will be used. It may not be possible to distinguish each class, and classes may be grouped as appropriate to the resolution of the data.
- **Forest canopy structure** indicates the layering of the canopy, as seen from above. Remote sensing may separate only single layered from multilayered canopies. Field data may distinguish additional layers.
- **Tree overstory size class** provides information about the typical or average diameter class of the canopy trees visible from above. This is generally interpreted from tree crown diameter. Size classes (in inches) specified include 0-5, 5-10, 10-20, 20-30, 30-50, and greater than 50. Remote sensing data resolution may require lumping classes.
- **Species** can be either cover types according to Society of American Foresters or Society for Range Management lists or a list of canopy species, when seen from above, in decreasing order of abundance. This really represents two attributes: cover type and species list.
- **Stand year of origin** comes from agency field records and pertains to even-aged stands.
- **Land cover class** provides a field for the land class according to Federal Geographic Data Committee standards (FGDC 1997), when they are finalized or accepted for agency use.
- **Potential vegetation** information is really a separate map product that provides a stratification of environments and an indication of vegetation at the endpoint of succession in each polygon. In the short term, potential vegetation at the series level is feasible. Over the longer term, plant association groups could be mapped.

Appendix B: Alternative Approaches Considered

Several possible approaches to collecting information on the large landscape-scale and stand-scale characteristics of LSOG forests surfaced during team discussions (table 9). These possibilities were evaluated regarding how well they would provide necessary LSOG information, and to what extent they would provide vegetation data for habitat analysis for northern spotted owls (Lint et al., in press) and marbled murrelet (Madsen et al., in press); the use of these data in monitoring for aquatic and riparian and survey-and-manage species is being evaluated. Based on this analysis, the team pursued a combination of grid plot data and new remote sensing image analysis.

- **Field query.** Poll field units for acres of harvest or catastrophic loss (fire, wind, etc.) that removes LSOG. Tally acres by physiographic province and land allocation. Presume that the remaining LSOG continues to exist and that younger stands in late-successional reserves continue to grow into LSOG. This is the lowest cost method of monitoring effects of the Forest Plan on LSOG, though field units would have to compile necessary information. No reliability estimates and no spatial analysis would be possible. No map for northern spotted owl and marbled murrelet habitat estimation would be generated.
- **Grid plot data only**. Analyze permanent grid plots by physiographic province and land allocation. Calculate amounts of LSOG from stand-scale definitions. Specify the reliability of these measures. No analysis of spatial distribution beyond province and land allocation would be possible. No map generated for northern spotted owl and marbled murrelet habitat estimation. Because grid plot data analysis is not hugely expensive (estimated at less than one full time staff person), it is included in all the following alternatives.
- **FEMAT map**. Use the FEMAT (1993) map as the baseline and compensate for stand conversions through 1997. Grid plot data analysis could be added at minimal expense. No accuracy assessment of map or spatial distribution of LSOG. This map would not be sufficient for northern spotted owl and marbled murrelet habitat work, or for field unit planning and operational uses.
- **Existing maps**. Combine existing maps. Coverage does not include the entire landscape (for example, southwestern Washington). Accuracy assessment would be possible on some parts of the map. Some parts would be suitable for northern spotted owl and marbled murrelet habitat work. Maps might be useful for unit planning but not consistently across administrative boundaries.
- **New image analysis**. Apply a consistent, peer reviewed, accuracy assessed method to produce new maps. Maps suitable for northern spotted owl and marbled murrelet habitat work and as a starting point for field unit planning or operational work would be generated. This is the recommended alternative because it provides information for all LSOG indicators, peer reviewed rigor, a vegetation map for northern spotted owl and marbled murrelet habitat analysis, and a starting point for unit planning or operational use.

Table 9—Comparison of alternative methods for collecting data for LSOG effectiveness monitoring analysis

Method	Accuracy assessment	Analysis of FEMAT and FSEIS criteria		Spotted owl and murrelet vegetation map[a]	Planning and operational use
		Spatial	Stand		
Field query	no	no	partial	no	partial
Grid plot data	yes	no	yes	no	partial
FEMAT map	no	partial	yes	no accuracy	no accuracy
Existing maps	partial	yes	yes	partial	partial
New image analysis	yes	yes	yes	yes	yes

[a] The use of LSOG vegetation data in monitoring for aquatic and riparian, survey-and-manage species, and other monitoring activities is being evaluated.

Rationale for Recommended LSOG Methods

Late-successional and old-growth effectiveness monitoring, as proposed, consists of analyzing vegetation maps and permanent plot data. It relies on vegetation maps for spatial indicators and permanent plots for stand-scale indicators. It also includes a spatially linked predictive model to project forest vegetation classes into the future, thereby allowing relatively quick detection of vegetation trends that deviate from those envisioned in the Forest Plan. Modeling also allows fine tuning of expected LSOG trends to the particular environments in different physiographic provinces. The criteria used (table 10) relate strongly to the development of consistent vegetation maps; those are key to the proposed methods. There are really only two choices for LSOG vegetation maps and grid plot data analysis: perform the data analysis and reporting, or not.

Predictive trend modeling is necessary because the estimated LSOG trends in FEMAT (1993) and the FSEIS (USDA and USDI 1994a) are one simple curve showing an upward trend in the next 100 years. No refined estimates for different provinces are provided, even though the development rates for LSOG differ with environmental differences by province. The proposed methodology includes refined trend estimates by province.

Table 10—Rationale for selecting recommended LSOG monitoring methods

Recommended method	Option selection criteria
Vegetation map and grid plot data analysis	Landscape and stand-scale analysis— better information Accuracy and detection of real change— reliable information Synergism with spotted owl and murrelet vegetation map needs Tie to field unit planning and operational use
Trend model	Allow quicker detection of change direction Refine crude FSEIS estimates Allow prediction of effects of management actions

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Hemstrom, Miles; Spies, Thomas; Palmer, Craig; Kiester, Ross; Teply, John; McDonald, Phil; Warbington, Ralph. 1998. Late-successional and old-growth forest effectiveness monitoring plan for the Northwest Forest Plan. Gen. Tech. Rep. PNW-GTR-438. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 37 p.

This report presents options for long-term effectiveness monitoring of late-successional and old-growth forests under the Northwest Forest Plan. It describes methods to answer questions about how much late-successional forest exists on Federal land, its pattern, how it's changing, and if the Forest Plan is providing for its conservation and management. It specifies data needed, analytic methods for using remotely sensed and grid plot data, and implementation options. A periodic process for reporting the status and trend of late-successional and old-growth forests on Federal lands is described, and links to finer scale monitoring of silvicultural and salvage effects on late-successional and old-growth forests are provided.

Keywords: Northwest Forest Plan, effectiveness monitoring, late-successional and old-growth forest, vegetation map, remote sensing, grid plot, GIS, landscape, stand-scale, trend model.

Pacific Northwest Research Station
333 S.W. First Avenue
P.O. Box 3890
Portland, Oregon 97208-3890

U.S. Department of Agriculture
Pacific Northwest Research Station
333 S.W. First Avenue
P.O. Box 3890
Portland, OR 97208